TB3203A

Real-Time Clock and Calendar (RTCC) with Battery Backup for the PIC16(L)F19197 Family Devices

Introduction

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The Real-Time Clock and Calendar (RTCC) module was designed to allow users to maintain accurate tracking for extended periods of time without the need for extensive CPU intervention. The module is optimized for battery powered LCD applications and is capable of providing extended battery life when applicable. The RTCC can be configured to run from multiple clock sources, including the option to use an external 32.768 kHz crystal oscillator attached to the Secondary Oscillator (SOSC) pins. It is capable of operating from a battery backup in the event of a V_{DD} supply voltage power failure, which allows the RTCC and SOSC modules to continue running and prevents data loss. This technical brief will give an overview of the RTCC module and the integrated V_{BAT} functionality.

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1. Real-Time Clock Calendar (RTCC) Overview

The RTCC module is an integrated 100-year clock and calendar with automatic leap year detection and correction. The range of the clock is from 00:00:00 (midnight) on January 1st, 2000 to 23:59:59 on December 31st, 2099. The RTCC module uses the 24-hour time format. The RTCC provides users with the ability to accurately keep track of time, date, and configure an alarm with an interrupt event. The RTCC module can be beneficial to use in applications where accurate time keeping is needed due to the module's optimized low-power consumption, the ability to minimize CPU overhead, and the available V_{BAT} external battery connect in the event of a V_{DD} power failure. Some features of the RTCC module include:

- Time: Hours, Minutes and Seconds
- 24-Hour Time Format
- Calendar: Weekday, Date, Month and Year (Year range: 2000 to 2099)
- Leap Year Correction
- Configurable Alarm
- Half-second Synchronization and Visibility
- BCD Format for Compact Firmware
- User Calibration with Auto-Adjust
- Multiple Clock Sources
- Low-Power Optimization

1.1 RTCC Module Operation

The RTCC module contains three register sets: control registers, clock value registers, and alarm value registers. The module works by using the configured clock source to increment several different counters, which represent the different time periods that are being tracked. Each clock value register represents the different units of time that the RTCC module keeps, and each of the counters for those registers are incremented based upon their defined intervals (i.e., the MINUTES register is clocked once a minute, the DAYS register is clocked once a day, the MONTH register is clocked once a month, etc.). The alarm feature of the RTCC can be configured to trigger at a frequency of every 1/2 second to every 1 year, with the option to repeat the alarm a specific number of times. An interrupt can be generated with every alarm event that can be used to trigger other peripherals on the device. Finally, the module has the option of V_{BAT} operation to maintain the RTCC data and SOSC operation in the event of a power loss or failure.

1.2 RTCC Module Configuration

When configuring the RTCC module, the user must first set the RTCWREN bit of the RTCCON register to disable the register write lockout function and allow RTCC registers to be updated. After setting the RTCWREN bit, the user should then disable to RTCC module, which will prevent the RTCC from incrementing the time and date registers while they are being configured. If the RTCC module were left enabled using the current time and date information while configuring, there is the possibility of an event in which one register is being written and clocked at the same time. The next step when configuring the RTCC module for the first time is to set the current time and date information by writing into the associated registers. This creates a known starting condition for the RTCC module from where it can begin to increment the date and time. When initializing the current time and date settings, the user must write the year, month, day, minutes and seconds information, each into their own associated register in memory. This information written to the time value registers must be implemented using the Binary Coded

Decimal (BCD) format that is explained in Section 1.5 Reading/Writing RTCC Using Binary Coded Decimal (BCD) Format.

When the RTCC registers are not being updated, the RTCWREN bit should remain cleared to enable the Write Lock function and avoid accidental writes to the RTCC registers during operation. As previously mentioned, each of the time value counters will increment based upon their defined time intervals. This increment leaves a large enough period between clocks to safely update the register without disabling the RTCC Write Lock. The user can also poll the RTCSYNC and the HALFSEC bits of the RTCCON register to observe the timing status and avoid a register getting updated and incremented simultaneously.

After the RTCC module and alarm settings have been initialized, the user can set the RTCEN bit of the RTCCON register. When enabling the RTCC module for the first time, it is recommended that the user polls the RTCEN bit to ensure that it reaches to desired logic level before the RTCWREN bit is cleared. The RTCEN bit is synchronized to the RTCC clock and will not set until the external oscillator is available, which means that the user must account for the crystal/oscillator start-up time in the initialization routine. Example 1-1 below demonstrates the first part of initializing the RTCC module, by disabling the RTCC write lock and initializing the time and date registers. Example 2-1 in Section 2.1 RTCC Alarm Configuration contains the second half of the RTCC initialization routine, which includes configuring the alarm feature.

