AN1303

Software Real-Time Clock and Calendar Using PIC16F1827

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INTRODUCTION

This application note describes the implementation of software Real-Time Clock and Calendar (RTCC). The implementation can be used either separately, replacing one of the hardware RTCC devices on the market, or as part of an application. In the latter example, there is no need for the I²C™ communication channel.

The implementation provides the time (seconds, minutes, and hour), date (day, month, and year), day of week, and one alarm. The user can customize the firmware according to his/her own needs.

IMPLEMENTATION

The basis of the Real-Time Clock (RTC) is the Timer1 counter. This timer can be configured to accept a clock source from the internal low-power oscillator. This internal circuit is used in conjunction with an external 32.768 kHz crystal. The oscillator has the ability to work during Sleep mode. This feature can be very helpful if the Real-Time Clock and Calendar circuit is to be powered from a battery. The Timer1 register pair (TMR1H:TMR1L) counts from 0x0000 to 0xFFFF. If the register is incremented from 0xFFFF, then a roll-over event occurs and the timer rolls over to 0x0000. Additionally, the interrupt flag, TMR1IF, is set and an interrupt will occur if enabled. The flag must be cleared in the software.

Timer1 can operate during Sleep mode to help reduce the current consumption of the application. A Timer1 roll-over event (TMR1IF bit) will wake the microcontroller from Sleep and execute the next instructions. It should be noted that, upon an overflow, the TMR1IF flag is set, but the counter continues to run. Time and date update can be done at a later time, provided that another Timer1 roll-over does not occur.

DATA INTERFACE

The Real-Time Clock and Calendar communicates with the host system via a two-wire I²C bus as a slave device. A set of I²C commands and RTCC registers are implemented to allow the host to read and write time and date information. All registers are read and write. The registers from 0x00 to 0x0E only support one byte read/write operation (for compatibility with hardware RTCCs already on the market). The registers from 0x0F and 0x10 support multiple byte read/write operation. This is to allow multiple data to be sent in one single transfer. Of course, the user has the ability the change the source code, thus changing the functionality to suit his/her own needs.

TABLE 1: INTERNAL REGISTER MAP

Hex address			Description	Range
0x01	Current Date/Time	Time	Seconds	00-59
0x02			Minutes	00-59
0x03			Hour	0-23
0x04		Date	Day	0-6
0x05			Date	1-31
0x06			Month	1-12
0x07			Year	0-99
0x08	Alarm Date/Time	Time	Minutes	00-59
0x09			Hour	0-23
0x0A		Date	Date	1-31
0x0B			Month	1-12
0x0C			Year	0-99
0x0D	Current/Date/Time	Time	Seconds Minutes Hour	00-59 00-59 0-23
0x0E		Date	Date Month Year	1-31 1-12 0-99

DAY OF WEEK CALCULATION

The algorithm must calculate the day of week (e.g., “Monday”, “Tuesday”...), based on a given date (e.g., 1st January 2000). There are several algorithms that provide this calculation, but one we have chosen is fast and the code implementation is small.

There are several considerations that can make the algorithm easier to implement. We do not need to store the “year” information using the full 4 digits (e.g., “2005”), but only the last two digits. The “year 2000 problem” is now history and, anyway, we are more interested in dates starting from present time to ten-to-twenty years from now.

The day-of-week algorithm must calculate four numbers:

1. Centuries: There is a table for centuries. But as we previously mentioned, we are interested only in the current century. So, the value for the years 2000-2099 is 6. The centuries number will always be 6.
2. Years: There are 365 days in one year. Each leap year has one more day than a normal year. If we add the number of years elapsed from the start of the century with the number of the leap years elapsed from the start of the century, we get the day of the week when the year starts. Here we take into account only the last two digits of the year.

EQUATION 1:

$$y = year + \left\lfloor \frac{year}{4} \right\rfloor$$

3. Months: we must use the months table to get the day of the week a month starts on. Every January starts on the first day of each year. Please notice that the table has corrections for the leap year.

TABLE 2: MONTHS

January	0 (in leap year 6)
February	3 (in leap year 2)
March	3
April	6
May	1
June	4
July	6
August	2
September	5
October	0
November	3
December	5

4. Day of month: We now know on which day of the week the month starts. We must simply add the day of the month to get the day of week.

After we have all the four numbers, we simply add them and use modulus of 7 to limit the values between zero and six. The corresponding day of the week is given in the following table:

TABLE 3: CORRESPONDING DAY OF WEEK

Value	Corresponding day of week
0	"Sunday"
1	"Monday"
2	"Tuesday"
3	"Wednesday"
4	"Thursday"
5	"Friday"
6	"Saturday"

Here is an example:

Let’s use Thursday, the 1st of October, 2009:

1. We are interested in this century only. The first number is 6.
2. Note the last two digits of the year: 09.
3. Divide 09 by 4, leave out the remainder. 9/4 = 2.
4. Look at the month table: for October, we have a value of 0.
5. Add all the numbers we have until now with the day the month. 6 + 9 + 2 + 0 + 1= 18
6. Divide 18 by 7 and find the remainder: 18/7= 2 remainder 4.
7. Use the corresponding day of week table (Table 3). For value 4, we get the day of Thursday.

LOW-POWER

A Real-Time Clock can be powered by an alternate backup power supply, such as a coin cell battery. Typically, while the main system is running, there will be power from the main power supply. While the main system is turned off, there cannot be any read/write request from the host, thus the Real-Time Clock circuit will typically draw power only to update the time and the date.

In order to preserve energy, the processor must stay in Sleep mode as much as possible. The internal low-power oscillator will continue to work during Sleep mode. The Timer1 counter is configured to wake the processor from Sleep once every second. The time is updated (also the calendar, if needed) and the processor goes back to Sleep mode. The same applies for accessing the internal registers via the I^2C bus. The processor wakes up from Sleep following a Start condition and goes back to Sleep mode after a Stop condition.

The user must make sure that all the unnecessary modules are turned off or disabled during Sleep mode. Also, all external power consuming parts must be turned off.

POSSIBLE UPGRADES

The current implementation updates the time and calendar once every second. In the previous chapter, we learned that, in order to preserve more power, the processor must stay in Sleep mode as much as possible. Thus, the time spent in Active mode, when the power consumption is higher, must be kept as short as possible. One possible upgrade would be to have a 32-bit register incremented once every second. This will help minimize the on-time of the microcontroller even more. The only task the processor will do during the active period would be to increment the counter. The actual conversion between the counter and the date and time will be made on demand, during an I^2C data transfer. Wake-up alarms or time-triggered events can also be implemented using this 32-bit time-stamp method.

CONCLUSION

This application note shows the ease of implementing a software Real-Time Clock and Calendar using the PIC16F1827. The Extreme-Low-Power (XLP) technology features make this design a well-suited solution in terms of overall cost, performance and power consumption.

CODE RESOURCE REQUIREMENTS:

- Flash program memory – 821 words (including I^2C communication with multi-byte reads and alarm implementation)
- Data RAM size: 53 bytes
- Interrupts: Timer1 interrupt
- Timers: Timer1
- Hardware resources: External 32.768 kHz crystal

NOTES:

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