AN1365

Recommended Usage of Microchip Serial RTCC Devices

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INTRODUCTION

Many embedded systems require some form of accurate timekeeping. There are a growing number of applications that require an external Real-Time Clock/ Calendar (RTCC) and higher integration of external peripheral components into the RTCC. In order to achieve a highly robust and repeatable system, the designer must consider the rest of the system components including pull-up resistor values and the crystal selection. 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 RTCC family of devices. This application note covers both the I^{2}C™ (MCP794XX) and SPI (MCP795XXX) 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 boards available from Microchip.

Appendix B: "Recommended Connections for MCP794XX Series Devices" shows the suggested connections for using the Microchip I^{2}C MCP794XX RTCC family. **Appendix C: "Recommended Connections for MCP795XXX Series Devices"** shows a similar schematic for the SPI MCP795XXX devices. The basis for these connections will be explained in the sections which follow.

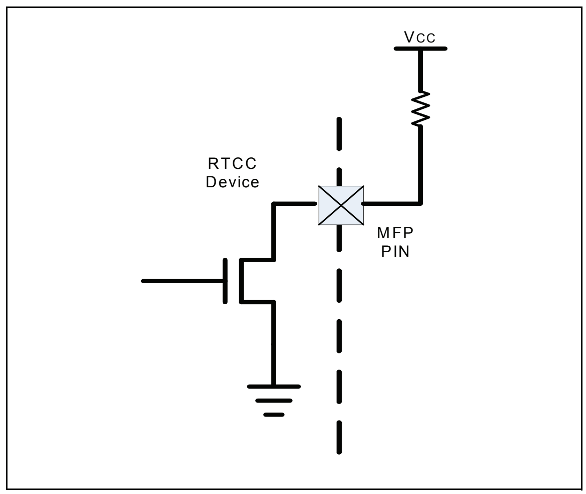
It is never good practice to leave a digital input pin floating. This can cause an elevated standby current as well as undesired functionality. If a pin is left floating, it can float either low or high. The final logic state is dependent upon a number of factors, including noise in the system and capacitive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

MFP Pin (I^{2}C)

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 VBAT timekeeping supply).

Refer to the device data sheet for the maximum sink current for this pin; care should be taken to ensure that the pull-up resistor is calculated to limit the current to this value.

FIGURE 1: MFP DIAGRAM



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

- 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.
- General purpose output – can be used as an additional I/O line under the control of the MCU.

- Output a Clock signal – 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.

When V_{CC} is removed and the device is running from the backup supply V_{BAT}, the only functions that are active on this pin are the alarms; all other functions are disabled until V_{CC} is restored.

I^{2}C Communication Pins

To follow the I^{2}C specification, both the Serial Data (SDA) and Serial Clock (SCL) lines require a pull up to V_{CC}. As the MCP794XX 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 note AN1028 on the Microchip web site provides additional guidance for the use and implementation of the I^{2}C bus.

POWER SUPPLY

Microchip I^{2}C RTCC devices feature a robust serial communication protocol that guards against unintentional writes and data corruption while power is within normal operating levels.

Information regarding the V_{BAT} supply is provided later in this text.

As shown in **Appendix B: "Recommended Connections for MCP794XX Series Devices"**, a decoupling capacitor (typically 0.1 μF) should be used to help filter out noise on V_{CC}.

SPI Communication Pins

The MCP795XXX supports the industry standard SPI bus protocol using the SCK, SD, SO and $\overline{CS}$ Lines.

The $\overline{CS}$ line must be brought low at the start of a command and raised at the end of the command. The $\overline{CS}$ line being raised completes the command and performs the write cycle for a nonvolatile memory write.

The $\overline{CS}$ line should not toggle during the command sequence, as raising the $\overline{CS}$ line before the command is complete terminates the current command.

CLKOUT Pin (14-pin SPI)

The CLKOUT is a push/pull output that can produce a square wave that is derived from the crystal and on-board oscillator.

Please consult the device data sheet for the source/sink specifications of this pin. On devices with the boot option (MCP795BXX enable the oscillator and this pin at power-up), if this pin is used to provide a clock source to another device, care must be taken to ensure that the driven device does not load this pin.

If this pin is not used it can be left floating; do not connect to V_{CC} or GND, as this is a digital output.

EVHS and EVLS (SPI Only)

The High-Speed Event (EVHS) detect and Low-Speed Event (EVLS) detect are digital input pins and require either a pull-up or pull-down resistor.

These pins are used as the input to the Event Detection circuit. If this feature is not being used in the application then these inputs should be connected to GND.