Example 1-1. RTCC Module Initialization (Part 1)

```
RTCCONbits.RTCWREN = 1;      // RTCC Registers can be written;
RTCCONbits.RTCEN = 0;        // RTCC Module is disabled;
RTCCONbits.RTCCLKSEL = 0x00; // RTCC Clock Selection Bits - SOSC;

    // Set RTCC Start Time:
    YEAR = 0x18;        // year;
    MONTH = 0x5;        // month;
    WEEKDAY = 0x2;      // weekday;
    DAY = 0x22;         // day;
    HOURS = 0x12;       // hours
    MINUTES = 0x30;     // minutes;
    SECONDS = 0x0;      // seconds;

RTCCAL = 0x00;  // RTCC Calibration;
```

1.3 RTCC Module Available Clock Sources

The RTCC module offers several different clock source options to the user that can be configured by setting the RTCCLKSEL<1:0> bits of the RTCCON register. The first option available is clocking the RTCC using an external 32.768 kHz crystal tied to the secondary oscillator (SOSC) pin. Using an external crystal oscillator to clock the module offers the advantages of high accuracy, low component cost, and relatively low power consumption along with the V_{BAT} battery backup option. One main disadvantage of using an external crystal oscillator is the discrete component's performance susceptibility to external variables. When using an external crystal oscillator as the clock source for the RTCC module, it is also important to ensure that any necessary circuitry is added. Refer to the crystal oscillator specifications for more information.

The Medium Frequency Internal Oscillator (MFINTOSC/16) can also be configured to clock the RTCC module at a frequency of 31.25 kHz. Using the internal oscillator eliminates the need for another external component, although one major tradeoff is sacrificing accuracy compared to the 32.768 kHz external crystal.

It is important to note that the V_{BAT} functionality is only available when the RTCC module is running from SOSC. V_{BAT} only provides a backup supply voltage directly to the SOSC and RTCC modules, therefore it can only be implemented when the clock source is the SOSC. In applications where AC power is available, the user can use the Zero-Cross Detect (ZCD) module to create a 50 Hz or 60 Hz signal that can be configured to clock the RTCC module. Each of these clock source selections have a fixed, known prescaler built into the module that is used to generate the required ½ clock signal needed by the RTCC. A block diagram that illustrates the multiplexing of the different available clock signals is available in the Real Time Clock Calendar (RTCC) section of the device data sheet. Table 1-1 summarizes the different clock source settings:

Table 1-1. RTCC Module Clock Source Summary

RTCC Clock Source	Ideal Frequency	Fixed Prescaler	RTCCLKSEL<1:0>
SOSC	32.768 kHz (Expected)	1:16384	`00`
MFINTOSC / 16	31.25 kHz	1:15625	`01`
ZCD Powerline Clock (1)	50 Hz	1:25	`10`
ZCD Powerline Clock (2)	60 Hz	1:30	`11`

1.4 RTCC Calibration

The RTCC module can be calibrated using the periodic auto-adjust feature and can provide the user with an error of less than three seconds per month, when calibrated correctly. The first step to calibrating the input clock source is to determine the error of the input clock frequency, which can be done using another timer resource available on the PIC® microcontroller such as the Signal Measurement Timer (SMT) module. The calculated error in the RTCC module source clock should be stored in the calibration register (RTCCAL) as a signed 8-bit value. The value stored in this register determines the auto adjustment that must be made to the RTCC clock source to calibrate it to the ideal frequency expected. Equation 1-1 below, from the RTCC section of the product data sheets, can be used to determine the error between the ideal expected frequency and the actual measured frequency. For more information about calibrating the RTCC and the SOSC, refer to the device data sheet.

Equation 1-1. Converting RTCC Source Clock Error Clock Pulses of SCK Output Signal Calculation

$$\frac{Error\ Clocks}{Minute} = \left(IdealFrequency\left(32,768\right) - MeasuredFrequency\right) \cdot 60$$

In the event where the measured frequency is **faster** than ideal (Equation 1-1 yields a negative result), the value stored in the RTCCAL register must be negative. When the measured frequency is **slower** than ideal (Equation 1-1 yields a positive result), the value stored in the RTCCAL register must be positive. Although the calibration value stored in RTCCAL from Equation 1-1 is specified in clock pulses per minute, the actual calibration is performed by applying RTCCAL<7:0>/4 clock pulses every 15 seconds. Any initial error from the clock source is not included in the calculation of Equation 1-1 and the user must consider that when calibrating the RTCC module. It is important to note that any writes to the RTCCAL register should only occur when the timer is turned off or right after the rising edge of the seconds pulse. The only exception to this is when the SECONDS value is 00 ,15 ,30, or 45 to avoid being manipulated by an auto-adjust events occurring.

