FREQUENCY MANAGEMENT PRODUCT SHORT FORM

Proud to be a small part of making a better world.
QUARTZ CRYSTAL PRODUCTS
METAL CAN PACKAGES

SUMMARY SPECIFICATIONS

CAA Series

- Frequency Range: 3.200 to 75.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating Temp: -20 to 70° C
- Aging: ±1 PPM to ±3 PPM per Year

CA Series

- Frequency Range: 3.200 to 75.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating Temp: -20 to 70° C
- Aging: ±1 PPM to ±3 PPM per Year

CA4 Series

- Frequency Range: 3.200 to 75.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating Temp: -20 to 70° C
- Aging: ±1 PPM to ±3 PPM per Year

To calculate the frequency stability, the parabolic curvature constant (K) is needed. For calculating the stability at 45 °C:

1- Change in temperature (ΔT) is (45 - 25) = 20 °C
2- Change in frequency is (-0.035 x (ΔT)^2) = (-0.035 x (20)^2) = -14 PPM

QUARTZ TUNING FORK PRODUCTS
METAL, CERAMIC & PLASTIC PACKAGES

SUMMARY SPECIFICATIONS

CT26 Series

- Nominal Frequency: 32.768 KHz
- Tolerance: ±20 PPM to ±50 PPM at 25° C
- Stability: Inverse Parabolic
- Operating Temperature: -20 to 70° C
- Aging: ±3 PPM per Year

CT26S Series

- Nominal Frequency: 32.768 KHz
- Tolerance: ±20 PPM to ±50 PPM at 25° C
- Stability: Inverse Parabolic
- Operating Temperature: -20 to 70° C
- Aging: ±3 PPM per Year

CTP3 Series

- Nominal Frequency: 32.768 KHz
- Tolerance: ±20 PPM to ±50 PPM at 25° C
- Stability: Inverse Parabolic
- Operating Temperature: -20 to 70° C
- Aging: ±3 PPM per Year

To calculate the frequency stability, the parabolic curvature constant (K) is needed. For calculating the stability at 45 °C:

1- Change in temperature (ΔT) is (45 - 25) = 20 °C
2- Change in frequency is (-0.035 x (ΔT)^2) = (-0.035 x (20)^2) = -14 PPM
**C7S Series 7 x 5 x 1.1**

- Frequency Range: 8.000 to 133.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±1 PPM to ±3 PPM per Year

**C6S Series 6 x 3.5 x 1.2**

- Frequency Range: 8.000 to 133.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±1 PPM to ±3 PPM per Year

**C5S Series 5 x 3.2 x 1**

- Frequency Range: 8.000 to 133.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±1 PPM to ±3 PPM per Year

**C2E Series 2.5 x 2 x 0.6**

- Frequency Range: 16.000 to 50.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±1 PPM to ±3 PPM per Year

**C3E Series 3.2 x 2.5 x 0.75**

- Frequency Range: 12.000 to 52.000 MHz
- Tolerance: ±10 PPM to ±50 PPM at 25° C
- Stability: ±10 PPM to ±100 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±1 PPM to ±3 PPM per Year

**C1E Series 2 x 1.6 x 0.5**

- Frequency Range: 24.000 to 80.000 MHz
- Tolerance: ±10 PPM to ±30 PPM at 25° C
- Stability: ±15 PPM to ±50 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±3 PPM per Year

**C16 Series 1.6 x 1.2 x 0.4**

- Frequency: 24,000, 27,000, 32,000, 36,000, 39,400, and 40,000 MHz
- Tolerance: ±10 PPM to ±30 PPM at 25° C
- Stability: ±15 PPM to ±50 PPM
- Operating: -20 to 70° C
- Temp: -40 to +85° C
- Aging: ±3 PPM per Year

**Solder Reflow Profile**

- Temperature: 260° C MAX
- Time: 10 sec
- Other temperatures and times are also mentioned for the reflow process.
CLOCK OSCILLATOR PRODUCTS