WD and IRQ (SPI Only)

The WD and IRQ pins are open-drain and are capable of sinking 10mA (Please refer to the DC Characteristics in the data sheet). A pull-up to V_{CC} is required on these pins.

If the WD and IRQ pins are not used they can be left floating.

Power-Up

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

However, if V_{CC} happens to fall below the minimum retention voltage for the device (see data sheet DC Characteristics), it is recommended that V_{CC} 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 V_{CC} 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 V_{BAT}

Internally, the RTCC will switch to the V_{BAT} supply when V_{CC} drops to the V_{TRIP} voltage detailed in the data sheet.

Failure of V_{CC} During a Read

During a read of the RTCC registers, SRAM or EEPROM, if the V_{CC} supply drops, the device will continue to operate and communicate until V_{CC} reaches the V_{BAT} trip point. It is not recommended to operate during this time and all I^{2}C and SPI communication should be halted as soon as V_{CC} failure is detected.

Failure of V_{CC} During an EEPROM Write

During the time that data is being written to the EEPROM or unique ID locations, V_{CC} should remain above the minimum operating voltage – typically 1.8V. If at any time V_{DD} drops below this minimum voltage but remains above the V_{BAT} switchover voltage (V_{TRIP} as specified in the device data sheet), care should be taken to ensure that the data written to the device is free from errors by verifying the contents of the memory written.

If at any time the V_{CC} voltage drops below 1.5V (V_{BAT} switchover) then the I^2C and SPI 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 V_{CC} During an SRAM or RTCC Write

As the SRAM and RTCC writes are still possible when V_{CC} is dropping until the V_{BAT} trip point is reached, again it is not recommended to operate during this time and all I^2C and SPI communication should be stopped as soon as possible.

VCC RAMP RATES

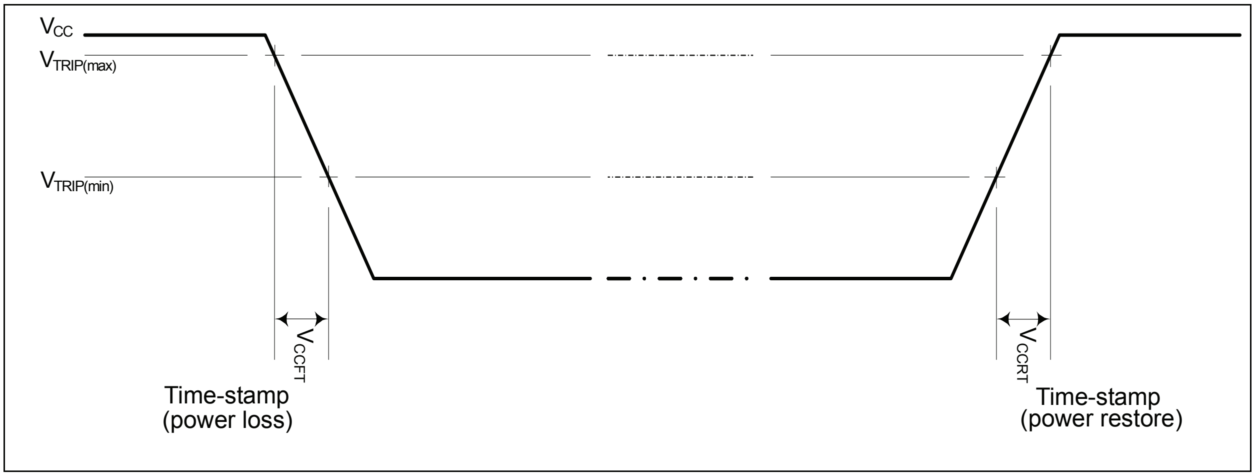
The Microchip RTCC family integrates a battery switchover circuit to maintain the time and also the contents of the SRAM during the time when VCC is below the VTRIP threshold as defined in the data sheet. Due to the fact that the circuit operates at a very low current level, care should be exercised 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 data sheet specifications should be met.

