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EPSON

Technical Note

Quartz Crystal SAW Resonator FS555 Using Guide

SEIKO EPSON CORP.

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This guide is valid until December, 1996.

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1. What is a SAW Resonator ?

While AT cut crystal resonators are currently well known and widely used, the first prototype SAW resonators were produced in 1974 by E.J. Staples as a frequency control element for even higher frequencies, namely, the VHF and UHF bands. Since then, SAW resonators have come to be used in RF modulators, CATV applications, faint radiowave applications, IF local oscillators, and voltage control oscillators (VCSO). SEIKO-EPSON's SAW resonators consist of a resonator (oscillator) that uses a Rayleigh wave that propagates across the crystal substrate (ST-X) surface to create a constant wave between a pair of reflectors.

The special characteristics of SAW resonators and of SEIKO-EPSON's products are described below.

Features of SAW Resonators

1. Because they are capable of basic wave oscillation, constructing circuits is easy; in addition, it is possible to avoid the unnecessary emissions that are generated when low frequencies are multiplied.
2. A low CI value can be easily obtained, making SAW resonators easy to utilize with little variation.
3. Because the frequencies are higher (250 to 500 MHz), operation is fast.

Features of the FS-555

1. The FS-555 is a compact, surface-mounted component. (Size: 5.2 x 4.8 x 1.5 mm)
2. Because the initial deviation of the frequency is low, the device offers excellent precision. (±80 ppm)
3. Because the FS-555 is fully fixed in place all along its surface, it offers excellent impact resistance characteristics.
4. Because the FS-555 uses a crystal with a high Q value, it can be used to construct an oscillator circuit with excellent frequency stability (C/N).

2. Basic Structure and Principles of Operation

2.1 SAW Resonator Type

SEIKO-EPSON's FS-555 was designed using the one-port type.

2.2 Structure and Operation of the Element

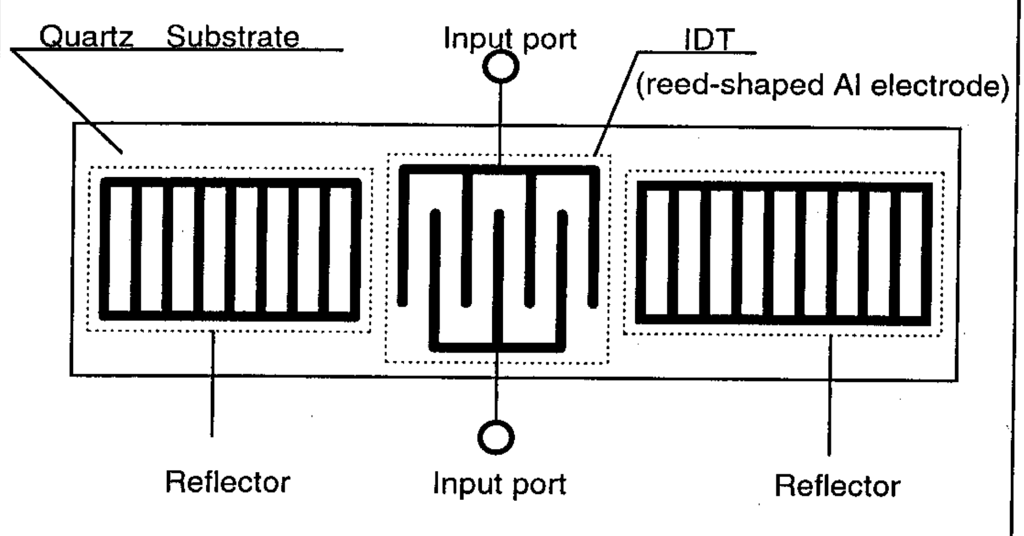
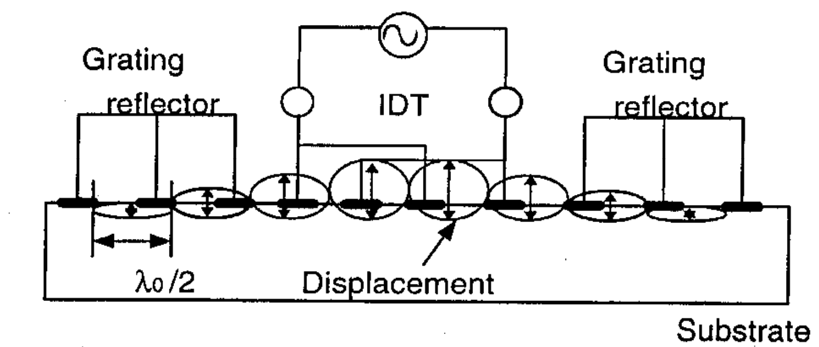


