AN1355

A Complete Electronic Watch Based on MCP79410 I²C™ RTCC

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INTRODUCTION

An increasing number of applications that involve time measurement are requiring a Real-Time Clock/ Calendar (RTCC) device. The MCP79410 is a feature-rich RTCC that incorporates EEPROM, SRAM, unique ID and time-stamp.

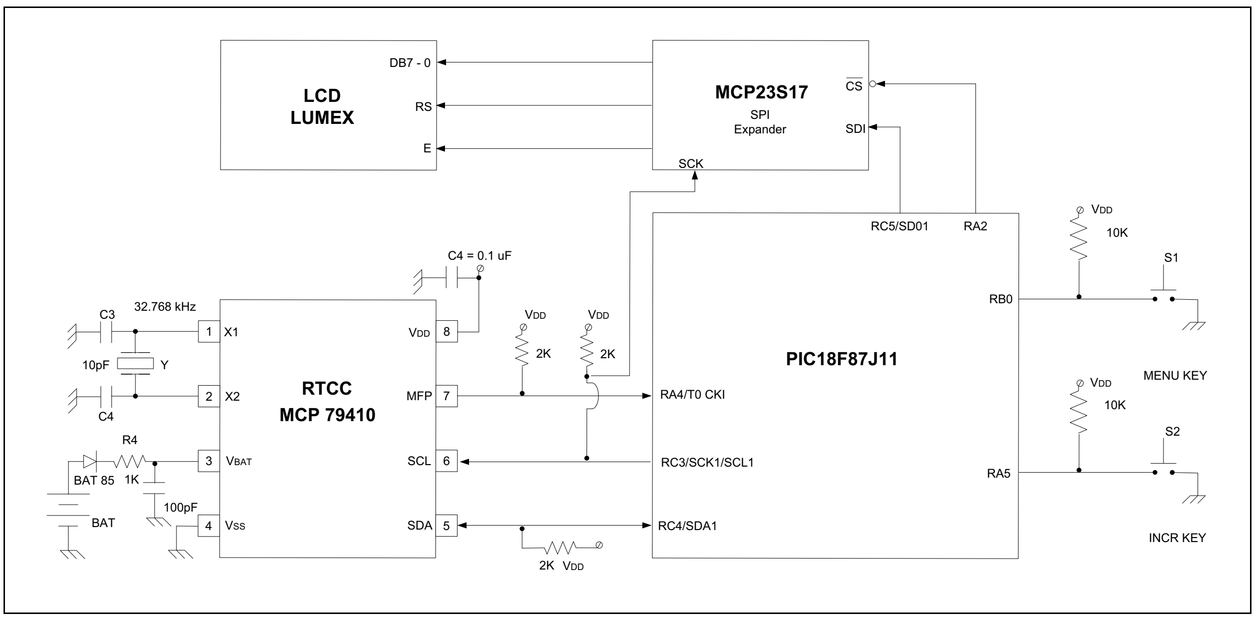
FEATURES OF THE RTCC STRUCTURE

- I²C™ Bus Interface
- RTCC with Time/Date Registers: Year, Month, Date, Day of Week, Hours, Minutes, Seconds
- Support for Leap Year
- Low-power CMOS Technology
- Input for External Battery Backup (maintains SRAM, RTCC and Timekeeping)
- On-board 32,768 kHz Crystal Oscillator for the RTCC
- On-chip Digital Trimming/Calibration of the Oscillator
- Operates down to 1.3V VBAT Minimum
- Operating Temperature Range:
  - Industrial (I): -40°C to +85°C
- Multi-function Pin:
  - Open-drain configuration
  - Programmable clock frequency out
  - Programmable alarm output
- Interrupt Capability (based on the 2 sets of Alarm Registers, ALM0 and ALM1)
- Time-stamp Registers for holding the Time/Date of Crossing:
  - from VDD to VBAT
  - from VBAT to VDD

SCHEMATIC

The schematic includes a PIC18 Explorer demo board and the I²C RTCC PICtail™ daughter board as shown in Figure 1.