- VCCFT – VTRIP(max) to VTRIP(min)
- VCCRT – VTRIP(min) to VTRIP(max)

FIGURE 2: VTRIP GRAPH

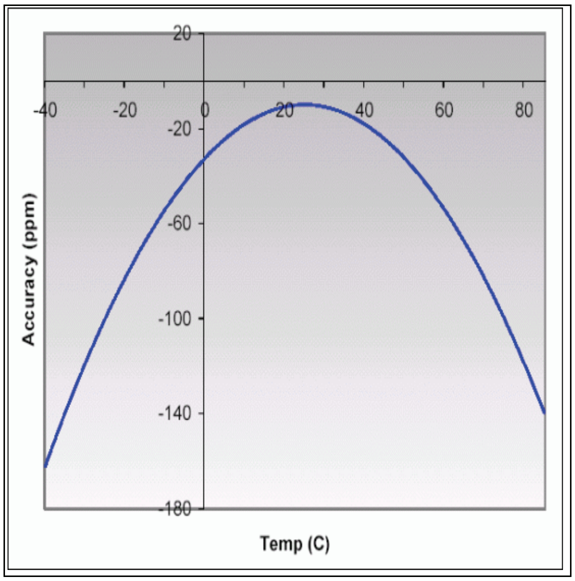


CRYSTAL SELECTION

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

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

FIGURE 3: TUNING FORK CRYSTAL



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

- By using temperature compensation and the digital trimming, the accuracy can be improved to better than 10 ppm across temperature.

The table below is given as design guidance and a starting point for crystal and capacitor selection.

Manufacturer	Part Number	Crystal Capacitance	CX1 Value	CX2 Value
Micro Crystal	CM7V-T1A	7pF	10pF	12pF
Citizen	CM200S-32.768KDZB-UT	6pF	10pF	8 pF
Please work with your crystal vendor.				

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Crystal Specification and Selection

The MCP794XX and MCP795XXX have been designed to operate with a standard 32.768 kHz tuning fork crystal. The on-board oscillator has been characterized to operate with a crystal of 7pF load capacitance.

Similar crystals with a maximum ESR of 70K Ohms are also suitable for use with the Microchip serial RTCC devices. Additional crystals are being characterized and results will be published as soon as the data has been analyzed.

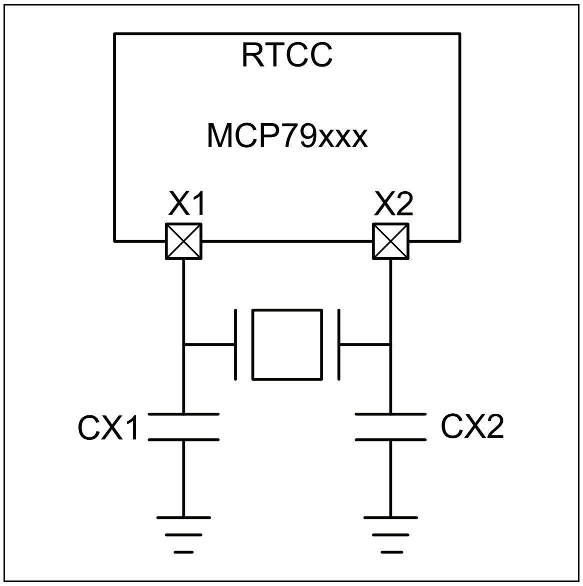
The crystal that has been fully characterized and tested is the 7pF CM7V from MicroCrystal.

This crystal requires an effective load capacitance of 7pF. When calculating the effective load capacitance, Equation 1 can be used:

EQUATION 1:

$$C_{load} = \frac{C_{x2} \times C_{x1}}{C_{x2} + C_{x1}} + C_{stray}$$

FIGURE 4: OSCILLATOR DIAGRAM



The following must also be taken into consideration:

Pin capacitance (to be included in Cx2 and Cx1)

Stray Board Capacitance.

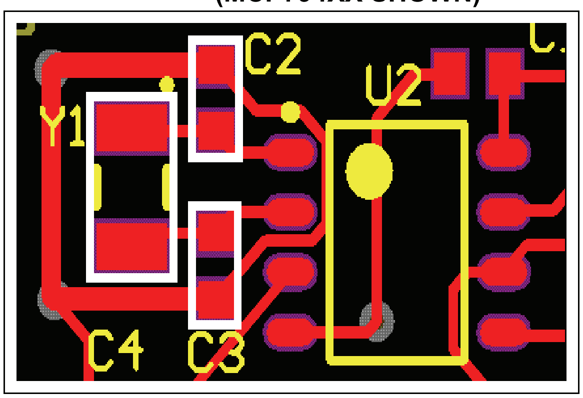
The recommended board layout for the oscillator area for the MCP794XX (also applicable to the MCP795XXX) is shown in Figure 4.

OSCILLATOR LAYOUT

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

- Keep traces as short as possible to the crystal and the load capacitors. Minimizing the length is important to keep stray capacitance to a minimum. 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 boards.
- 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 in Figure 5. In this PCB layout example, C2 and C3 are the CX1 and CX2 capacitors.

