This document is designed to serve as a starting point when choosing a crystal to operate alongside the Microchip Stand-Alone Real-Time Clock/Calendar devices (Figure 1). To oscillate as closely as possible to the desired frequency, a crystal must have load capacitors that match the value recommended by the manufacturer, according to Equation 1.

**EQUATION 1:**

\[
C_{load} = \frac{C_{x2} \cdot C_{x1}}{C_{x2} + C_{x1} + C_{stray}}
\]

Where:
- \(C_{x1}\) = Capacitor value on pin X1 + \(C_{pin}\)
- \(C_{x2}\) = Capacitor value on pin X2 + \(C_{pin}\)
- \(C_{stray}\) = Trace capacitance
- \(C_{pin}\) = 3 pF

Also, the oscillator pin capacitance (available in the device data sheet as COSC) must be included in \(C_{X1}\) and \(C_{X2}\), and stray board capacitance (\(C_{stray}\)) must be taken into consideration when choosing the capacitors.

**CONSIDERATIONS**

The Microchip stand-alone RTCC’s have been designed to work with 32.768 kHz tuning fork crystals with a load capacitance (\(C_{LOAD}\) or \(CL\)) of 6-9pF. For tuning fork crystals, the frequency has a parabolic dependence on temperature. Therefore, when it changes, the frequency decreases accordingly, as shown in Equation 2 and Figure 2. See AN1413, “Temperature Compensation of a Tuning Fork Crystal Based on MCP79410” (DS01413).

**EQUATION 2:**

\[
f = f_0 \times [1 - Tc \times (T - T_0)^2]
\]

Where:
- \(f_0\) – frequency at turnover point
- \(Tc\) – temperature coefficient
- \(T-T_0\) – deviation from turnover point
- \(T\) – current temperature (°C)
- \(T_0\) – turnover point (°C)

**FIGURE 2: PARABOLIC CURVE FOR TUNING FORK CRYSTALS**

![Parabolic curve for tuning fork crystals](image)

**FIGURE 1: OSCILLATOR DIAGRAM**

![Oscillator diagram](image)
For best results, it is recommended that a ground ring should encompass the crystal and the X1 and X2 pins. See AN1365, “Recommended Usage of Microchip Serial RTCC Devices” (DS01365). Also, the traces from the RTCC to the capacitors and crystal should be as short as possible in order to minimize the stray board capacitance (CSTRAY). See AN1288, “Design Practices for Low-Power External Oscillators” (DS01288).

Table 1 shows recommended crystals and load capacitors.

Some vendors use the term oscillation allowance as the sum of negative R value and ESR (Equation 3). The negative R (-R) which has been measured on the AC164140 RTCC PICtail™ board is a measure of the ability of the oscillator to drive the crystal over temperature (Figure 3). An oscillation allowance value of three to five times the crystal ESR will provide an acceptable margin. See AN943, “Practical PICmicro® Oscillator Analysis and Design” (DS00943) and AN949, “Making Your Oscillator Work” (DS00949).

EQUATION 3:

\[
\text{Oscillation Allowance} = I - R \text{I} + ESR \, [\Omega]
\]

FIGURE 3: NEGATIVE RESISTANCE TEST SETUP

<table>
<thead>
<tr>
<th>Oscillation Allowance</th>
<th>Oscillation Allowance /ESR Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 kΩ</td>
<td>10.28</td>
</tr>
<tr>
<td>600 kΩ</td>
<td>17.14</td>
</tr>
<tr>
<td>800 kΩ</td>
<td>11.42</td>
</tr>
<tr>
<td>980 kΩ</td>
<td>9.6</td>
</tr>
<tr>
<td>1180 kΩ</td>
<td>8.2</td>
</tr>
<tr>
<td>1380 kΩ</td>
<td>7.1</td>
</tr>
<tr>
<td>1580 kΩ</td>
<td>6.2</td>
</tr>
</tbody>
</table>

