INTRODUCTION
This technical brief discusses the interfacing and characterization of the Micro Crystal MS1V-T1K 32.768 kHz tuning fork (watch) crystal with the PIC16F690 PIC® microcontroller Timer1 low-power oscillator. This information can be used to assist the designer in interfacing 32.768 kHz tuning fork crystal to the PIC16F690 MCU.
The information in this technical brief is intended as a design suggestion. The designer should verify proper operation for their particular application.

MICRO CRYSTAL MS1V-T1K
The Micro Crystal MS1V-T1K is a high-quality tuning fork quartz crystal resonator. It is packaged in a square-bodied 2x2x6 mm metal-can package with formed leads intended for surface mounting and reflow soldering.
More information about the MS1V-T1K can be found in the data sheet available on the Micro Crystal web site www.microcrystal.com.

PIC16F690
The PIC16F690 clock oscillator can be configured as a Timer1 oscillator by setting control bit T1OSCEN (T1CON<3>). The oscillator is a low-power oscillator and will continue to run during Sleep. This mode of operation is only allowed if the primary system clock is configured for the internal oscillator.
More information can be found in the PIC16F631/677/685/687/689/690 Data Sheet (DS41262) available from the Microchip web site www.microchip.com.

SCHEMATIC DIAGRAM
The schematic for the circuit is shown in Figure 1. The tuning fork crystal resonator is connected to the PIC16F690 OSC1 and OSC2 pins. Capacitors CD and CG are the load capacitors and resistor RD is the dumping resistor.

Load Capacitors
The load capacitors CD and CG are regarded in series. To determine the total effective load capacitance, the board layout stray (parasitic) capacitance has to be taken into account. For best frequency accuracy, the total effective load capacitance should match the crystal’s CL specification.

\[
C_{\text{EffectiveLoad}} = \frac{C_D \cdot C_G}{C_D + C_G} + C_{\text{Stray}}
\]

Overtone Mode Suppression
Resistor RD together with load capacitor CD form a low-pass filter that will suppress the crystal resonator’s overtone mode of operation. Resistor RD also limits the amount of drive to the crystal resonator. The maximum drive current of tuning fork crystals is 1 μW.
FIGURE 1: SCHEMATIC DIAGRAM

![Schematic Diagram]

**PCB LAYOUT**

The PCB layout is shown in Figure 2. The PIC16F690 package is a 20-lead plastic shrink small outline (SSOP). The load capacitors and dumping resistors are 0603 size surface mount packages.

The PCB is 0.062" double sided FR4 material. Not shown in the diagram is a solid ground plane on the bottom side.

**FIGURE 2: PCB LAYOUT (TOP COPPER)**

![PCB Layout Diagram]

**CHARACTERIZATION REPORT**

A PCB was constructed and submitted to Micro Crystal for characterization. The three page report is shown below.
In accordance with our policy of continuous development and improvement, Micro Crystal reserves the right to modify specifications or design-recommendations without prior notice. The recommendations stated above are based on measured-results, respecting the “oscillator design rules”. Micro Crystal makes no representation or warranty for information in this “Design and Crystal Recommendations”.

Date: October 2005
Revision N°: 1.0
Page 1/3

Oscillator Design Check

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage $V_{DD}$</td>
<td>2.0 – 5.0 V</td>
</tr>
<tr>
<td>Load Capacitors $C_D$ / $C_G$</td>
<td>22 / 22 pF</td>
</tr>
<tr>
<td>Serial Resistor $R_D$</td>
<td>220 kΩ</td>
</tr>
<tr>
<td>Effective Load Capacitance</td>
<td>12.33 pF</td>
</tr>
<tr>
<td>Oscillation Allowance $\Omega$</td>
<td>417 kΩ</td>
</tr>
<tr>
<td>Oscillator Output Voltage $\Omega$</td>
<td>690 mV $\Omega$</td>
</tr>
<tr>
<td>Drive Level $\Omega$</td>
<td>0.300 $\mu$W</td>
</tr>
<tr>
<td>Startup Time $\Omega$</td>
<td>600 ms</td>
</tr>
<tr>
<td>$R_D$ min. for Safe Overtone Mode Suppression</td>
<td>110 kΩ</td>
</tr>
</tbody>
</table>

1) Measured at $V_{DD} = 2.0$ V.  
2) Measured at $V_{DD} = 5.0$ V.

