AN1379

Stopwatch Based on MCP79410 I²C™ RTCC

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INTRODUCTION

The Real-Time Clock/Calendar (RTCC) devices can be successfully used in applications that require very accurate timekeeping. MCP79410 is a feature-rich RTCC that incorporates EEPROM, SRAM, unique ID and time-stamp.

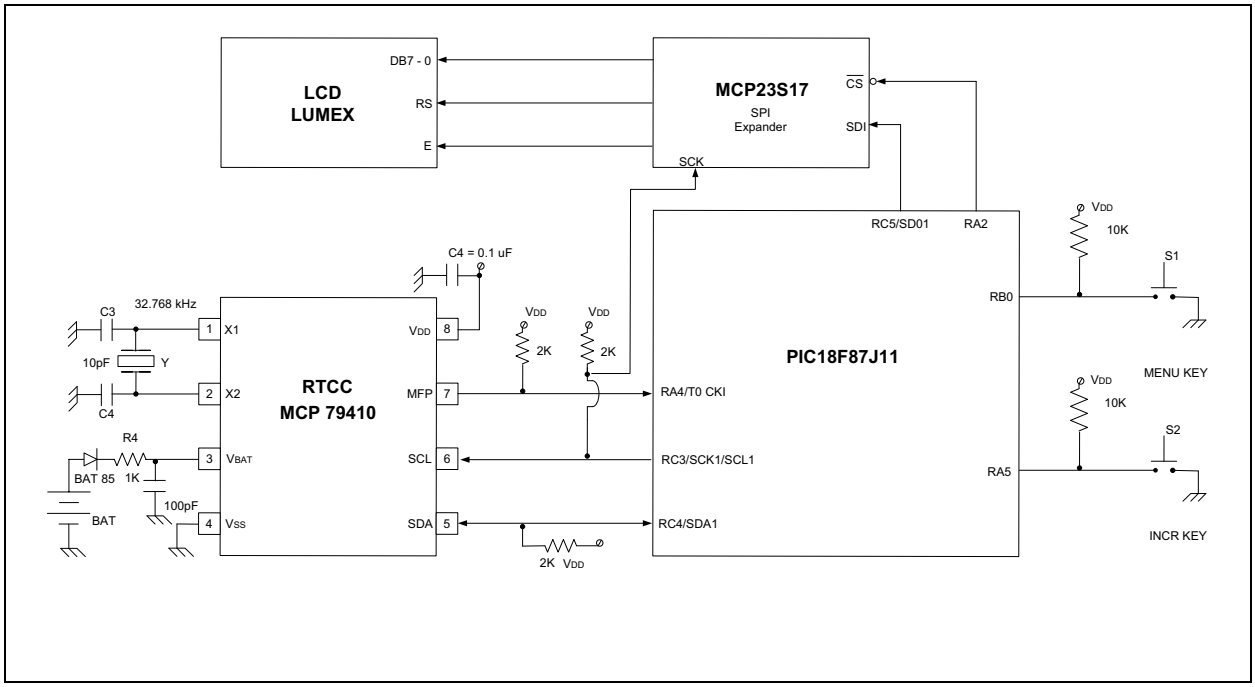
FEATURES OF THE RTCC

- 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



The hardware modules 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 S1 and S2 are connected to RB0, RA5 GPIOs. The I^2C RTCC is part of the RTCC PICtail evaluation board and is connected to the MSSP1 module of the MCU.

The hardware supports two ways for reading from RTCC and displaying the time on LCD:

- using the connection (if TMR0 interrupt is used to read/display the time) between the MFP signal of the RTCC and RA4 (T0CKI), the TMR0 clock input. The RTCC can offer a square wave of 1 Hz on MFP, in order to give a software interrupt per second
- using a special software loop (see Displaying Function paragraph for details)

The loop method was used for this firmware.

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 developed around the PIC18 Explorer demo board using a PIC18F87J11 MCU. The code is written in C using the C18 compiler. It implements an electronic stopwatch (based on the MCP79410 RTCC), displaying the three basic time/date variables (hours, minutes, seconds) on the on-board LCD. It can start or stop/restart the stopwatch (hours, minutes, seconds) using the two push buttons of the evaluation board (S1 = START KEY, S2 = STOP/RESTART KEY).