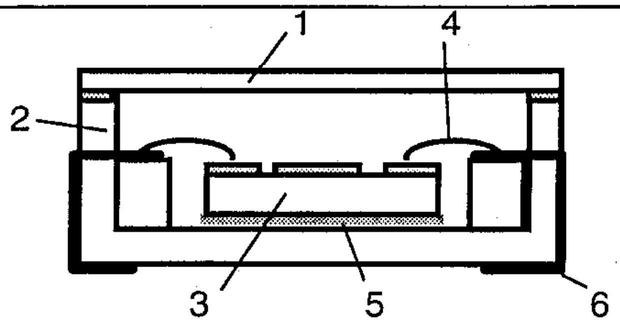
Fig. 1 Structure of the One-port Type SAW Resonator



Resonation frequency $f_r = V_s/\lambda_0$, Vs: S A W speed (3158m/s)

Fig. 2 Diagram of Operating State

2.3 Package Construction



1 : Cap
2 : Ceramic base
3 : SAW chip
4 : Al wire
5 : Adhesive
6 : Terminal

Fig. 3 Package Structure

3. Equivalent Circuit and Basic Characteristics of the Resonator

3.1 Circle Diagram of Admittance during Resonance

$$Y(\omega) = G(\omega) + jB(\omega)$$

$$Y(\omega) = j\omega C_0 + 1 / \{R_1 + j(\omega L_1 - 1/\omega C_1)\} \quad (1)$$

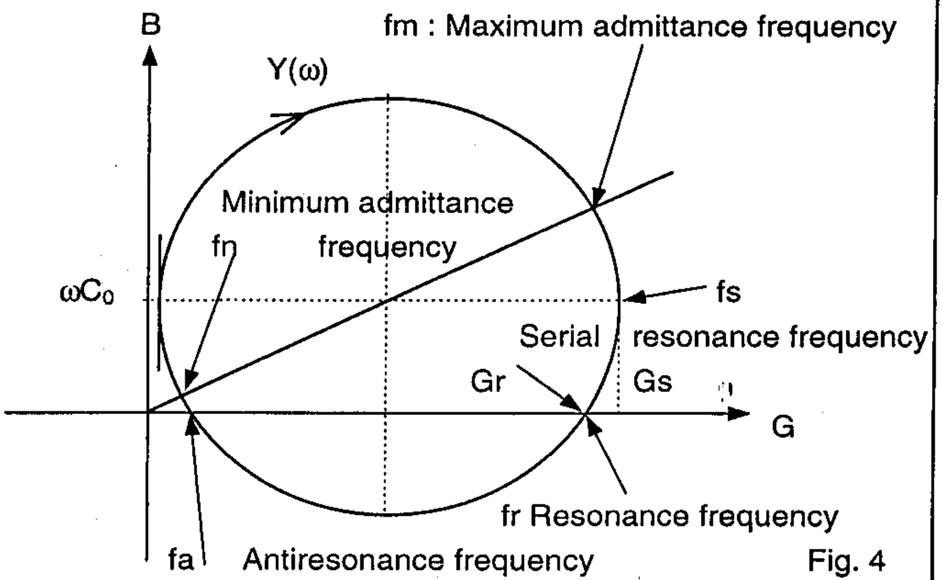


Fig. 4

3.2 Resonator Equivalent Circuit Diagram

An electrically equivalent circuit to the resonator is shown in the diagram below.

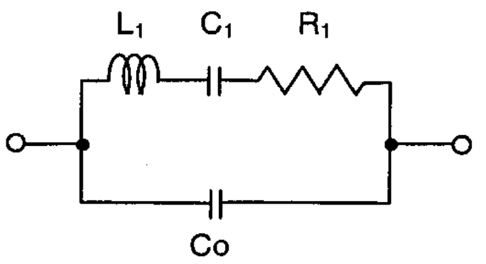


Fig. 5

R_1: Equivalent series resonance resistance
R_1=1/Gs
C_1: Equivalent capacitance
L_1: Equivalent inductance
C_0: Parallel capacitance
Rr: Equivalent resistance
Rr=1/Gr

Series resonance frequency : $fs = 1/(2\pi\sqrt{L_1 \bullet C_1})$ (2)
Capacitance ratio: $\gamma = C_0/C_1$
Q value: $Q = 2\pi fs\ L_1/R_1$

3.3 Frequency Temperature Characteristics P(θ)

SEIKO-EPSON's ST cut SAW resonator generally demonstrates frequency change of a second-order function. This change is expressed through the mathematical formula shown below.

$$P(\theta) = \Delta f/f_0 - \beta(\theta_0-\theta_{max})^2 + \beta(\theta-\theta_{max})^2 \quad \text{(ppm)} \qquad (3)$$

Where,
$\Delta f/f_0$: Frequency deviation (ppm) ,(at 25 °C)
f_0 : Nominal frequency(Hz)
θ : Temperature(°C), θ_0=25 (°C)
θ_{max} : Turn-over temperature(°C)
β : Second-order temperature coefficient ,
$\beta = -3.5\times10^{-8}/°C^2$

3.4 Suprious modes

The rectangular crystal substrate that forms the SAW resonator has a number of inherent resonance modes.
Those modes that have an actual effect are described below.