FIGURE 1: SCHEMATIC



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The resources used on the demo board are:

- LCD
- 2 push buttons
- AC164140 RTCC PICtail daughter board

To access the LCD through a minimum of pins, the SPI on the MSSP1 module is used, in conjunction with a 16-bit I/O expander with SPI interface (MCP23S17). The two on-board push buttons are S1 and S2, connected to RB0, RA5 GPIOs. The I^2C RTCC is part of the RTCC PICtail evaluation board and is directly connected to the MSSP1 module of the MCU. Another necessary connection is between the MFP signal of the RTCC and RA4 (T0CKI), the clock input of TMR0. The RTCC is programmed to offer a square wave of 1Hz on MFP. TMR0 is programmed as the counter and is initialized at 0xFFFF, in order to give a software interrupt at every second. All connections between the I^2C RTCC and the MCU (SDA, SCL, MFP) are open drain and use pull-up resistors. The RTCC PICtail daughter board has two other components:

- a 32,768 Hz crystal driving the internal clock of the RTCC
- a 3-volt battery sustaining the RTCC when V_{DD} is not present on the demo board

DETAILS ABOUT IMPLEMENTATION

The application is performed on a PIC18 Explorer demo board on which is mounted a PIC18F87J11 MCU. The code is written in 'C' using the C18 compiler. It implements an electronic watch (based on the MCP79410 RTCC), displaying the six basic time/date variables on the on-board LCD. It includes a setup sequence, which sets the same six time/date variables, using the two push buttons of the evaluation board (S1 = MENU KEY, S2 = INCREMENT KEY).

FUNCTIONAL DESCRIPTION

The MCP79410 is an I^2C slave device, working on the related bidirectional 2-wire bus. SDA is a bidirectional pin used to transfer addresses and data in and out of the device. It is an open-drain terminal, therefore, the SDA bus requires a pull-up resistor to V_{CC} (typically 10kΩ for 100 kHz and 2kΩ for 400 kHz). For normal data transfers, SDA is allowed to change only during SCL low. Changes during SCL high are reserved for indicating the Start and Stop conditions. SCL input is used to synchronize the data transfer from and to the device. The related internal structures have the following device addresses/control bytes (the RTCC is included in the SRAM bank):

- RTCC + SRAM: 0xDE for writes, 0xDF for reads
- EEPROM: 0xAE for writes, 0xAF for reads

The chip can support speeds up to:

- 400 kHz 2.5 to 5V
- 100 kHz 1.8 to 2.5V

APPLICATION DESCRIPTION

The application performs an electronic watch that has two main functions:

- display of the six time/date variables (year, month, date, hour, minutes, seconds) using the interrupts of the microcontroller (this operation is performed on the on-board LCD; the format is 24 hours).
- setup of the above variables using the two on-board push buttons: S1 = MENU KEY, S2 = INCREMENT KEY. The real-time display of the time/date variables is performed as long as the MENU KEY (S1) is not pressed (the action of the INCREMENT KEY (S2) has no effect on the watch continuously displaying the time and the date).

Pressing the MENU KEY will start the setup menu, disabling the interrupts. The menu is covered once in the following order: year, month, date, hour, minutes, and seconds. Going from one variable to another is performed through the MENU KEY, and incrementing a variable is performed through the INCREMENT KEY. The last action of the MENU KEY exits the setup menu. Accordingly, to correct a possible setup error, the setup menu must be re-entered. The upper limits of every variable are: year = (20) 99; month = 12; date = (always) 31; hour = 23 (24 hours format); minutes = 59; seconds = 59. Entering the setup menu will not stop the oscillator of the RTCC. At the end of the setup, the time/date variables are updated and entering the menu will stop the counting. If the user enters the Time Setup mode, all changes are written to the RTCC, even if no variables are changed. When entering the menu the watch will resume counting from the point where it was stopped.