1.5 Reading/Writing RTCC Using Binary Coded Decimal (BCD) Format

The register interface for the RTCC module time and alarm values must be implemented using the Binary Coded Decimal (BCD) format. The BCD format is a system of representing numbers where a 4-bit wide binary code is assigned to represent the numerical value of a digit ranging from 0 through 9. Each of the corresponding time and date values are represented and contained within their own 4-bit values. For more information about writing to the Time Value and Alarm Value registers using the BCD format, refer to the RTCC section of the device data sheet. Each register in the data sheet will have specific information about the range of values of the specific time or date that the register accepts.

Figure 1-1 below illustrates the time digit and alarm digit format, along with the acceptable ranges for each numerical value. Using this format to represent the time and date values simplifies the firmware and allows for smaller software overhead. It is important to note that since the Time and Date registers for the RTCC and alarm feature are represented in the BCD format, the carry to the upper BCD digit always occurs on a count of 10 rather than a count of 16. For more information regarding the carry rules of this RTCC module, refer to the RTCC chapter of the device data sheet.

Figure 1-1. Time/Alarm Register Value Format (BCD)

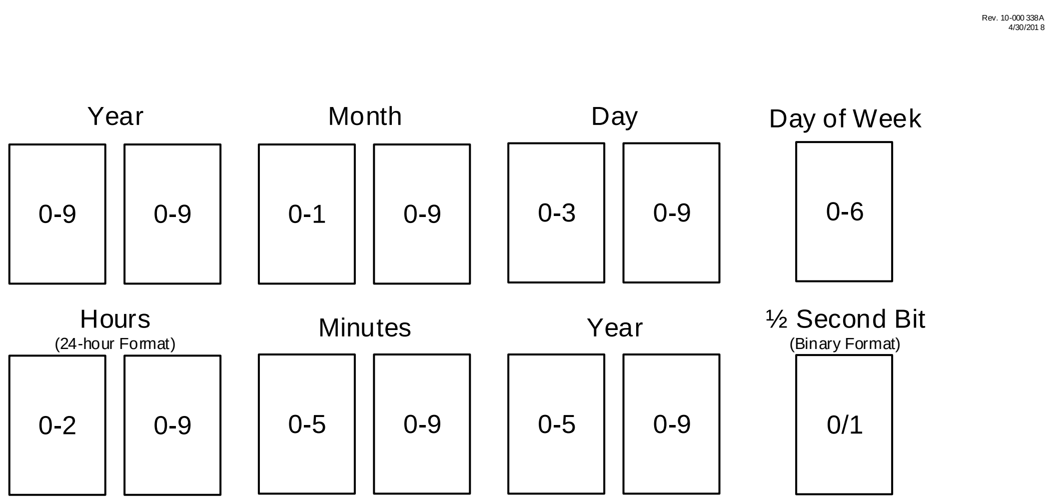
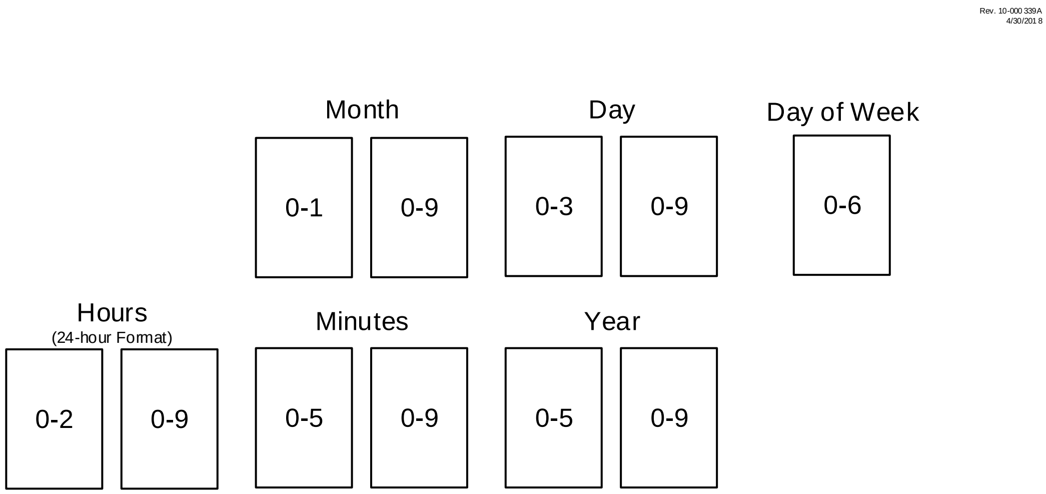


