M243-50

EPSON

Application Manual

Temprature Sensing Crystal

HTS-206

SEIKO EPSON CORPORATION

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Crystal Temperature Sensor

HTS-206

- Small crystal temperature sensor (Compact size: 2 x 6 mm)
- Oscillation frequency changes in linear relationship with change in temperature
- Frequency change ratio is large and precise
- Low current consumption due to low operation frequency (40 kHz)
- Compatible with a broad temperature range (-40°C to 85°C)
- Ideal for thermometers, D-TCXO, etc.

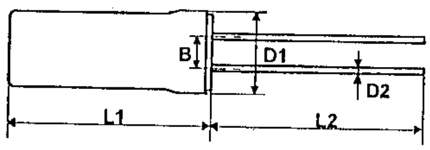
■General

This crystal temperature sensor uses a tuning fork-type crystal with an oscillating frequency that changes in a linear relationship with changes in the ambient temperature. Therefore, the temperature can be determined by measuring the oscillating frequency of the crystal. Because the temperature data is displayed in terms of the frequency (digitally), data processing is simple. Furthermore, because this device has the same basic structure as the crystal oscillators used for timekeeping with which Epson has had many years of experience, this device is highly reliable. This device is ideal for applications such as high-precision thermometers or D-TCXO.

■Characteristics

Item		Symbol	Specifications	Conditions
Frequency range		f	40KHz	
Storage temperature range		Tstg	-55 ~ 125°C	
Operating temperature range		Topr	-40 ~ 85°C	
Maximum drive level		GL	1μW MAX.	Must not suffer damage
Drive level		DL	0.1μW	
Frequency tolerance		Δf/f	±20000ppm	Ta=25°C
Frequency-temperature coefficients	Primary coefficient	α	$-29.6\times10^{-6}/°C$ [±2%]	Ta=25°C
	Secondary coefficient	β	$-6.4\times10^{-8}/°C^2$ [±8%]	
	Tertiary coefficient	γ	$-0.57\times10^{-10}/°C^3$ MAX.	
Series resonance resistance		R1	30kΩ MAX.	
Shunt capacitance		C0	0.9pF TYP.	
Motional capacitance		C1	2.0fF TYP.	
Insulation resistance		IR	100MΩ MIN.	
Aging		fa	±3ppm/Year MAX.	Ta=25°C ±3°C
Shock resistance		S.R.	±3ppm MAX.	Drop three times on hard wooden board from a height of 50 cm
Thermal time constant			2sec. (7sec.)	In oil(in air)
Temperature stability			±0.2°C MAX.	