FUNCTIONAL DESCRIPTION

The MCP79410 is an I^2C slave device. SDA is a bidirectional pin used to transfer 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 10 kΩ for 100 kHz and 2 kΩ 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 MCP7941X uses the following I^2C addresses:

- 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 stopwatch that has two main functions:

- display of the three time/date variables (hours, minutes, seconds). This operation is performed on the on-board LCD; the format is 24 hours.
- start or stop/restart of the stopwatch using the two on-board push buttons: S1 = START KEY, S2 = STOP/RESTART KEY. The time variables are displayed if the START KEY (S1) was pressed. The action of the STOP/RESTART KEY (S2) stops or restarts (when pressed twice) the stopwatch.

Pressing the START KEY will start the stopwatch and also the communication with the RTCC device (initialize the starting date and time). As a result, three time variables will be displayed on the LCD: hours, minutes and seconds.

When the user will press the STOP KEY once, the stopwatch will stop, disabling the oscillator from the RTCC. If the STOP KEY is pressed once again, the stopwatch will restart and the display will show the three time variables with their value set to zero.

Pressing the START KEY again will enable the oscillator of the RTCC and will start the count from the last time variables or to all zeros (if restarted).

FIRMWARE DESCRIPTION

Drivers

Drivers are divided into 5 classes:

- LCD drivers
- I^2C drivers
- SPI drivers
- RTCC register access drivers
- Drivers related to the operating system (setup menu): keyboard drivers

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 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 it through polling and not through interrupts.

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

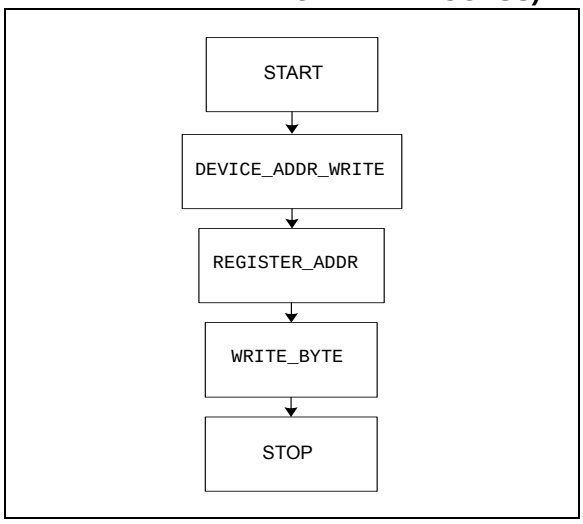
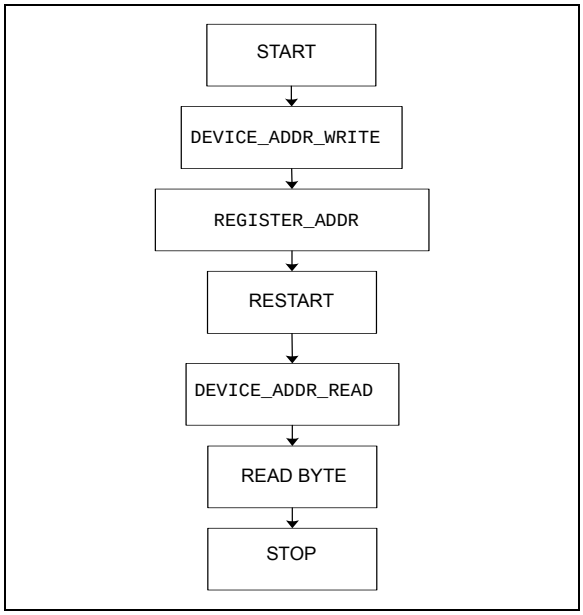


FIGURE 3: FLOWCHART FOR A TYPICAL READ OPERATION



The two 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 firmware is waiting for the selection of one of the two on-board switches: S1 (START KEY) or S2 (STOP/RESTART KEY). In order to know which key was pressed, a variable is used to read the keyboard (the key variable can have Start, Stop or Restart value) and another variable to wait the release of the keyboard. A 100 ms delay can be used in order to avoid keyboard hazard.