TABLE 1: CRYSTALS

<table>
<thead>
<tr>
<th>Crystal Manufacturer</th>
<th>Crystal Part Number</th>
<th>ESR (Max.)</th>
<th>CLOAD (pF)</th>
<th>C1 Capacitor Value (pF)</th>
<th>C2 Capacitor Value (pF)</th>
<th>PPM Error (at 25°C)</th>
<th>Seconds /Day</th>
<th>Oscillation Allowance</th>
<th>Oscillation Allowance /ESR Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizen</td>
<td>CMR200T-32.768KDZB-UT</td>
<td>50 kΩ</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>-3.17</td>
<td>-0.274</td>
<td>480 kΩ</td>
<td>9.6</td>
</tr>
<tr>
<td>Citizen</td>
<td>CFS206-32.768KDZB-UB</td>
<td>35 kΩ</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>-9.60</td>
<td>-0.829</td>
<td>780 kΩ</td>
<td>22.28</td>
</tr>
<tr>
<td>ECS</td>
<td>ECS.327-6-13X</td>
<td>35 kΩ</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>1.07</td>
<td>0.092</td>
<td>360 kΩ</td>
<td>10.28</td>
</tr>
<tr>
<td>ECS</td>
<td>ECS.327-6-17X-TR</td>
<td>40 kΩ</td>
<td>6</td>
<td>10</td>
<td>8.2</td>
<td>10.93</td>
<td>0.944</td>
<td>540 kΩ</td>
<td>13.5</td>
</tr>
<tr>
<td>Epson Crystals</td>
<td>MC405-32.7KE3R</td>
<td>50 kΩ</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>-1.71</td>
<td>-0.148</td>
<td>300 kΩ</td>
<td>6</td>
</tr>
<tr>
<td>Epson Crystals</td>
<td>C002RX32.76k-K4P-UB</td>
<td>60 kΩ</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>-0.66</td>
<td>-0.057</td>
<td>370 kΩ</td>
<td>6.18</td>
</tr>
<tr>
<td>AVX Crystals</td>
<td>ST3215SB32768C0HP-WBB</td>
<td>70 kΩ</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>-1.22</td>
<td>-1.105</td>
<td>800 kΩ</td>
<td>11.42</td>
</tr>
<tr>
<td>FOX Crystals</td>
<td>NC38LF-32.768kHz</td>
<td>35 kΩ</td>
<td>6</td>
<td>8.2</td>
<td>8.2</td>
<td>1.47</td>
<td>0.127</td>
<td>600 kΩ</td>
<td>17.14</td>
</tr>
<tr>
<td>Micro Crystal</td>
<td>CM77V-T1A</td>
<td>70 kΩ</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>3</td>
<td>0.259</td>
<td>300 kΩ</td>
<td>4.28</td>
</tr>
<tr>
<td>Citizen (Note)</td>
<td>CM200S32.768KDZB-UT</td>
<td>50 kΩ</td>
<td>6</td>
<td>10</td>
<td>8</td>
<td>1.2</td>
<td>0.104</td>
<td>480 kΩ</td>
<td>9.6</td>
</tr>
<tr>
<td>Seiko (Note)</td>
<td>SSP-T7-F</td>
<td>65 kΩ</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>-0.76</td>
<td>0.066</td>
<td>390 kΩ</td>
<td>6</td>
</tr>
<tr>
<td>Seiko (Note)</td>
<td>VT-200-F</td>
<td>50 kΩ</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>-2.14</td>
<td>0.185</td>
<td>460 kΩ</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Note: Not included in this document.
CRYSTAL TEST RESULTS

The crystals detailed above have been tested on the AC164140 RTCC PICtail board (unless noted). The results are in Table 2.

**TABLE 2: CRYSTAL TEST RESULTS**

<table>
<thead>
<tr>
<th>Crystal</th>
<th>Appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizen CMR200T-32.768KDZB-UT</td>
<td>Appendix A: “CMR200T-32.768KDZB-UT”</td>
</tr>
<tr>
<td>Citizen CFS206-32.768KDZB-UB</td>
<td>Appendix B: “CMR-32.768KDZB-UB”</td>
</tr>
<tr>
<td>ECS ECS.327-6-13X</td>
<td>Appendix C: “ECS327-6-13X”</td>
</tr>
<tr>
<td>ECS ECS.327-6-17X-TR</td>
<td>Appendix D: “ECS.327-6-17X-TR”</td>
</tr>
<tr>
<td>Epson MC405-32.7KE3R</td>
<td>Appendix E: “EPSON MC405-32.7KE3R”</td>
</tr>
<tr>
<td>Epson C002RX32.76K-EPB</td>
<td>Appendix F: “EPSON C002RX32.76K-EPB”</td>
</tr>
<tr>
<td>AVX ST3215SB32768C0HPWBB</td>
<td>Appendix G: “AVX ST3215SB32768C0HPWBB”</td>
</tr>
<tr>
<td>FOX NC38LF-32.768kHz</td>
<td>Appendix H: “FOX NC38LF-32.768kHz”</td>
</tr>
</tbody>
</table>
APPENDIX A: CMR200T-32.768KDZB-UT