■External Dimensions

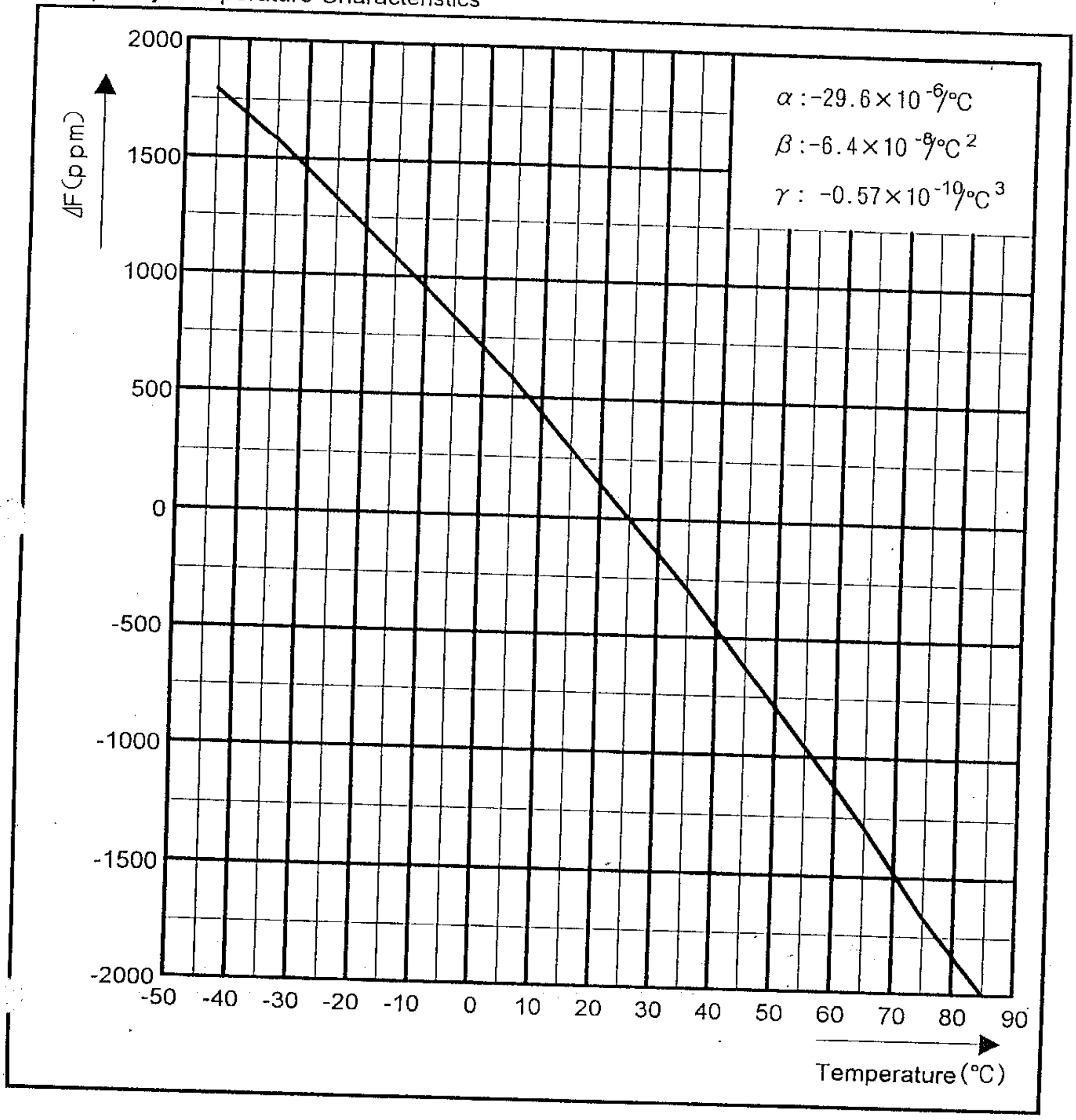


Unit:mm

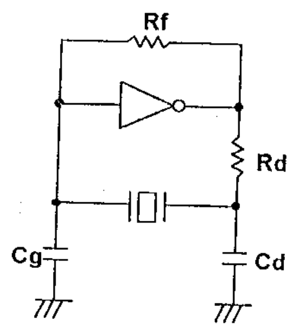
	L1	L2	D1	D2	B
HTS-206	6.0 MAX.	4.0 MIN.	Ø2.0 MAX.	Ø0.2	0.6

HTS-206

■Frequency-Temperature Characteristics



■Oscillation Circuit Example



IC:74HCU04 (Made by Toshiba)
Rf:20MΩ
Rd:470kΩ
Cg:7pF
Cd:20pF

■Explanation

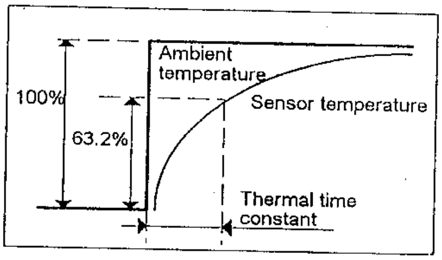
1. Characteristics

The crystal oscillator's frequency-temperature characteristics can be expressed by the following equation.

$$\Delta f / f0 = k + \alpha T + \beta T^2 + \gamma T^3$$

k: Frequency deviation at reference temperature
f0: Reference frequency (40 kHz)
T: Difference from reference temperature ($T = \theta$ - Ta; θ: any temperature)
α, β, γ : temperature coefficients

