AXTAL Application Note AXAN-101

Miniature Temperature Sensor Crystals RKTV206

The miniature temperature sensor crystals RKTV206 with a diameter of only 2 mm allows the high-resolution precision measurements of temperature. It is a specially designed tuning fork crystal with a resonance frequency in the range 32 kHz to 36 kHz and has a temperature coefficient of about -51.8 ppm/K @ 25°C. In connection with a reference crystal RKOV206 the overall temperature coefficient can be increased by a factor of > 50 through the use of the heterodyne principle.
The main features of the RKTV206 are

- Wide operating temperature range -50°C to +180°C (standard) and optionally up to +320°C
- High resolution down to µK range
- Short time constant due to low thermal mass
- high shock and vibration resistance
- miniature size (2 mm diameter)

Typical applications are

- precision electronic thermometers
- precision temperature controllers
- Temperature-to-frequency (T/f) converters

The advantage over other temperature sensors is, that it allows a direct conversion of temperature to a digital signal (frequency), which can be directly processed by a microcontroller.

Package

The RKTV206 comes in a cylindrical metal package with a diameter of 2 mm and a length of 6 mm. The package is sealed with high-temperature solder (standard). For the high-temperature options laser welding is used.

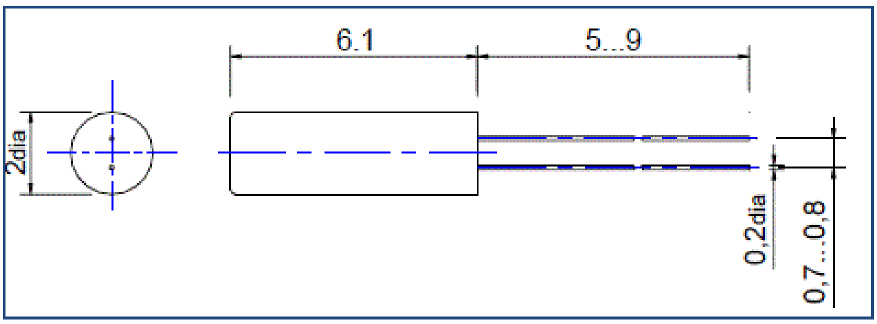

Fig. 1: Package drawing

AXTAL GmbH & Co. KG
Römerring 9
D-74821 Mosbach
Germany
web : www.AXTAL.com
fon : +49 (6261) 939834
fax : +49 (6261) 939836
e-mail: info@axtal.com

Frequency vs. Temperature characteristic

Temperature sensor crystal RKTV206

The temperature sensor crystal RKTV206 shows a monotonic response of the resonance frequency vs. temperature T as can be seen in Fig. 2 (blue dot-and-dash line).