FIRMWARE DESCRIPTION

Drivers

Drivers are divided into 4 classes:

- LCD drivers
- RTCC register access drivers
- Drivers related to the operating system (setup menu): keyboard drivers
- Interrupt system drivers (the interrupt function based on TMR0's overflow and the related functions (interrupt initialization, start/stop interrupts)

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LCD Drivers

The application is specifically implemented on the PIC18 Explorer demo board. On this board it was important to reduce the number of GPIO pins used to access the LCD. Accessing the LCD is performed on a SPI bus (included in the MSSP1 module) through an auxiliary chip, the MCP23S17 SPI expander. The related drivers are:

- Write command to LCD:
  `wrcmnd_lcd (unsigned char cmnd_lcd)`
- Write data byte/character to LCD:
  `wrdata_lcd (unsigned char data_lcd)`
- Write to LCD a string stored in the flash:
  `wrstr_lcd (const rom unsigned char *str_lcd)`

Drivers to Access RTCC Register

Since the MCP79410 is an I^2C RTCC, it will use the I^2C bus of the MCU (the MSSP1 module). Accordingly, the related drivers will be divided into two categories: basic I^2C drivers and RTCC drivers. They use as a control method the SPP1IF bit (flag) in the PIR1 register (interrupt flag of the MSSP1 module). They read through polling and not through interrupts, since interrupts are allocated to display the time/date using TMR0's overflow, once per second. Keep in mind that TMR0 acts as a counter, and its input is activated by the MFP signal coming from the RTCC (programmed as an one second square wave). The method represents an alternative to the classical "`i2c.h`" library, included in the C18 compiler.

FIGURE 2: FLOWCHART FOR A TYPICAL WRITE OPERATION (FOR A RANDOM BYTE ACCESS):

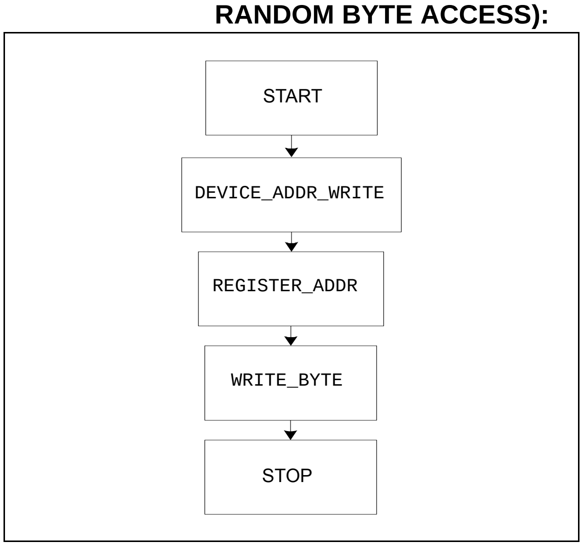
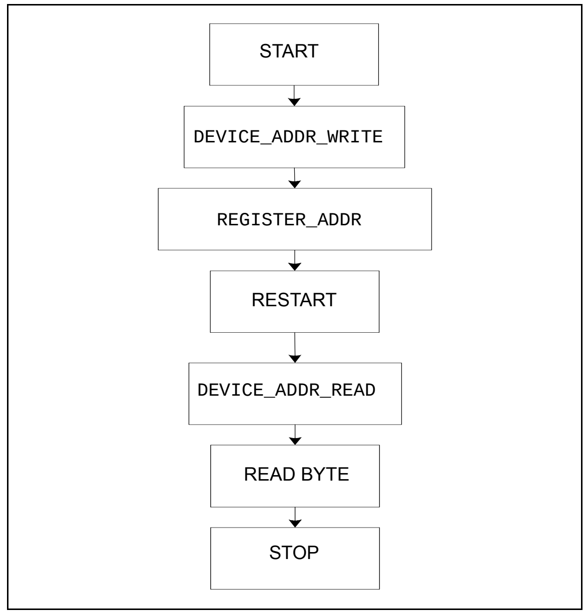


FIGURE 3: FLOWCHART FOR A TYPICAL READ OPERATION



The two related functions are: `void rtcc_wr (unsigned char time_var, unsigned char rtcc_reg);` `unsigned char rtcc_rd (unsigned char rtcc_reg);`

Keyboard Drivers (2 keys O.S.)