Because β and γ are very small versus α in this crystal temperature sensor, the oscillating frequency changes according to the temperature in almost a linear fashion. As a result, the ambient temperature can be measured by measuring the oscillating frequency. The actual characteristics are shown on page 2. Because the frequency changes by 20 ppm or more per degree centigrade, the sensor has a temperature measurement resolution of 0.05°C per 1 ppm. (The primary temperature coefficient can be made to be anywhere from -20 to -29 ppm. In addition, the secondary temperature coefficient changes, albeit slightly, when the primary temperature coefficient is changed. The tertiary temperature coefficient changes hardly at all.)
However, a small amount of error (stable temperature ± 0.2°C max.) may appear in actual measurements due to oscillation stability, temperature hysteresis, and reproducibility factors. The measurement accuracy of the counter, etc., being used to measure the frequency must also be given consideration. If the clock accuracy of the measuring device is not very good, use of a high-precision external oscillation source (more than $\pm 1 \times 10^{-10}$) is recommended.
In addition, the thermal time constant (the amount of time needed for the change in the sensor temperature to reach 63.2% of the change in the ambient temperature: refer to the diagram at right) of this crystal temperature sensor is 2 seconds in an environment with a large heat capacity (for example, in oil) and seven seconds in an environment with a small heat capacity (for example, in open air); therefore, an adequate amount of time must be allowed for the measurement process. In order to obtain the most accurate measurement, the temperature sensor should be in contact with the object/substance being measured.

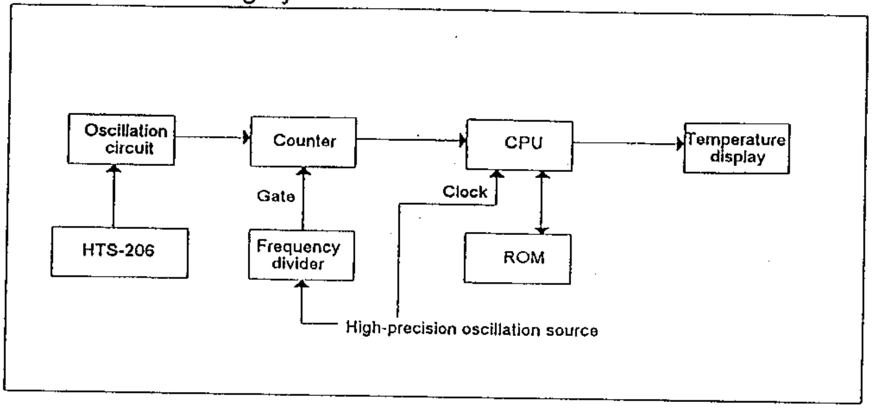


2. Oscillation circuit

An example of a circuit that drives the oscillation of this crystal temperature sensor is shown on page 2. Although oscillation can be possible with other typical oscillation circuits, when designing such a circuit caution should be exercised to prevent excessive drive level of the sensor while maintaining adequate negative resistance within the temperature range in which the sensor is to be used.