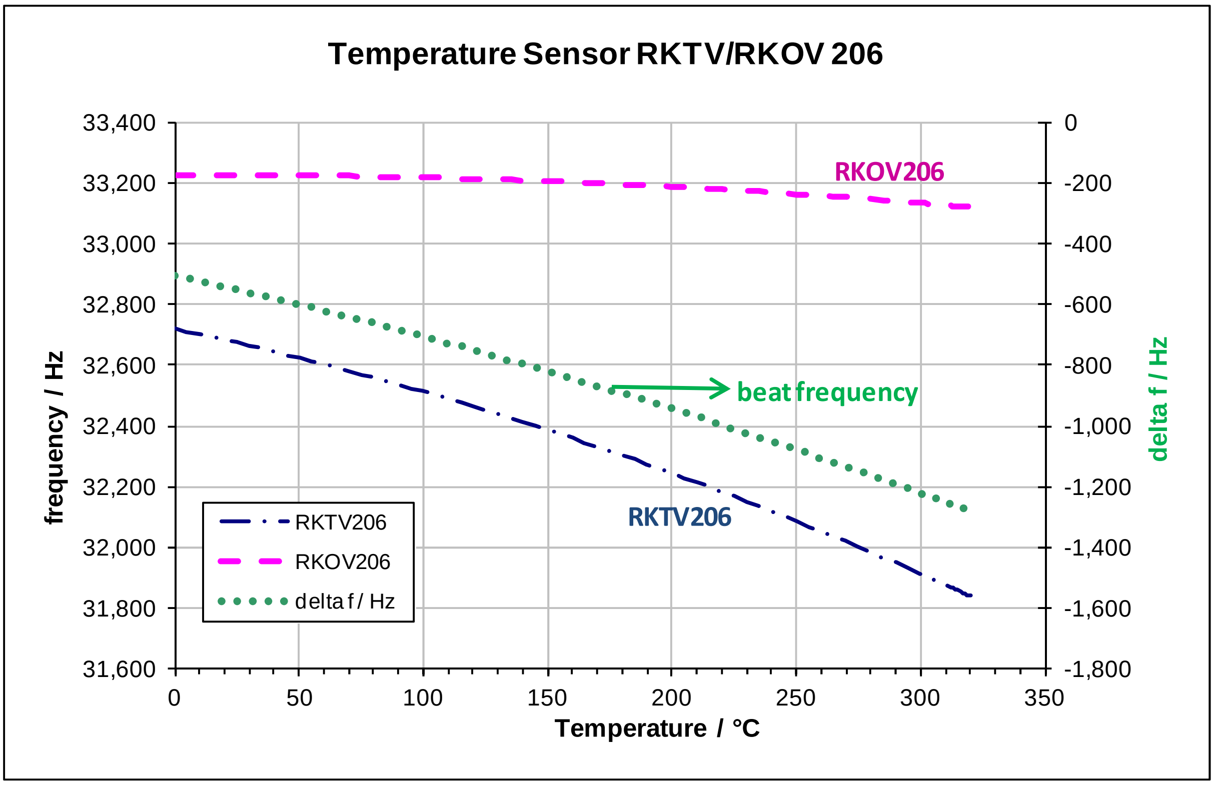

Fig. 2: Frequency vs. temperature of RKTV206 and RKOV206

It can be approximated by the equation

$$f_T(T) = f_0 + a_1 \cdot (T - T_{0)} + a_2 \cdot (T - T_0)^2$$

where

f_T = crystal frequency at temperature *T* (in °C)
f_0 = crystal frequency at reference temperature T_0, here 32720 Hz
T_0 = reference temperature T_0 = 0°C
a_1 = (-1.76±0.1) Hz/K
a_2 = (-0.00310±0.0001) Hz/K^2

For higher accuracy over a wide temperature range an approximation by a 3rd order polynomial is recommended:

$$f_T(T) = f_0 + a_1 \cdot (T - T_{0)} + a_2 \cdot (T - T_0)^2 + a_3 \cdot (T - T_0)^3$$

Reference crystal RKOV206

The reference crystal RKOV206 is a tuning fork crystal, whose frequency has only small temperature dependence.
The f(T) response is shown in Fig. 2 as dashed line. It can be described by the equation

$$f_{ref}(T) = f_{0ref} + a_2 \cdot (T - T_0)^2$$

with

- f_{ref} = crystal frequency at temperature T (in °C)
- f_{0ref} = crystal frequency at reference temperature T_0, here 33225 Hz
- T_0 = reference temperature T_0 = (25±5)°C
- a_2 = (-0.00120±0.0001) Hz/K^2

Beat frequency

If the reference crystal RKOV206 is used in combination with the sensor crystal RKTV206, both crystals are used in pairs with a frequency difference of about 550 Hz @ 25°C.
If both crystals are subject to the same temperature, the resulting frequency difference (beat frequency) between RKTV206 and RKOV206 is shown in Fig. 2 (green dotted line).
The temperature coefficient of the beat frequency is depicted in Fig.3. It is 15 times higher than the temperature coefficient of the RKTV frequency alone (at 25°C).