* **Longitudinally imharmonic mode** surface wave resonance:
  Exist below the primary resonance frequency in a range of 1000 to several thousand ppm.
* **Transversely imharmonic mode** surface wave resonance:
  Exist above the primary resonance frequency in a range of several hundred to several thousand ppm.

Because the equivalent resistance R_{sp} for the resonance caused by these modes is designed to be more than adequate for the primary resonance, oscillation does not normally occur at these frequencies.
Before ordering the resonator, carefully study the application for which it is to be used, especially when it is to be used in a variable frequency application, such as a VCSO.

3.5 Drive Level Characteristics

Like other electronic components, SAW resonators also have suitable levels for operating power that are appropriate drive levels. If the drive level is too high, a frequency shift may result; in an extreme case, the device could even be damaged.
The drive level characteristics indicate the resonator's frequency and the change in the equivalent series resistance for different levels of operating power supplied to the resonator. These characteristics are defined below:

* Maximum operating power (maximum drive level)
  Range of power with which the resonator can be used and at which it will operate normally.
* Recommended drive level (testing drive level)
  Level of operating power that will satisfy the standards indicated in the specifications.
* Operating power P_w:

$$P_W = R_L \cdot I^2 \ (W) \qquad (4)$$

R_L : Effective equivalent resistance of the resonator when it is operating (Ω)

I : Current that flows through the resonator when it is operating (A)

SEIKO-EPSON's FS-555 has a recommended operating power of 2 mW, a maximum operating power of 10 mW, and, within its maximum operating power range a rate of change of frequency (fr) and equivalent resistance change (ΔRr/Rr) of 5 ppm and 5%, respectively. In general, the FS-555 should be used at low power as much as possible.

4. Method of Use

Keep the following points in mind when using a SEIKO-EPSON SAW resonator in an oscillating circuit.

4.1 Port Connections

Connect the FS-555 as shown in the diagram below. Avoid the application of large DC voltages between input ports C and G.

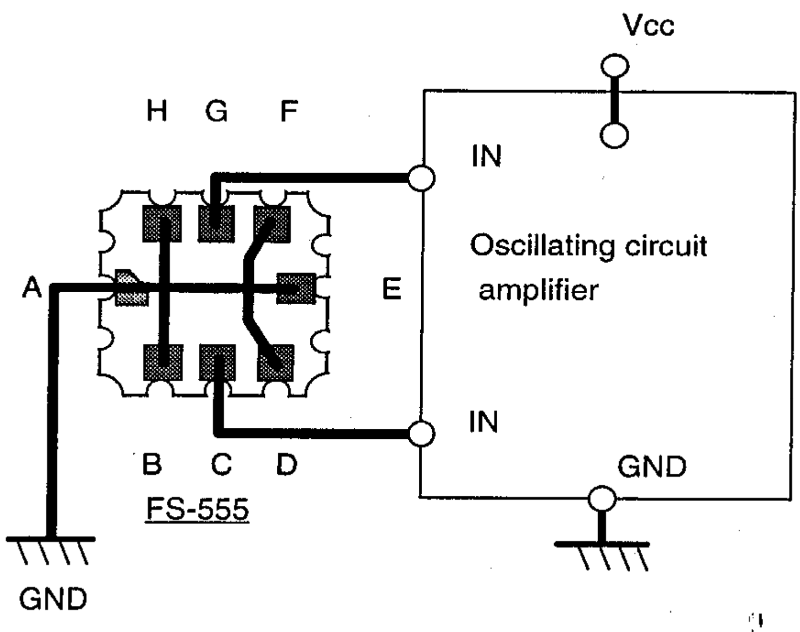


Fig. 6 Connection Diagram

4.2 Factors that Determine the Oscillating Frequency (fosc)

The factors that determine the oscillating frequency differ in the following two cases, depending on how the SAW resonator load is set. The formulas given below also give an approximate value for fosc.