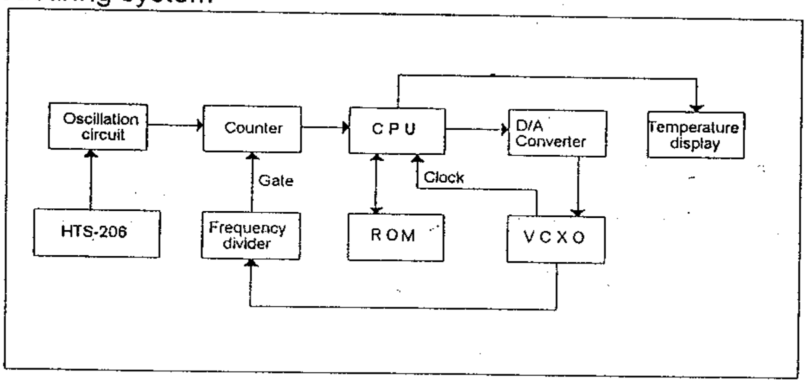
■Example Mesuring System Configurations

1. High-precision measuring system



The above diagram is an example of a temperature measuring system. The oscillation of the HTS-206 temperature sensor is driven by the oscillation circuit, and the output frequency is read by the counter. In this case, the measurement accuracy of the counter has a large effect on the accuracy of the temperature measurement, so use a high-precision oscillation source (with precision at least as good as the OCXO). Then, using the value read by the counter, the CPU reads the corresponding temperature data already stored in ROM and displays the temperature on an LCD or other display device. Other processing of the temperature data is possible if doing so suits the application. Whatever is required for the CPU clock is fine, but if the high-precision oscillation source is used, there is no need for more than one clock. The temperature data stored in ROM simply reflects the characteristics of the HTS-206, i.e., what frequency corresponds to what temperature. Although data that is more precise than the required temperature precision can be stored in memory, doing so requires a large amount of storage capacity. Therefore, the recommended approach is to have the CPU calculate the temperature according to the characteristics equation shown on page 3. With this method, the only data that is required is k, α, β, and γ. However, because the constants k, α, β, and γ vary for each device, always be sure to calibrate the reference data first when producing a measurement system. Measure this data at a minimum of four temperature points and use a third-degree equation to calculate approximations for the rest of the data. The more temperature points that data is measured for, the better the accuracy will be. If this process is not performed, the accuracy of the temperature measurements cannot be guaranteed. In addition, because the temperature sensor changes over time (± 3 ppm over the first year), periodic recalibration should be performed according to a cycle in line with the required accuracy. (Such recalibration will entail rewriting k among the data.)

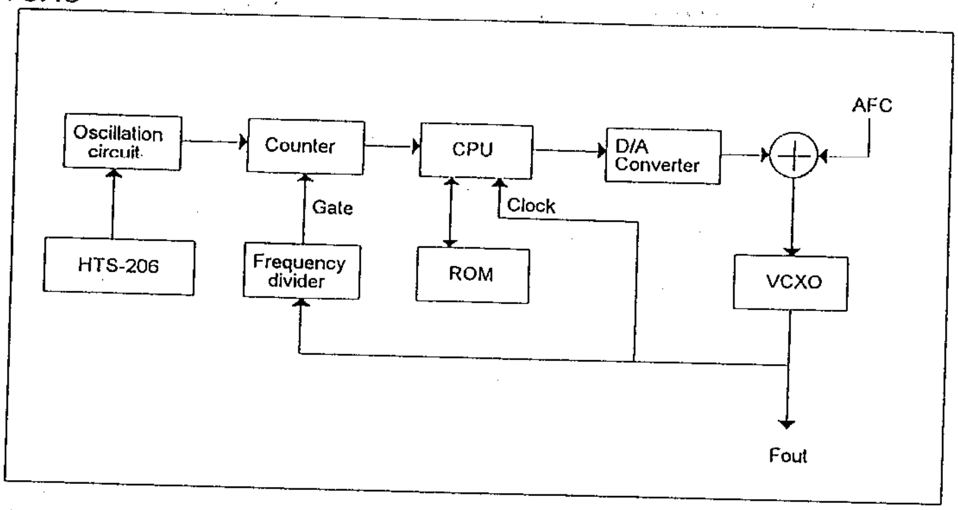
2. Simple measuring system



This measuring system has an internal clock, making it suitable for instances where an external high-precision oscillation source cannot be used.

The basic configuration is the same as in example 1 above, except that a clock circuit has been added. In this example, the VCXO is used for the clock. Although the VCXO is accurate enough for use as a CPU clock (about ±20 ppm), it is not accurate enough for a counter clock. Therefore, Conpensation using temperature sensor data in order to improve the VCXO precision. A "feedback loop" is formed to assure accuracy. When this method is used, the temperature characteristics of the VCXO are stored in ROM, and the compensation value corresponding to the temperature is output by the CPU. Because the frequency of the VCXO is controlled by voltage (analog), control entails signal conversion of the compensation value by the D/A converter As a result, clock precision of at least 1×10^{-7} can be assured. Accordingly, temperature precision of 0.1°C is possible.

3. D-TCXO



This circuit is designed to obtain a high-precision clock signal from the VCXO in example 2. Basically, there is no temperature display function. However, a requirement for D-TCXO is a reference clock for the wireless communications terminal. This is commonly provided by using an AFC (Automatic Frequency Control) circuit that synchronizes the frequency with a signal received from a ground station; in such a case, the D/A converter output that is used to control the VCXO can be combined with the AFC signal.