CERAMIC PACKAGES

SUMMARY SPECIFICATIONS

**S7 Series 7 x 5 x 1.4**

- **Frequency Range:** 1.000 to 156.250 MHz
- **Stability:** ±20 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

**S3 Series 3.2 x 2.5 x 1.2**

- **Frequency Range:** 1.000 to 75.000 MHz
- **Stability:** ±20 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

**S2 Series 2.5 x 2 x 0.95**

- **Frequency Range:** 2.000 to 50.000 MHz
- **Stability:** ±20 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

**S7A Series 7 x 5 x 1.4**

- **Frequency Range:** 10.000 to 625.500 MHz
- **Stability:** ±25 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

**S5 Series 5 x 3.2 x 1.3**

- **Frequency Range:** 1.000 to 75.000 MHz
- **Stability:** ±20 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

**Also available:**

- 32.768 KHz (Real Time Clock)
- Low EMI—Spread Spectrum

**HCMOS & TTL CLOCK OSCILLATORS**

**S5A Series 5 x 3.2 x 1.3**

**LVDS & LVPECL CLOCK OSCILLATORS**

- **Frequency Range:** 25.000 to 160.000 MHz
- **Stability:** ±25 PPM to ±100 PPM
- **Operating Temp:** 0 to 70°C
- **Temp:** -40 to +85°C
- **Aging:** ±3 PPM per Year

- **CMOS**
- **LVPECL**
- **LVDS**
- **3.3V**
- **5V**
- **80% Swing**
- **50% Swing**
- **20% Swing**

**3.3V**

- **LVDS**
- **5V**
- **80% Swing**
- **50% Swing**
- **20% Swing**

- **3.3V**

- **LVDS**
- **5V**
- **80% Swing**
- **50% Swing**
- **20% Swing**
VCXO & TCXO CLOCK OSCILLATOR PRODUCTS

CERAMIC PACKAGES

VCXO SUMMARY SPECIFICATIONS

**V7 Series 7 x 5 x 1.8**
- Frequency Range: 1.000 to 52.000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

**V5 Series 5 x 3.2 x 1.2**
- Frequency Range: 1.000 to 52.000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

TCXO SUMMARY SPECIFICATIONS

**TX22 Series 2.5 x 2 x 1.1**
- Frequency Range: 13,000 to 26,000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

**TX32 Series 3.2 x 2.5 x 1.1**
- Frequency Range: 13,000 to 26,000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

HCMOS VOLTAGE CONTROLLED CLOCK OSCILLATORS

**HCMOS AND SINEWAVE TEMPERATURE COMPENSATED CLOCK OSCILLATORS**

**V7 Series 7 x 5 x 1.8**
- Frequency Range: 1.000 to 52.000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

**V5 Series 5 x 3.2 x 1.2**
- Frequency Range: 1.000 to 52.000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

**TX22 Series 2.5 x 2 x 1.1**
- Frequency Range: 13,000 to 26,000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V

**TX32 Series 3.2 x 2.5 x 1.1**
- Frequency Range: 13,000 to 26,000 MHz
- Frequency Stability: ±25 PPM to ±100 PPM
- Voltage Control: ±30 to ±150 PPM Typical
- Aging: ±3 PPM per Year Maximum
- Operating Temp: 0°C to +70°C and -40°C to +85°C
- Waveform: HCMOS
- Voltage: +3.3 V and +5.0 V
Certified to Automotive Quality Standard ISO/TS16949.
Superior Shock and Vibration Performance.
Specifically designed to meet the severe environments of automotive products.
Environmentally Friendly Lead-Free/RoHS Compliant Products - ISO14000.
AEC-Q200 Qualified Reliability.