Recommendation

<table>
<thead>
<tr>
<th>Crystal Type</th>
<th>MS1V-T1K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>32.768 kHz</td>
</tr>
<tr>
<td>Load Capacitance $C_L$</td>
<td>12.5 pF</td>
</tr>
<tr>
<td>Tolerance</td>
<td>+/-20 ppm</td>
</tr>
</tbody>
</table>

Oscillator Design

<table>
<thead>
<tr>
<th>$R_D$</th>
<th>220 kΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_D$</td>
<td>22 pF</td>
</tr>
<tr>
<td>$C_G$</td>
<td>22 pF</td>
</tr>
</tbody>
</table>

Remarks

The PIC16F690 consists of a self limiting Pierce Oscillator. Due to internal voltage regulator, the oscillator characteristics and performances remain stable down to $V_{DD} = 2.4$ V. Below this level, the waveforms change; however the oscillator works safely down to $V_{DD} = 2.0$ V.

The serial resistor $R_D$ is needed for safe overtone mode suppression. Despite a 110 kΩ resistor would be sufficient, a resistor value of 220 kΩ is recommended in order to reduce the crystal’s drive level.

Placing $C_D = 22$ pF and $C_G = 22$ pF load capacitors on each side of the crystal results in an effective load capacitance of 12.33 pF (including board stray capacitances) which is a perfect match for a crystal specified for $C_L = 12.5$ pF.

The oscillator circuit provides an oscillation allowance of 417 kΩ; this allows the safe use of smallest SMD quartz crystals (ESR ≤ 80 kΩ).

The PIC16F690 consists of a self limiting Pierce Oscillator. Due to internal voltage regulator, the oscillator characteristics and performances remain stable down to $V_{DD} = 2.4$ V. Below this level, the waveforms change; however the oscillator works safely down to $V_{DD} = 2.0$ V.

The serial resistor $R_D$ is needed for safe overtone mode suppression. Despite a 110 kΩ resistor would be sufficient, a resistor value of 220 kΩ is recommended in order to reduce the crystal’s drive level.

Placing $C_D = 22$ pF and $C_G = 22$ pF load capacitors on each side of the crystal results in an effective load capacitance of 12.33 pF (including board stray capacitances) which is a perfect match for a crystal specified for $C_L = 12.5$ pF.

The oscillator circuit provides an oscillation allowance of 417 kΩ; this allows the safe use of smallest SMD quartz crystals (ESR ≤ 80 kΩ).
Oscillator Input and Output waveforms ($V_{DD} = 2.0V$):

![Oscillator waveforms (VDD = 2.0V)](image1)

- C1: CLKOUT (500 mV/div - AC)
- C2: CLKin (500 mV/div - AC)
- Time base: 10 μs/div

Oscillator Input and Output waveforms ($V_{DD} = 5.0V$):

![Oscillator waveforms (VDD = 5.0V)](image2)

- C1: CLKOUT (500 mV/div - AC)
- C2: CLKin (500 mV/div - AC)
- Time base: 10 μs/div
Oscillator Output start-up waveform ($V_{DD} = 2.0V$):

- C1: CLKOUT (500 mV/div - DC)  Time base: 100 ms/div

Oscillator Output start-up waveform ($V_{DD} = 5.0V$):

- C1: CLKOUT (500 mV/div - DC)  Time base: 100 ms/div
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.

Trademark:
The Microchip name and logo, the Microchip logo, Accuron, dsPIC, KEELoQ, KEELoQ logo, microID, MPLAB, PIC, PICmicro, PICSTART, PRO MATE, PowerSmart, rPIC, and SmartShunt are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.
AmpLab, FilterLab, Linear Active Thermistor, Migratable Memory, MXDEV, MXLAB, PS logo, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.
Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, ECAN, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSIP, ICEPIC, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, PICkit, PICDEM, PICDEM.net, PICLAB, PICtail, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rfLAB, rFPICDEM, Select Mode, Smart Serial, SmartTel, Total Endurance, UNI/O, WiperLock and ZENA 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.
All other trademarks mentioned herein are property of their respective companies.
© 2007, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.
Printed on recycled paper.