*Supplement

Because an AT-cut crystal oscillator is typically used in the VCXO, the temperature characteristics become the tertiary characteristics. For example, as shown in the charts at right, if the accuracy is ±20 ppm/-40 to 85°C and the frequency control characteristics are ±50 ppm/0.5 to 4.5 V, the compensation value is as shown in the bottom graph. These characteristics can be expressed as a characteristics equation in the same way as for the temperature sensor to generate the compensation data.

$\Delta f / f0 = k_A + \alpha_A T + \beta_A T^2 + \gamma_A T^3$

- k_A: Frequency deviation at the reference temperature
- $f0$: Reference frequency of the VCXO
- T: Difference from the reference temperature
- $\alpha_A, \beta_A, \gamma_A$: Temperature coefficients

$\Delta f / f0 = k_v + A V_c$

- k_v: Reference frequency at the reference control voltage
- A: Voltage coefficient (ppm/V)
- Vc: Control voltage

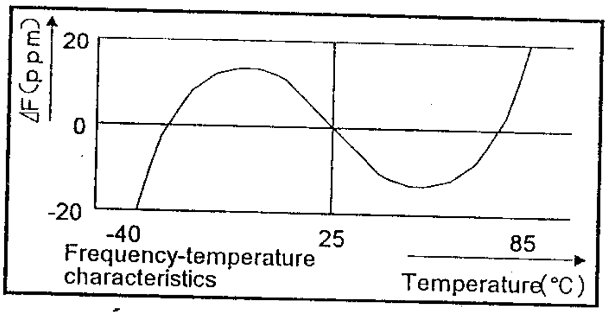
(This may not always yield the primary characteristics in their entirety. In such a case, provide compensation in the calculation equation.)

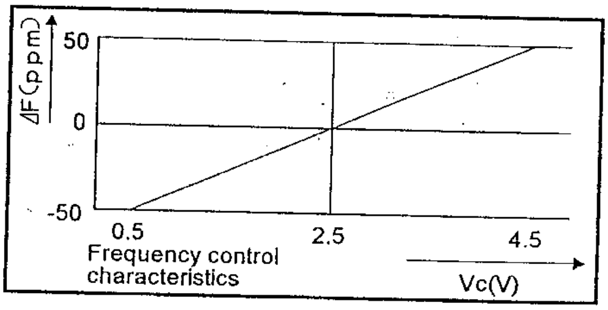
Accordingly, the compensation equation is:

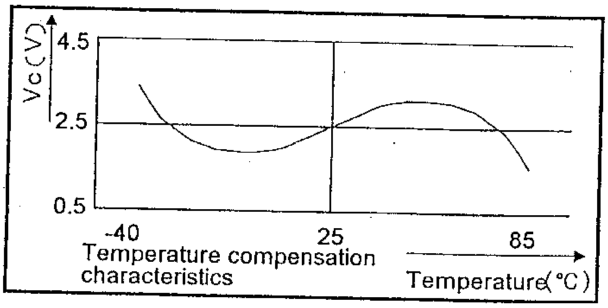
$V_c = (k_c + \alpha_A T + \beta_A T^2 + \gamma_A T^3) / A$

- $k_c : k_A - k_v$
- T: Temperature difference measured by the temperature sensor

The VCXO also has frequency aging.
Overwriting k_c through periodic recalibration is recommended.
The above is just one example. It is also possible to calculate the temperature sensor characteristics and VCXO compensation values directly. Adjust the design as necessary.







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■Notes on Use

1. System design

When designing the measuring system hardware and software, be sure to observe all patents, etc.

2. Temperature requirements for soldering

Because the characteristics will be degraded or the device may be damaged if the internal temperature of the package exceeds 150°C, limit the application of heat for soldering, etc., to the package leads only.

Soldering conditions: 260°C or less for 10 seconds or less

3. Ultrasonic cleaning

Depending on the conditions, ultrasonic cleaning can cause resonance in the crystal oscillator and damage the device. Because Epson has no control over the conditions under which ultrasonic cleaning is performed (the type of cleaner, the power level, the duration, the condition of the inside of the cleaner, etc.), Epson cannot guarantee that ultrasonic cleaning is safe for this device.

4. Miscellaneous

If any questions arise, contact Epson.