**INTRODUCTION**

Many embedded systems require some form of accurate timekeeping. It is true that a number of MCUs offer internal systems to maintain the time. There is still a growing number of applications that require an external RTCC (Real-Time Clock/Calendar) and higher integration of external peripheral components into the RTCC.

In order to achieve a highly robust and repeatable system, the designer must consider more than just the data sheet specifications and parameters.

There are a number of situations that can result in less than optimal operation, many of which are easy mistakes that are avoidable with some initial knowledge. The most important of these are discussed in this application note.

This application note provides assistance and guidance in using the Microchip I²C™ RTCC family of devices. These recommendations are not meant as requirements; however, their adoption will lead to a more robust overall design. The following topics are discussed:

- Basic Design Considerations
- VCC Ramp Rates
- Crystal Selection
- Oscillator Layout
- VBAT Selection
- UL Considerations
- RTCC Registers

All of the recommended practices that are detailed in this document are used on the RTCC PICtail™ daughter board available from Microchip – AC164140.

Figure 1 shows the suggested connections for using the Microchip I²C MCP7941X RTCC family. The basis for these connections will be explained in the sections which follow.

**FIGURE 1: RECOMMENDED CONNECTIONS FOR MCP79410 SERIES DEVICES**

Note 1: A 100 nF capacitor should be placed as close to the Vcc Pin on the device as possible.
BASIC DESIGN CONSIDERATIONS

It is never good practice to leave an input pin floating. This can cause high standby current as well as undesired functionality. If a pin is left floating, it can either float low or high. Which direction the signal goes is dependent upon a number of factors, including noise in the system and capacitive coupling. Because of this, the level seen by the input circuitry is relatively random and likely to change during operation.

MFP Pin

The multi-function pin (MFP) is used for a number of functions when enabled by the RTCC registers. As this pin is an open drain output, a pull up is required to Vcc (it is not recommended to use a pull up to the backup supply).

The output driver for this pin is able to sink a maximum current of 10 mA; care should be taken to ensure that the pull-up resistor is calculated to limit the current to this value.

The MFP pin is used for the following operation when Vcc is present on the device:

• General purpose output – can be used as an additional I/O line under the control of the MCU.
• Output a frequency – can be used to output a frequency derived from the 32.768 kHz crystal. As this is an open drain, the size of the pull-up resistor and the bus capacitance of that line will determine the rise and fall time of the signal.
• Alarm output – an active alarm generated from one of the programmable alarms will assert this line (pull the line low). The line can be wire OR’d to other open drain signals to drive a single MCU IRQ line.

When Vcc is removed and the device is running from the backup supply VBAT, the only functions that are active on this pin are the alarms; all other functions are disabled until Vcc is restored.

I²C Communication Pins

To follow the I²C specification, both the SDA (Serial Data) and SCL (Serial Clock) lines require a pull up to Vcc. As the MCP7941X is designed to run at a maximum of 400 kHz, suggested values for both SCL and SDA are 2.2K Ohms at 5.5V.

Application notes exist on the Microchip web site; they cover in great depth the calculations required to determine optimal resistor values (AN1028).

POWER SUPPLY

Microchip I²C RTCC devices feature a robust serial communication protocol that helps to prevent unintentional writes and data corruption while power is within normal operating levels. But certain considerations should be made regarding power-up and power-down conditions to ensure the same level of protection during those times when power is not within normal operating levels.

Information regarding the VBAT supply is provided later in this text.

As shown in Figure 1, a decoupling capacitor (typically 0.1 µF) should be used to help filter out small ripples on Vcc.

Power-Up

On power-up, Vcc should always begin at 0V and rise straight to its normal operating level to ensure a proper Power-on Reset. Vcc should not linger at an ambiguous level (i.e., below the minimum operating voltage).

However, if Vcc happens to fall below the minimum retention voltage for the device (see data sheet DC characteristics), it is recommended that Vcc be brought down fully to 0V before returning to normal operating level. This will help to ensure that the device is reset properly.

Furthermore, if the microcontroller features a Brown-out Reset with a threshold higher than that of the RTCC, bringing Vcc down to 0V will allow both devices to be reset together. Otherwise, the microcontroller may reset during communication while the RTCC is still in an operational condition.

Internal Switch to VBAT

Internally the RTCC will switch to the VBAT supply when Vcc drops to a typical value of 1.5V

Failure of VCC During a Read

During a read of the SRAM/RTCC or EEPROM, if the Vcc fails, the device will continue to operate and communicate until Vcc reaches the VBAT trip point. It is not recommended to operate during this time and all I²C communication should be halted as soon as Vcc failure is detected.
Failure of VCC During an EEPROM Write

During the time that data is being written to the EEPROM or unique ID locations, VCC should remain above the minimum operating voltage — typically 1.8V. If at any time VDD drops below this minimum voltage but remains above the VBAT switchover voltage (as specified in the product data sheet), care should be taken to ensure that the data written to the device is free from errors.

If at any time the VCC voltage drops below 1.5V (V BAT switchover) then the I 2 C interface is disabled and any writes that are in process will be terminated. It is recommended that after a power fail the EEPROM is checked.

It is not recommended to operate during a power fail.

Failure of VCC During an SRAM/RTCC Write

As the EEPROM writes are still possible when VCC is dropping until the VBAT trip point is reached, again it is not recommended to operate during this time and all I 2 C communication should be stopped as soon as possible.

VCC RAMP RATES

The Microchip MCP7941X family integrates a battery switchover circuit to maintain the time and also the contents of the SRAM during the time when Vcc fails. Due to the fact that the circuit operates at a very low current level, care should be exercised to ensure that the rise and fall times listed in the data sheet are met.