Figure 1-2. Alarm Value Register Format (BCD)



Tip: When using the Microchip Code Configurator (MCC) to implement the RTCC module into a project, the APIs needed to convert from HEX to BCD and vice versa are automatically generated.

2. RTCC Alarm Overview

The RTCC module offers a configurable alarm feature that provides the flexibility to be configured with several different options. The alarm can be setup to trigger an alarm interrupt flag once every ½ second to once every year, with an included alarm repeat counter register that is used to determine how many times the alarm repeats before the alarm enable bit (ALRMEN) is lowered. An alarm event is generated when the RTCC time/date matches the time/date stored in the alarm registers, which are configured by the user. Aside from ALRMRPT and the CHIME bit, the alarm registers should not be updated while the alarm is enabled to prevent false alarm triggers. This feature of the RTCC module generates an Interrupt Flag (RTCCIF) every time an alarm alert is issued, which can be implemented in many applications as a trigger for other peripherals or as an interrupt service routine. In addition to the interrupt flag that is raised with every alarm alert, the RTCC can also provide an alarm pulse output that is synchronous with the RTCC clock that can be used as a trigger for other peripherals. To implement the RTCC interrupt, the RTCCIE bit of the Peripheral Interrupt Enable (PIE) register must be set.

2.1 RTCC Alarm Configuration

When configuring the alarm feature of the RTCC, the first step is to ensure that the RTCWREN bit is set to allow RTCC register writes. The user should also verify that the alarm is in a disabled state before performing any register updates. The ALRMEN bit will be cleared every time an alarm is issued, if the ALRMRPT register has decremented to zero and the CHIME bit is configured to not allow rollovers. If the CHIME bit is enabled, the alarm repeat register (ALRMRPT) will be allowed to continuously roll over rather than stopping once it decrements to zero.The frequency which the alarm is repeated can be configured using the AMASK<3:0> bits of the ARMCON register and can be selected to be anywhere from every ½ second to once a year.

The ALRMRPT register is used to determine how many times the configured alarm is repeated. The user can set this to repeat anywhere from 0 to 255 times until the RTCC alarm is disabled. The CHIME bit of the alarm configuration register determines if the alarm repeat counter rolls over and restarts when it reaches zero. Similar to when initializing the time and date settings for the RTCC module start condition, there are several alarm specific registers that must be initialized to determine the date and time of the first alarm event. This information written to the alarm registers must be implemented using the Binary Coded Decimal (BCD) format that is explained in Section 1.5 Reading/Writing RTCC Using Binary Coded Decimal (BCD) Format. Once all of the alarm configuration registers have been updated and initialized, the final step for the user is to enable the alarm by setting the ALRMEN bit of the ALRMCON register and clear the RTCC Write Lock bit. If the RTCC module is still disabled at this point, the user would need to enable the RTCC module by setting the RTCEN bit of the RTCCON register and then clear the Write Lock bit to prevent accidental writes to any of the RTCC registers. Example 2-1 demonstrates how to configure the alarm and shows the remainder of the initialization routine that was started in Example 1-1. Note that the RTCWREN bit was already set and the RTCC module was already disabled in the first part of the initialization routine.

Example 2-1. RTCC Module Initialization (Part 2)

```
ALRMCONbits.ALRMEN = 0;    // Alarm is disabled;
ALRMRPT = 0xFF; // Alarm Repeat Register;

    // Set RTCC Alarm Time:05/22/2018 @ 12:30:10
    ALRMMTH = 0x5;    // month;
    ALRMWD = 0x2;     // weekday;
    ALRMDAY = 0x22;   // day;
    ALRMHR = 0x12;    // hours;
    ALRMMIN = 0x30;   // minutes;
    ALRMSEC = 0x10;   // seconds;

ALRMCONbits.ALRMEN = 1;    // Re-enable the alarm
ALRMCON = 0xC8;            // AMASK Every 10 Second; CHIME enabled;
RTCCONbits.RTCEN = 1;      // RTCC Module is enabled
While(!RTCCONbits.RTCEN);
RTCCONbits.RTCWREN = 0;    // RTCC Registers Write Lockout;
PIR8bits.RTCCIF = 0;       // Clear RTCC Interrupt Flag;
PIE8bits.RTCCIE = 1;       // Enable RTCC Interrupt (Alarm);
```