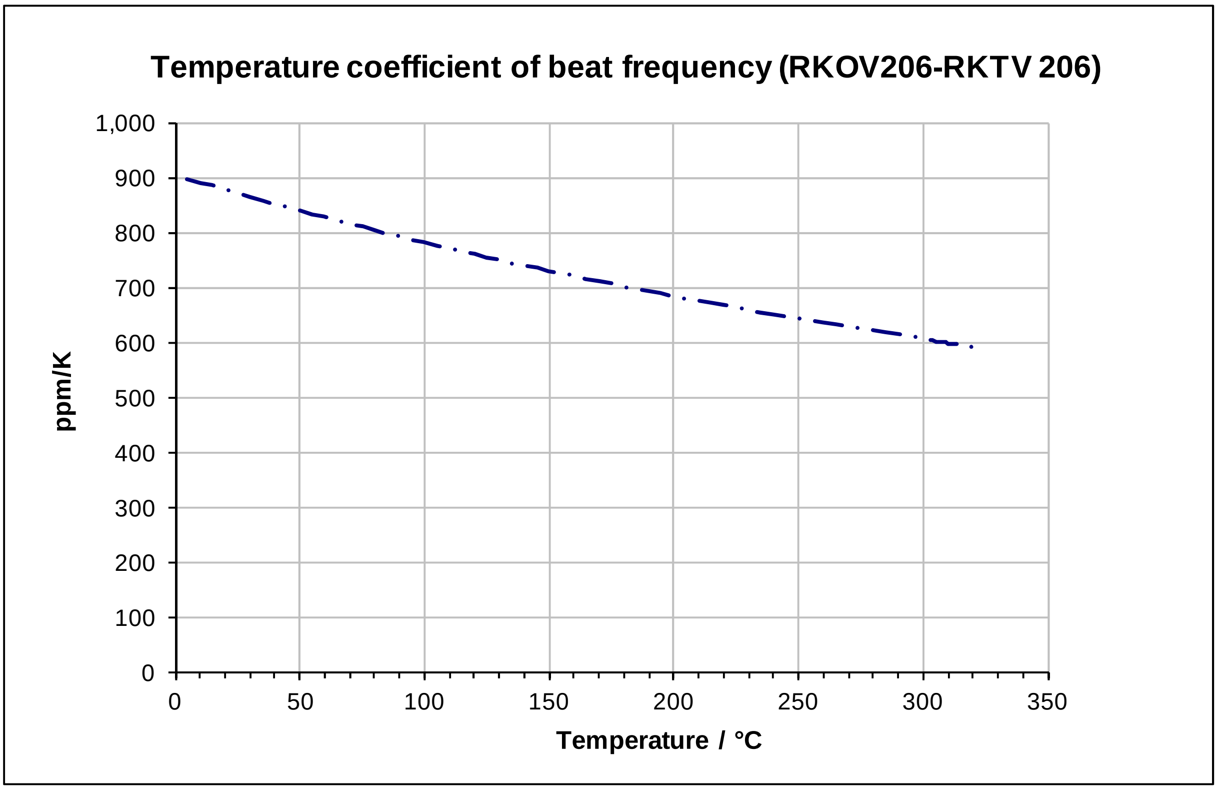

Fig. 3: Temperature coefficient of the beat frequency between RKTV and RKOV

AXTAL GmbH & Co. KG
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D-74821 Mosbach
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fax : +49 (6261) 939836
e-mail: info@axtal.com

Practical application

Both crystals can be operated separately in a suitable oscillator circuit. There are two recommended circuits, the "Pierce" oscillator with one logic inverter gate, and the "Heegner" circuit, which uses two logic inverters in series.

Pierce oscillator circuit

The basic circuit os shown in Fig. 4.

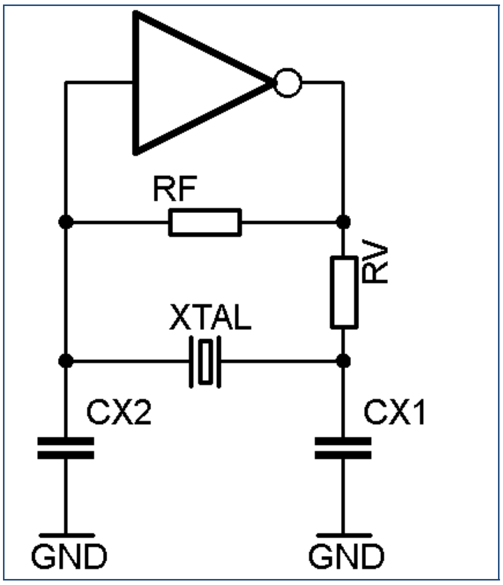

Fig. 4: Pierce oscillator circuit

The resistor RGK is needed to linearise the transfer characteristic of the inverter gate. Its typical value is about 1 ~ 10 MΩ for HCMOS logic gates.
The series resistor RV is required to protect the crystal from overload by excessive crystal current, which can lead to a permanent damage of the crystal. Its value is in the range of about 47 kΩ to 470 kΩ. As this resistor reduces the loop gain, it must be selected carefully.
The two capacitors CX1 and CX2 are in the range of 4.7 pF to 10 pF.
The line between the crystal terminals and the oscillator circuit must be short (a few cm) and have low a capacitance to ground and between the two lines.