a) Capacitance load ($f_{osc} = f_{CL}$)

$$f\ osc = fs\ \{1+C_1/2(C_0+C_L)\} \qquad (5)$$

$$R_L = Rr\ (1+C_0/C_L)^2 \qquad (6)$$

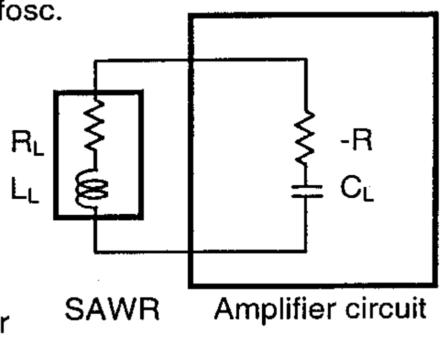


Fig.7

The negative resistance -R of the amplifier circuit must be set with adequate margin form R_L.

b) When using a coil for extension pull range

$$f\ osc = fs_L\ \{1+C_1/2(C_0+C_L)\} \qquad (7)$$

$$fs_L = 1/(2\pi\sqrt{L_{1p} \bullet C_1}) \qquad L_{1p} = L_1 + L \qquad (8)$$

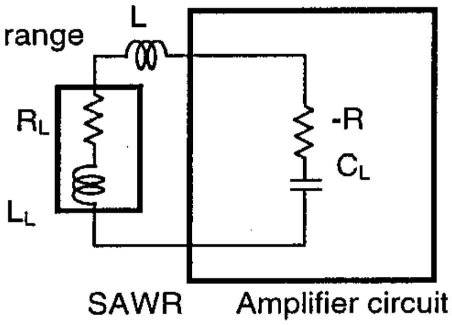


Fig.8

Notes

* The floating capacitance and inductance of the substrate can affect the actual oscillation frequency; check the oscillation frequency in the actual unit.

* Make sure that L of the extension coil is adequately smaller than L_1 of the SAW resonator. Less than -500 ppm from Fs is desirable. Stability suffers if L is too large.

5. Measurement Methods

Methods for measuring the frequency fr (fs) and the equivalent resistance Rr, both of which are important for evaluating SAW resonators, are described in this section. There are basically two methods that can be used to measure these values.

SEIKO-EPSON uses the π network based on the IEC standards for taking measurements.

5.1 π Network Transmission Method

Using the test circuit configuration shown in the figure below, fr is the resonance frequency at which the transmission characteristics S_{21}^{-1} reaches phase zero. The equivalent resistance Rr is derived from the value of $S_{21}^{-1}(fr)$ at that moment according to the following formula:

$$Rr = (KS_{21}^{-1}-1) \cdot 25 \quad (\Omega) \qquad (9)$$

where, $S_{21}^{-1} = V_A/V_B$

$K=V_{BS}/V_{AS}$

V_{BS} and V_{AS} are the voltages V_B and V_A when the test pin is shorted.

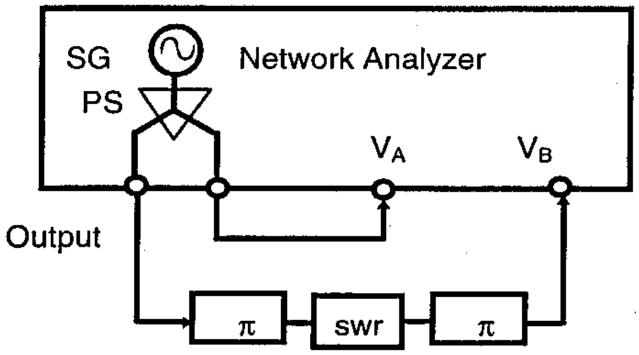
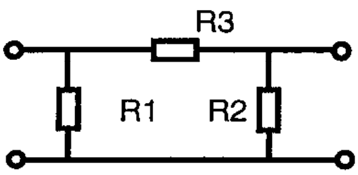


Fig. 10 π Network Measurement System



R1 = 159 (Ω)
R2 = 14.2 (Ω)
R3 = 66.2 (Ω)

Fig. 11 πNetwork Evaluation Circuit Diagram

Regarding test samples, assuming ΔP as the difference for correcting from your oscillating circuit frequency fosc, the following relationship exists (at 25°C).

$$\Delta P = -(fosc - fr)/f_0 \quad (ppm) \quad (at\ 25\ °C) \quad (10)$$

where, $fr = f_0$

f_0 : Oscillating frequency target value (Hz)

fr : SEIKO-EPSON's measured resonance frequency (when CL = infinity)

We can provide a π test jig for a fee.

5.2 Impedance Measurement Method

Use an impedance tester (HP4195A,HP4291A etc.) on the market to measure the SAW resonator impedance $Z(\omega)=1/Y(\omega)$.

6. Miscellaneous

This guide provides explanations of basic matter regarding the use of SEIKO-EPSON's SAW resonator. Consult the product specifications for specific values regarding specifications mentioned in this guide. If you have any questions concerning the information provided in this guide, contact SEIKO-EPSON at:

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