**FREQUENCY CONTROL PRODUCTS**

**FOR AUTOMOTIVE APPLICATIONS**

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Series</th>
<th>Dimensions (mm)</th>
<th>TPMS</th>
<th>ECU</th>
<th>Sensor</th>
<th>GPS</th>
<th>Airbag</th>
<th>Multimedia</th>
<th>Satellite Radio</th>
<th>RKE</th>
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<td>Crystals</td>
<td>C2E</td>
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<td>C3E</td>
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<td>Oscillators</td>
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**C2 Series** 2.5 x 2 x 0.6
**C3 Series** 3.2 x 2.5 x 0.75
**C5 Series** 5 x 3.2 x 1.0
**C7 Series** 7 x 5 x 1.1

**S2 Series** 2.5 x 2 x 0.95
**S3 Series** 3.2 x 2.5 x 1.2
**S5 Series** 5 x 3.2 x 1.3
**S7 Series** 7 x 5 x 1.4

**Frequency Range:** 8 to 150 MHz
Frequency Tolerance: ± 30 PPM to ± 50 PPM at 25°C
Frequency Stability: ± 50 to ± 100 PPM
Operating Temp. Range: -40°C to +125°C
Superior Shock and Vibration Resistance
Low Drive Levels from 15 uW to 500 uW
Excellent Thermal Hysteresis
Low Aging

**S5 Series** 5 x 3.2 x 1.3
**S7 Series** 7 x 5 x 1.4

Frequency Range: 1 to 156 MHz
Frequency Stability: ±50 PPM to ±100 PPM
Operating Temp. Range: -40 to +125°C
Supply Voltage: +2.5 / +3.3 / +5.0 VDC
Output: HCMOS
Tristate – Enable/Disable
Low Power Consumption
Tight Symmetry of 45/55%
ASIC manufacturers use a unipolar oscillator cell. Proper selection of five external capacitors, resistors, and crystal load can increase frequency stability, reduce cost, and reduce dppm.

Two Barkhausen rules are also necessary for oscillation:

- The summation of the phase shifts around a closed loop must be $\pi$ or 360 degrees where $N$ is an integer (0, 1, 2, ...)
- Summation of the gains around a closed loop must be equal to or greater than 1.

**Crystal Equivalent Circuit.** Fig 1 is the equivalent circuit for a crystal plus external load.

**Oscillator Schematic.** Most ASIC use the Pierce oscillator configuration. Ref Fig 2.

**Pi Capacitors:** Pi cap reactance values should be in the low hundreds of ohms and should be approximately equal to the output impedance of the ASIC cell. Oscillator cells designed for lower frequency AT-cut crystals have -300 to 500 ohms Thevenin output resistance (Rout). Higher frequency fundamentals are -100 to 300 ohms.

Pi caps are changed as a function of crystal load and VDD. Pi caps are usually the same value or C1 may be slightly smaller than C2. Ref Table 1.

**Rd selection** Rd, sometimes called a phase shift resistor, is between IC output and crystal. The phase shift resistor has 4 functions:

- Reduce crystal power
- Reduce C2 output loading
- Shift phase
- Increase frequency stability

If Rd equals Xc2, a Bode plot would show there is fast rate-of-change of phase at the 360 deg oscillation requirement. Fast rate-of-change of phase is critical for good frequency stability. Ref Fig 3.

Rout and Rd are in series. The series combination is in parallel with C2. Select Rd = Rout = Xc2 unless cell has insufficient drive capability. First select C2, then select Rd.

Rout in series with Rd are shunting C2 (Rout + Rd) // Xc2). Drive capability. First select C2, then select Rd. Select Rd = Rout = Xc2 unless cell has insufficient requirement. Fast rate-of-change of phase at the 360 deg oscillation requirement. Fast rate-of-change of phase is critical for good frequency stability. Ref Fig 3.

If Rd is omitted (sometimes done at higher frequencies or with low output drive), layout should still include Rd as a short. If Rd is a short, top of C2 should be a squarewave with rounded corners. Sharp rise and fall times are indications of excessively high drive or insufficient C2.