Many applications will meet these requirements simply based on the capacitance on the VCC lines and also the output impedance of the power supply circuit and the copper resistance.

The following specifications should be met.
- VCCFT – 300 µs min from VTRIP(max) to VTRIP(min)
- VCCRT – 0 µs min from VTRIP(min) to VTRIP(max)
CRYSTAL SELECTION

Without the correct crystal, the RTCC will not operate as to specification. There are two basic types of crystals that are suitable for use with the RTCC.

• Tuning fork crystal – these are the most common types of crystals and are traditionally used with RTCC devices due to availability and low cost. The typical temperature curve for tuning fork crystals is shown below.

The accuracy of the crystal is acceptable around the 25°C temperature, moving away from this point the PPM changes drastically. It is recommended that the internal calibration be used to improve the accuracy at other temperatures.

• AT-Cut crystal – these can be used in applications where a broader temperature curve is required and using the calibration available on the RTCC is not an option. AT-Cut crystals are not as common as tuning fork crystals and are higher in cost. The advantage is the temperature curve.

The following crystals have been tested and found to work with the MCP7941X family. This is not a definitive list.

• CM200S 12pF surface mount crystals from Citizen.
• ECS-.327 12pF surface mount crystals from ECS INC.
• CFS206 12pF leaded crystals from Citizen.

Good engineering practice dictates that the final design be tested across both VCC and temperature and any additional environmental factors that may affect performance.

OSCILLATOR LAYOUT

Given that the oscillator is designed for minimum operating current, care must be taken when laying out the PCB traces. These are discussed below.

• Keep traces as short as possible to the crystal and the load capacitors. Minimizing the length is important. For that reason, it is not recommended to use any kind of a socket, or package interposer when developing with the RTCC devices. An alternative that can be used is the RTCC PICTail daughter board (AC164140). This can easily be connected to the target system using the SCL and SDA lines.

• Match the capacitors to the crystal – the MCP7941X is designed to operate with either 12pF or 6pF crystals. Care must be taken to ensure that correct load capacitors are used with the crystal. The pin capacitance of the device should also be taken into consideration (approx. 3pF per pin).
• Use a ground ring – during the PCB layout, a ground ring should be placed around both the crystal and also the X1 and X2 pins (pins 1, 2) on the device. This ground ring should be connected to a low-impedance ground connection. A recommended layout is shown below.

**FIGURE 5: CRYSTAL LAYOUT**

The Gerber files for the PICtail daughter board are available on the web site following the link on www.microchip.com/rtcc.

**VBAT SELECTION**

The external VBAT pin supports a voltage that is used to maintain the RTCC and also the SRAM during a VCC power fail. If this function is not required, then the VBAT pin should be left floating or connected to GND. Connecting this pin to GND will result in the lowest current configuration.

The supported voltage on this pin is from 1.3v to 5.5v. The recommended voltage is 3-3.6V. The internal circuit will switch to the VBAT voltage when VCC drops to 1.5V. The RTCC and SRAM will continue to be maintained until the VBAT voltage drops to 1.3V.

The MCP7941X will support both primary backup supplies (battery etc.) and also rechargeable solutions (NiCad, Super Cap, etc). When using any supply it is recommended to include a 1K series resistor between the supply and the VBAT pin. Additionally, a series diode is recommended when using a non-rechargeable supply to eliminate reverse leakage into the cell.

When using a rechargeable solution, additional components will be required to support a charge current to maintain the voltage on the battery/capacitor. Care should be exercised to ensure that the backup supply cannot power the VCC supply during a main supply failure. If using a capacitor a series resistor should be used to supply charge from the Vcc line to reduce the inrush current.

**UL CONSIDERATIONS**

One of the requirements for UL approval and certification is related to the VBAT supply. If a lithium cell is used (CR2032 or similar), then there are reverse leakage currents that have to be taken into consideration. By using the recommended Schottky diode in series with the lithium backup battery this issue is limited.

In addition to the recommended diode and series resistor, internally the VBAT/VCC switchover circuit has been designed such that in the event of a catastrophic failure of the device, the switch will fail in a safe manner and not conduct from VCC to VBAT.

**RTCC COMMON MISTAKES**

There are many common mistakes that can be made when using an RTCC device, many of which have been discussed in this text. Some of the common questions and answers are shown below.

**Q.** I have the board laid out as per your recommendations but the crystal does not start! What should I check?

**A.** Make sure that the capacitor is correct for the crystal. Have you taken into account the pin capacitance? Have you set the ST bit in register 00h? Setting the ST bit will enable the oscillator and start the RTCC counting.

**Q.** When the VCC fails, my clock stops running. I have a battery on the board.

**A.** Make sure that you have set the VBATEN bit in register 03h. This bit enables the VBAT pin and connects the VBAT supply to the internal circuitry.

**Q.** When the VCC fails, my clock stops running. I have a battery on the board.

**A.** Make sure that the board is clean. Some of the flux used in the Pb-free may be slightly conductive; leaving this residue on the board will delay the oscillator from starting or prevent oscillation completely. This is a very low-power oscillator and is significantly different to the one offered on the PIC® devices.
SUMMARY

This application note illustrates recommended techniques for increasing design robustness when using the Microchip MCP7941X family of I²C RTCC’s. These recommendations fall directly in line with how Microchip designs, manufactures, qualifies and tests its RTCC devices and will allow the devices to operate within the data sheet parameters. It also serves to explain in detail some of the features of the device and makes the user aware of any potential pitfalls that may be encountered.
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