FIGURE 5: CRYSTAL LAYOUT (MCP794XX SHOWN)



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

VBAT SELECTION

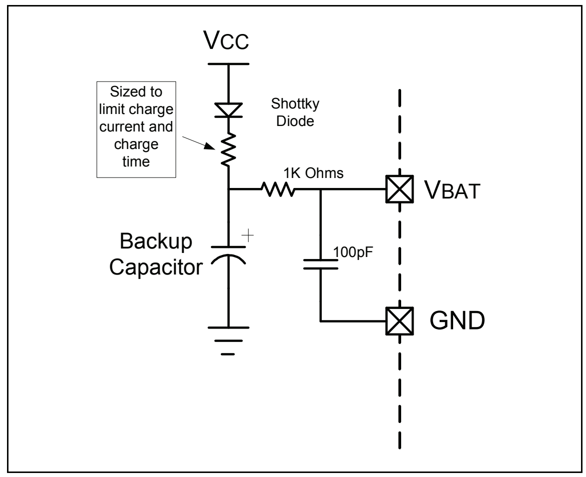
The external VBAT pin supplies power to maintain the RTCC and also the SRAM during a VCC power fail. If this function is not required, then the VBAT pin should be connected to GND. Connecting this pin to GND will result in the lowest current configuration.

The supported voltage on this pin is from 1.3V to 5.5V. The internal circuit will switch to the VBAT voltage when VCC drops to 1.5V (data sheet parameter VTRIP). The RTCC and SRAM will continue to be maintained until the VBAT voltage drops to 1.3V.

The Microchip RTCC devices 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 any current flowing into the cell during a catastrophic failure.

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.

FIGURE 6: SUPERCAP



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. I changed the crystal and now the system is not running reliably.

A. Crystals are not interchangeable like passive components, please work with your preferred crystal manufacturer.

Q. When the V_{CC} 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 for MCP794XX and 04 for MCP795XXX. This bit enables the V_{BAT} pin and connects the V_{BAT} supply to the internal circuitry.

Q. How do I know if the oscillator stopped?

A. Your software can periodically check the OSCON bit to see if this has become set.

Q: Do I need to stop the clock before I update the time from my application?

A. No, not if you can update the time within a second. If your code will take more than one second to update then you should stop the clock, update and restart the clock.

Q. I have everything connected and all the registers set, but the oscillator still does not start.

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. In addition, due to the delicate nature of a quartz tuning fork crystal, when hand soldering, use the lowest temperature for the shortest time possible. Also, please consult the manufacturers data sheet for suggested solder reflow profiles.

SUMMARY

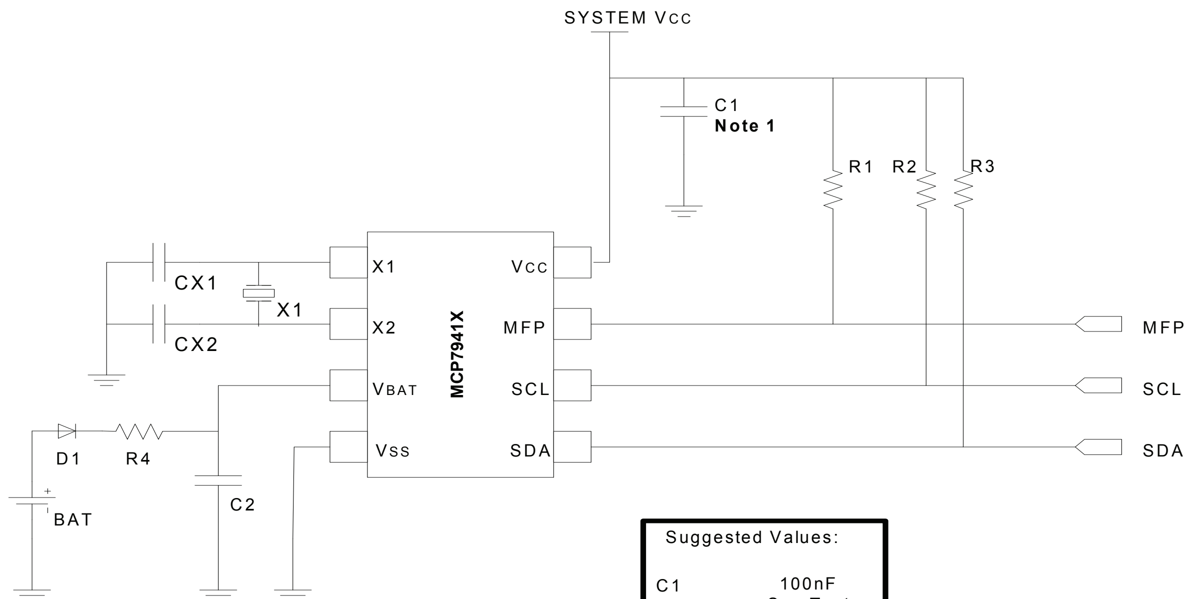
This application note illustrates recommended techniques for increasing design robustness when using the Microchip family of RTCC's. These recommendations fall directly in line with how Microchip designs, manufactures, qualifies and tests its RTCC devices and will allow the devices to operate within 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.