If C2 is too small, a low resistance crystal may have high ESR. ESR = $\frac{1}{1 + \frac{C1}{C2}}$. Less than full amplitude squarewave is an indication that Rd may be too large or C2 may be too large and is passing signal to ground.

**Starting Voltage Checks.** Continuously monitor the waveshape at the IC output for any abnormalities during all starting tests. This may be difficult on a PCB regulated supply is overridden. Low voltage starting checks should be made by slowly increasing VDD from 0 volts. Perform this test first to detect and prevent effects of a sleepy crystal. Expect that oscillator should be started at half the nominal VDD. If not, loading on the IC may be too large or the IC may have insufficient gain. Continue this test up to nominal VDD plus 1.5 VDC.

High voltage starting checks are made by applying numerous VDD step functions starting with VDD plus 1.5 VDC and slowly decreasing to low voltage starting point. Intermittent starting problems may be an indication that Co or Cstray are too large. Medium voltage starting checks are made by switching the power supply switch on and off. Perform this test from half VDD to VDD plus 1.5 volts.

**Negative Resistance Testing.** Negative resistance is similar to circuit gain. Test the circuit by installing a resistive pot in series with an AVDEEC crystal. Do not perform this test on a known bad crystal. Negative resistance is the value of the pot plus the crystal's series resistance.

**Crystal Power.** While the crystal is disconnected, attach a current probe and measure current output. Do not exceed maximum rated power of crystal unit.

$$\text{Crystal Power} = \frac{\text{Irms}}{\text{Rm}}$$

Adjusting $\tau$. Where gm is the transconductance of the inverter and:

$$\tau = \frac{1}{wC1} - \frac{1}{Xc2}$$

$\omega = 2\pi \cdot \text{frequency}$

By making C1 and C2 smaller, one can raise the negative resistance. Caps too small will cause high ESR and reduced phase shifting.

**Circuit Margin.** Circuit margin is defined as the absolute value of negative resistance $\pm \tau$ divided by the average value of ESR.

$$\text{CM} = \frac{1}{\text{ESR}_{\text{avg}}}$$

For low dppm, circuit margins should be at least 10. Some approximate values taken from experimental data can be found in Table III.

**Temperature Testing.** Quick temperature testing can be performed using a few seconds of freeze mist (or a can of duster spray held upside down) and a hair dryer. Test only when circuit is returning to room ambient.

**Summary.** Oscillator designers and crystal suppliers working together can assemble circuits having single digit dppm failure rates. This starts with the oscillator being designed on sound basics and working with a crystal supplier, who designs, manufactures and controls his production. On first designs, it is suggested that the schematic or even the PCB should be sent to the crystal supplier for circuit board matching.

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**C1 & C2 selection for Crystal Load**

<table>
<thead>
<tr>
<th>C1 Load</th>
<th>C2 Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3.3 VDC</td>
<td>+5 VDC</td>
</tr>
<tr>
<td>6 PF</td>
<td>8 PF</td>
</tr>
<tr>
<td>7 PF</td>
<td>10 PF</td>
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<td>11 PF</td>
<td>15 PF</td>
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<tr>
<td>12 PF</td>
<td>22 PF</td>
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<tr>
<td>20 PF</td>
<td>33 PF</td>
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**Table 2: Suggested Loads for Fundamental Crystals**

<table>
<thead>
<tr>
<th>LOAD</th>
<th>FREQUENCY RANGE</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>+3.3 VDC</td>
</tr>
<tr>
<td>2</td>
<td>+5 VDC</td>
</tr>
<tr>
<td>C1</td>
<td>C2</td>
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**Table 3: Expected DPPM**

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<th>DPPM</th>
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<td>47</td>
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<tr>
<td>25</td>
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</tr>
</tbody>
</table>

**Figure 1: Equivalent Circuit of a Crystal**

**Figure 2: Oscillators Schematic**

**Figure 3: Bode Plots with and without Rd**

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