FIGURE 4: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_BAT = 1.3V, V_CC = 1.3V)

FIGURE 5: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_CC = 3.3V)
FIGURE 6: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (\(V_{cc} = 5.0V\))

FIGURE 7: OSCILLATOR INPUT AND OUTPUT (\(V_{cc} = 5.5V\))
FIGURE 8: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

FIGURE 9: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)
FIGURE 10: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 ms/div

FIGURE 11: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 10 PF

C1 = 10 pF, C2 = 10 pF

Voltage (V)

Frequency (Hz)
APPENDIX B: CMR-32.768KDZB-UB

FIGURE 12: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

FIGURE 13: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)
FIGURE 14: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 15: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 16: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

FIGURE 17: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)
FIGURE 18: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

FIGURE 19: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 12 PF
APPENDIX C: ECS327-6-13X

FIGURE 20: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_BAT = 1.3V, V_CC = 1.3V)

FIGURE 21: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_CC = 3.3V)
FIGURE 22: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 23: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 24: OSCILLATOR START-UP WAVEFORM (VCC = 3.3V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 ms/div

FIGURE 25: OSCILLATOR START-UP WAVEFORM (VCC = 5.0V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 ms/div
FIGURE 26: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

FIGURE 27: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 12 PF; C2 = 10 PF

C1 = 12 pF, C2 = 10 pF
FIGURE 28: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3VL, V_{CC} = 1.3V)

FIGURE 29: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)
FIGURE 30: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 31: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 32: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

FIGURE 33: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)
FIGURE 34: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

FIGURE 35: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 8.2 PF
APPENDIX E: EPSON MC405-32.7KE3R

FIGURE 36: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

FIGURE 37: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)
FIGURE 38: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 39: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 40: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

FIGURE 41: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)
FIGURE 42: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 mS/div

FIGURE 43: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 10 PF

C1 = 10 pF, C2 = 10 pF

Frequency (Hz)

32,767.930
32,767.935
32,767.940
32,767.945
32,767.950
32,767.955

Voltage (V)

1.3v
3.3v
5.0v
5.5v
APPENDIX F: EPSON C002RX32.76K-EPB

FIGURE 44: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_{BAT} = 1.3V, V_{CC} = 1.3V)

FIGURE 45: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_{CC} = 3.3V)
FIGURE 46: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 47: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 50: OSCILLATOR START-UP WAVEFORM ($V_{cc} = 5.5V$)

FIGURE 51: FREQUENCY/VOLTAGE CHARACTERISTIC FOR $C_1 = 12$ PF; $C_2 = 10$ PF
APPENDIX G: AVX ST3215SB32768C0HPWBB

FIGURE 52: OSCILLATOR INPUT AND OUTPUT WAVEFORM (V_BAT = 1.3V, V_CC = 1.3V)

FIGURE 53: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (V_CC = 3.3V)
FIGURE 54: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 55: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 56: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 ms/div

FIGURE 57: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)

C2 - Oscillator Out (100 mV/div - DC)  Time base: 500 ms/div
FIGURE 58: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

FIGURE 59: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 10 PF; C2 = 12 PF
APPENDIX H: FOX NC38LF-32.768KHZ

FIGURE 60: OSCILLATOR INPUT AND OUTPUT WAVEFORM (VBAT = 1.3V, VCC = 1.3V)

FIGURE 61: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (VCC = 3.3V)
FIGURE 62: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.0V)

FIGURE 63: OSCILLATOR INPUT AND OUTPUT WAVEFORMS (Vcc = 5.5V)
FIGURE 64: OSCILLATOR START-UP WAVEFORM (Vcc = 3.3V)

FIGURE 65: OSCILLATOR START-UP WAVEFORM (Vcc = 5.0V)
FIGURE 66: OSCILLATOR START-UP WAVEFORM (Vcc = 5.5V)

FIGURE 67: FREQUENCY/VOLTAGE CHARACTERISTIC FOR C1 = 8.2 PF; C2 = 8.2 PF
Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip’s Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip’s code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer’s risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

Trademarks
The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC32 logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, Hi-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Incorporated in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MFP, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICKit, PICtail, REAL ICE, rFLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2013, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.
ISBN: 9781620771457

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company’s quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
ISO/TS 16949