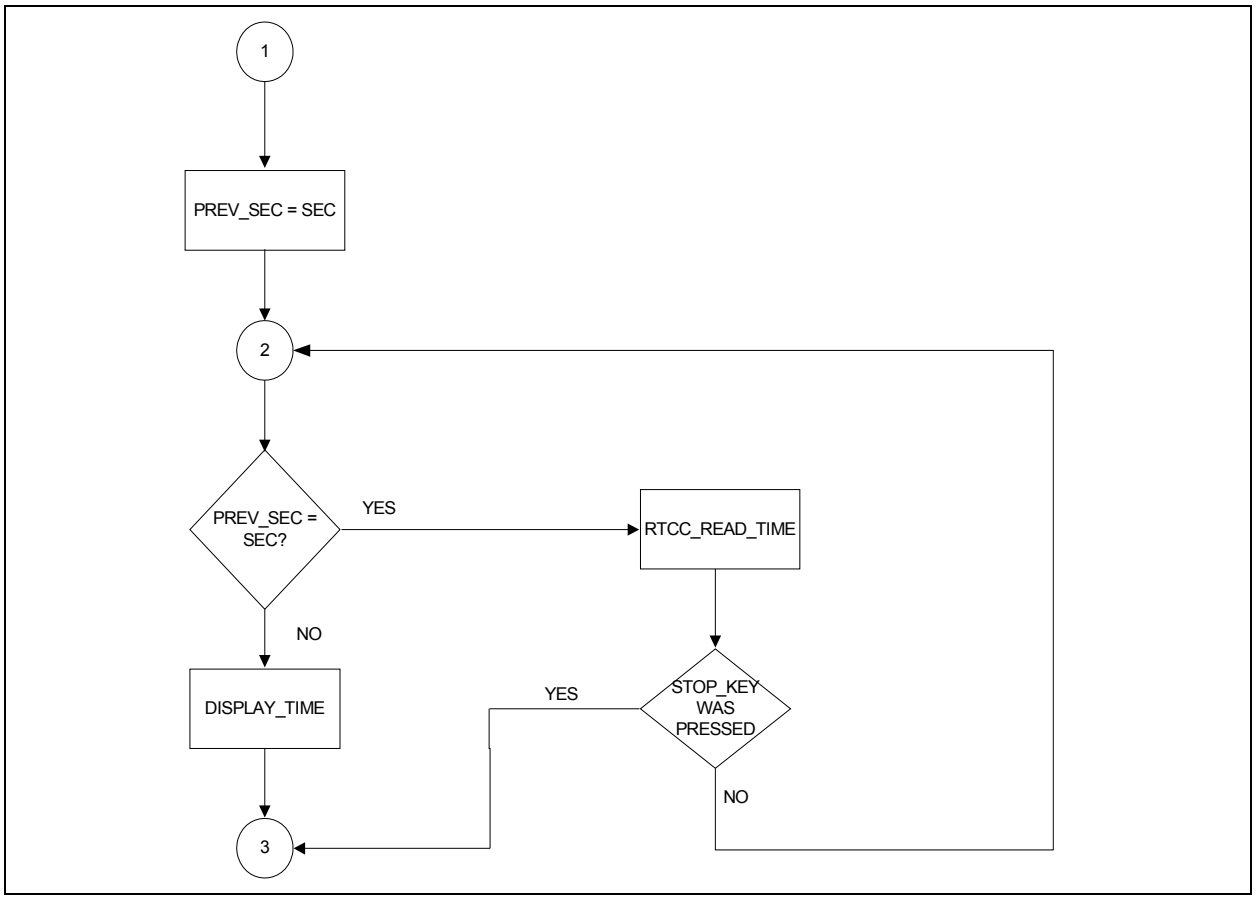
The firmware reacts when the switch is pressed, not when it is released. This method of reading the keyboard eliminates the unpleasant effect of multiple counting when a key is pressed for a long time, without releasing it.

The Displaying Function

The time variables (hours, minutes and seconds) are displayed on the LCD once per second, using a software loop in the main function and not the TMR0 interrupt. An additional variable (`prev_sec`) is used to memorize the value of the last second received from the RTCC. Inside a loop, the main function constantly reads the RTCC seconds' register value and is compared with the variable `prev_sec`. In case of inequality, a second has passed and the time can be displayed on the LCD according to the format below:

ROW1:	Time elapsed		
ROW2:	hours	minutes	seconds

FIGURE 4: FLOWCHART FOR DISPLAYING THE TIME



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).

CONCLUSION

This application note presents how to control an electronic stopwatch, 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 PIC18F87J11.

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