3. V_{BAT} Overview

The PIC16(L)F19197 family of devices come equipped with a V_{BAT} pin that provides users with the ability to use an external backup power source to ensure that the SOSC and RTCC modules continue running if the V_{DD} supply voltage were to fail. Utilizing the V_{BAT} functionality of the module can be beneficial in applications that use the RTCC module, by helping to ensure that the time keeping values are retained when the V_{DD} power supply is lost. The V_{BAT} hardware determines when the V_{DD} power supply to the RTCC and SOSC modules are no longer sufficient. When the supply drops below the required V_{DD} voltage level, the RTCC and SOSC modules will automatically switch their supply voltage to run from the available V_{BAT} power supply.

The RTCC and SOSC modules were designed with low power consumption in mind to help prolong battery life. The VBATBOR and BOR bits of the Power Control register set (PCONx) can be used to indicate whether a Brown-out Reset (BOR) occurred and to determine if a V_{BAT} Brown-out Reset occurred, specifically. Table 3-1 summarizes the behavior that the PIC microcontroller will inhibit in the event of a Brown-out Reset when V_{BAT} is utilized as a battery backup.

Table 3-1. V_{DD} Vs. V_{BAT} Switching

V_{DD} Status	V_{BAT} Status	Description
$V_{DD}>V_{BOR}$	$V_{BAT}>V_{BOR}$	All peripherals will operate from V_{DD}. RTCC and SOSC modules will run from V_{BAT}, if V_{BAT} is greater than V_{DD}. VBATBOR bit remains unchanged. BOR bit remains unchanged.
$V_{DD}>V_{BOR}$	$V_{BAT}<V_{BOR}$	All peripherals will operate from V_{DD}. VBATBOR bit remains unchanged. BOR bit remains unchanged.
$V_{DD}<V_{BOR}$	$V_{BAT}>V_{BOR}$	RTCC and SOSC will operate from V_{BAT} while all other peripherals are held in a Reset state until V_{DD} power supply is restored. VBATBOR bit remains unchanged. BOR bit is cleared to indicate Brown-out Reset
$V_{DD}<V_{BOR}$	$V_{BAT}<V_{BOR}$	All peripherals (Including RTCC and SOSC) are held in a Reset state until a sufficient V_{DD} or V_{BAT} power supply is detected. VBATBOR bit cleared to indicate a Brown-out Reset. BOR bit is cleared to indicate Brown-out Reset.

3.1 V_{BAT} Configuration

When configuring the V_{BAT} functionality for the PIC16(L)F19197 family of devices, the first step is to determine the external source that will be connected to the VBAT pin. The battery typically used for this feature is a 3.0V coin cell. However, this system offers the versatility to use any battery supply that is within the entire device V_{DD} range or even use a super capacitor in place of a battery. The positive terminal of the battery backup source should connect to the VBAT pin of the PIC microcontroller, and the negative terminal should connect to the V_{SS} pins of the PIC microcontroller. Battery backup functionality is enabled by setting the VBATEN bit of Configuration Word 1 (VBATEN = ON). The VBAT pin of the PIC microcontroller is not a regular bidirectional GPIO, and when not being used for a battery backup can only be configured as an input pin only. Refer to the device data sheet pin out diagram for location of the reserved VBAT pin.

4. Conclusion

This technical brief provides an overview of the RTCC module and the integrated V_{BAT} capabilities that it offers. The Real Time Clock Calendar (RTCC) module allows users to maintain accurate time tracking in applications for extended periods while reducing software overhead. Some advantages to the RTCC module in the PIC16(L)F19197 family of devices are the low power consumption, versatility, and the minimal software requirements needed to implement it. The RTCC module has built-in auto adjust functionality to calibrate the clock source, to help maintain accurate time keeping for longer periods. For more details about this module, refer to the RTCC chapter of the device data sheet, utilize the MPLAB® Code Configurator plug-in available in MPLAB X IDE, or browse the MPLAB Xpress example library.

Tip: Complete working demo code for the RTCC module with VBAT functionality can be found on the MPLAB Xpress Cloud-Based IDE platform. See the example section here.

5. Revision History

Revision	Date	Comments
A	6/2018	Initial release of this document.

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