The set of keyboard drivers has only one function: `keyb_press()`. The `keyb_press()` function awaits the selection of one of the two on-board switches: S1 (MENU KEY) or S2 (INCREMENT KEY). After the selection is made, the firmware updates the code of the pressed key. Upon exiting the function, a value is returned in either `KEYB_MENU` or `KEYB_INCR`. The function performs a key debounce of (2 x 100 msec). The function will exit only after the pressed key is released (deactivated). For more details about the operating system based on the two on-board switches, refer to the **"Application Description"** paragraph.

The Interrupt Function

Interrupts are generated by the TMR0 overflow, which is initialized at 0xFFFF as a counter. TIMER0 is incremented once per second by the MFP signal coming from the RTCC. The interrupt function calls one function: `display_time()`, which reads the six related registers of the RTCC and puts them in the six global variables (year, month, date, hour, minute, seconds). The Random Byte Access mode is used, as some versions of the application can use only a subset of these six variables. In the end, the interrupt function (through the `display_time()`driver) displays these six variables on the on-board LCD, according to the format below:

ROW1:	"date" string	year	month	date
ROW2:	"time" string	hour	minutes	seconds

ACCESSING THE RTCC REGISTERS

There are two basic functions for accessing the RTCC register: one for writes and one for reads. They can be defined as: `void rtcc_wr (unsigned char time_var, unsigned char rtcc_reg)`, `unsigned char rtcc_rd (unsigned char rtcc_reg)`. Each of these two functions include error messages displayed on LEDs, which could signal when an operation is not acknowledged by the slave (RTCC).

EXAMPLE 1: WRITES TO THE RTCC

```
i2c_start()           ; //   start I2C communication: SDA goes down while SCL remains high
i2c_wr(ADDR_RTCC_WRITE); //  send the RTCC's address for write = 0xde
i2c_wr(rtcc_reg)      ; //   send the register's address
i2c_wr (time_var)     ; //   send the data byte
i2c_stop()            ; //   stop I2C communication: SDA goes high while SCL remains high
```

EXAMPLE 2: READS FROM THE RTCC

```
i2c_start()           ; //   start I2C communication: SDA goes down while SCL remains high
i2c_wr(ADDR_RTCC_WRITE ; //  send the RTCC's address for write = 0xde
i2c_wr(rtcc_reg)      ; //   send the register's address
i2c_restart()         ; //   switch to reads
i2c_wr(ADDR_RTCC_READ) ; //  send the RTCC's address for read = 0xdf
i2c_rd()              ; //   read the byte from the RTCC (register's content)
i2c_nack              ; //   NoACK from MCU to the RTCC (no more bytes to read)
i2c_stop()            ; //   stop I2C communication: SDA goes high while SCL remains high
```

As described in the data sheet, the addresses of the RTCC register are shown in Table 1.

TABLE 1: RTCC REGISTER ADDRESSES

Address	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	FUNCTION	RANGE
00h	ST	10 Seconds			Seconds				Seconds	00-59
01h		10 Minutes			Minutes				Minutes	00-59
02h		12/$\overline{24}$	10 Hour AM/PM	10 Hour	Hour				Hours	1-2 + AM/PM 00-23
03h			OSCON	V_{BAT}	VBATEN		Day		Day	1-7
04h			10 Date		Date				Date	01-31
05h			LP	10 Month	Month				Month	01-12
06h	10 Year				Year				Year	00-99
07h	OUT	SQWE	ALM1	ALM0	EXTOSC	RS2	RS1	RS0	Control Reg.	

According to these addresses, in the basic read/write functions, only the register's address will differ. Reads are used in the interrupt function (once/second). Writes are used in the initialization function and in the setup sequence (the main function).

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CONCLUSION

This application note presents how to control (display and setup) an electronic watch, based on Microchip's I^2C RTCC, MC79410. The project is performed on a PIC18 Explorer demo board, using the on-board resources: LCD (accessed through the SPI bus) and push buttons. The code (drivers and main function) is written in 'C', using the C18 compiler. The preferred microcontroller is the PIC18F87J11.

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