APPENDIX A: REVISION HISTORY

Revision C (11/2011)

Changed part number from MCP795XX to MCP795XXX; Added Revision History.

APPENDIX B: RECOMMENDED CONNECTIONS FOR MCP794XX SERIES DEVICES

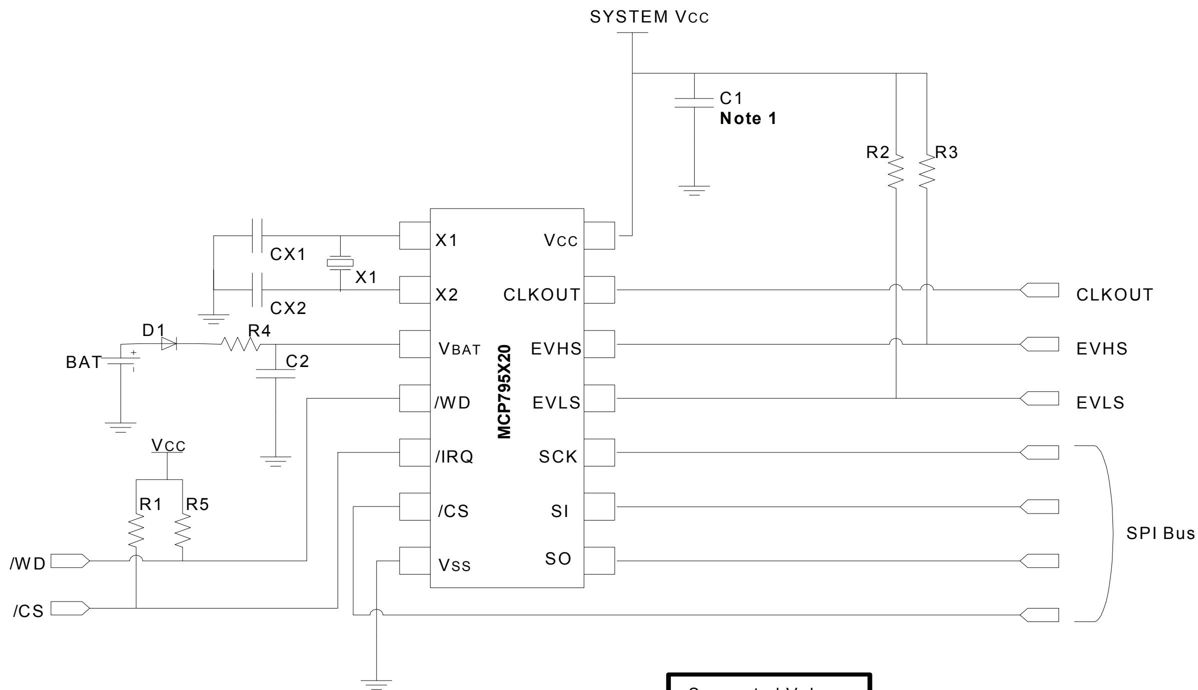


Note 1: A 100nF Capacitor should be placed as close to the Vcc pin on the device as possible.

Suggested Values:

C1	100nF
CX1, CX2	See Text
C2	100pF
R1	10K
R2,3	2.2K
R4	1K
D1	Schottky
BAT	Backup Supply
X1	32.768 kHz Crystal (See Text)

APPENDIX C: RECOMMENDED CONNECTIONS FOR MCP795XXX SERIES DEVICES



Note 1: A 100nF Capacitor should be placed as close to the Vcc pin on the device as possible.

Suggested Values:

C1	100nF
CX1, CX2	See Text
C2	100pF
R1,5	10K
R2,3	10K
R4	1K
D1	Schottky
BAT	Backup
X1	Supply
	32.768 kHz
	Crystal
	(See Text)

NOTES:

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.
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