Two-inverter (Heegner) circuit

This circuit basically consists of two logic inverter gates connected in series, and the crystal is inserted between the output of the second inverter to the input of the first inverter. This circuit allows to connect the crystal with somewhat longer leads than the Pierce oscillator.

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In the real circuit of Fig. 5, additional components are inserted to avoid overloading or damaging of the crystal and spurious oscillations.

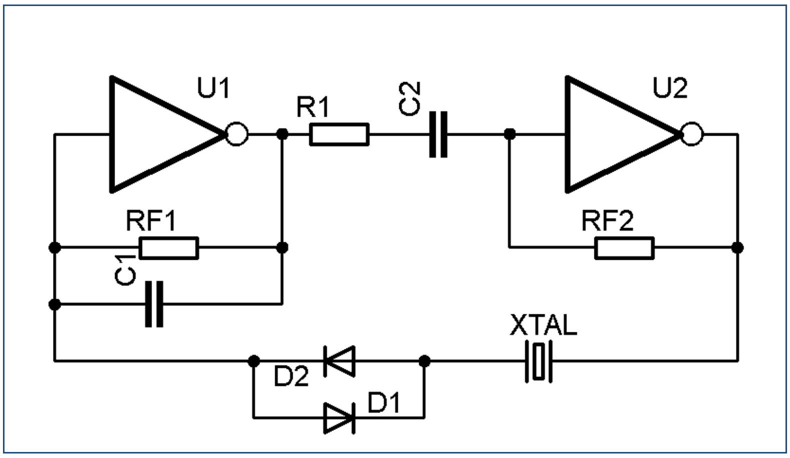

Fig. 5: Two-inverter (Heegner) oscillator circuit

The diodes D1 and D2 are Schottky types like BAS40-04 or similar.
The proposed values of the other components are

RF1 = RF2 = 300 kΩ

R1 = 5.1 kΩ

C1 = 10 pF

C2 = 470 pF

The values are given for guidance only, and may be needed to be modified, depending on the logic gates used.

Heterodyning (mixing) circuit

To generate the beat frequency, the output signal of the RKTV and the RKOV oscillator must be connected to a mixer. The output must be filtered by a suitable low-pass filter with a corner frequency of about 2 ~ 3 kHz.
Mixing can be accomplished by a digital mixer using a quad NAND IC as shown in Fig. 6.

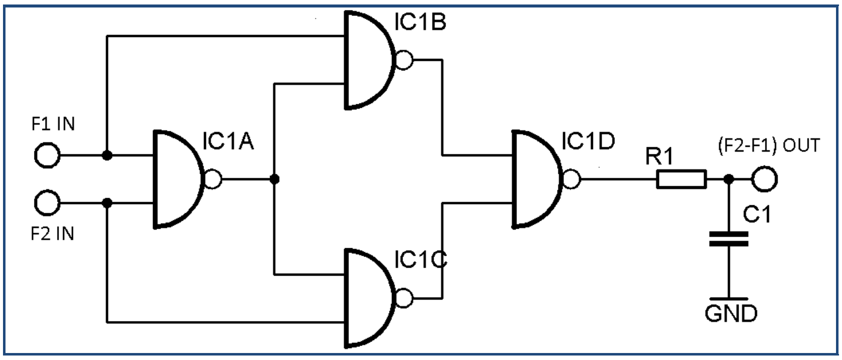

Fig. 6: Digital mixer with four NANDs

The R1-C1 low-pass shown in the schematic is only symbolic and may not provide sufficient filtering.

Alternatively the mixing can be performed directly by software in a microcontroller.

Mosbach, June 2014

Bernd Neubig

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