M16C/26

Implementing Real Time Clock and WAIT Mode

1.0 Abstract

The following article describes the implementation of a low-power, real time clock using the sub-clock circuit with a 32.768 kHz crystal and Wait mode of the M16C/26 microcontroller (MCU).

2.0 Introduction

This article shows how to use the M16C/26 MCU's WAIT mode and implement a real time clock function on the M16C/26 MCU using a 32.768KHz crystal on the sub-clock circuit.

The Renesas M16C/26 is a 16-bit MCU based on the M16C/60 CPU core. It has multiple peripherals such as 10-bit A/D, UARTs, clock circuits, etc.

There are three oscillator circuits in the M16C/26, which includes a main clock circuit, a sub-clock circuit, and a ring oscillator. After a reset, the MCU always starts running from the main clock, which is usually used in normal operation. The ring oscillator is an internal oscillator, which can be used in case the main clock stops. The sub-clock, which needs to be enabled after reset, is a low frequency clock, that is useful for power reduction and as a low speed clock source for timers and other peripherals. Using a 32.768KHz crystal in the sub-clock circuit, a one-second timer can be generated and a real time clock (RTC) function is easily implemented.

The M16C/26 has two low power modes of operation, STOP mode and WAIT mode. When placed in STOP mode all oscillation circuits are stopped and the MCU remains in the STOP state until an external interrupt or Reset occurs. In WAIT mode, the clock that drives the MCU core logic, BCLK, is switched from the main clock to the sub-clock circuit to lower power consumption. The peripheral clocks can be stopped, but not the sub-clock oscillator divided by 32 (fc32), to further lower power consumption. Similar to STOP mode, an interrupt or a reset is required to exit from WAIT mode.

A demo program for the MSV30262-SKP was developed to show the RTC-WAIT implementation.

3.0 Real-Time Clock Setup and Implementation

3.1 Sub-Clock Block and Hardware

Figure 1 shows the block diagram of the M16C/26 clock generating circuit. Figure 2 shows examples on how to wire the sub-clock pins to a crystal or an oscillator. The sub-clock circuit generates two signals internally, fc and fc32 (fc/32), and can be used as a clock source for the different M16C/26 MCU peripherals. A 32.768KHz crystal is connected to the sub-clock pins on the MSV30262 Board.

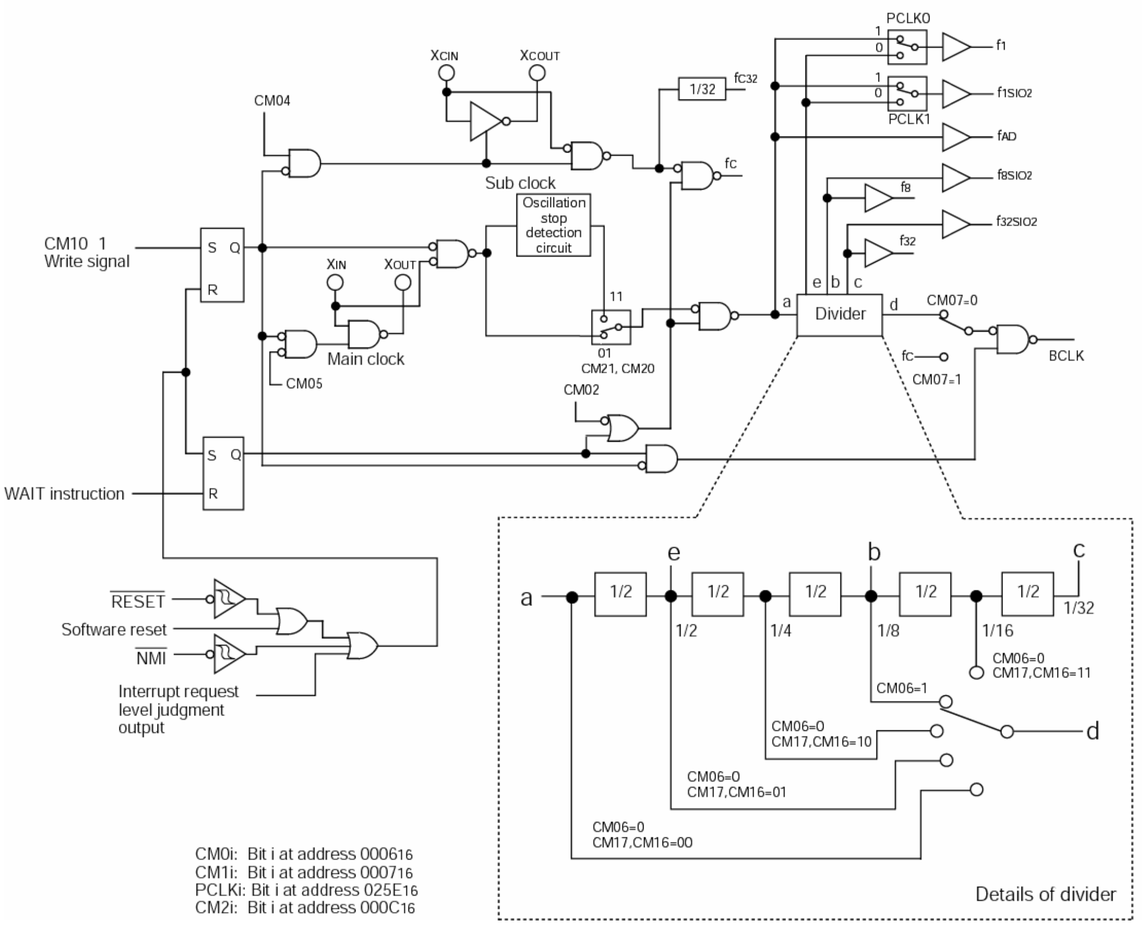
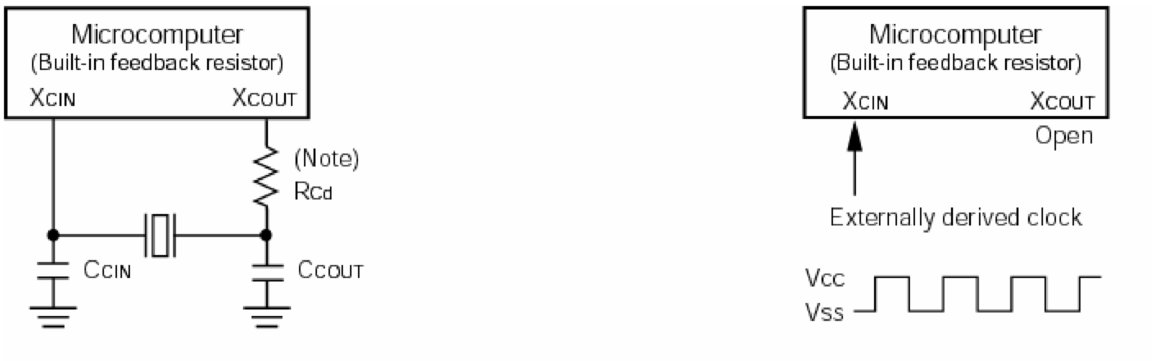


Figure 1 M16C/26 Clock Circuit Block Diagram



Note: Insert a damping resistor if required. The resistance will vary depending on the oscillator and the oscillation drive capacity setting. Use the value recommended by the maker of the oscillator.
Also, if the oscillator manufacturer's data sheet specifies that a feedback resistor be added external to the chip, insert a feedback resistor between XCIN and XCOUT following the instruction.

Figure 2 Connecting to Sub-clock Pins

3.2 Enabling the Sub-clock Circuit

As mentioned earlier, the sub-clock oscillation circuit is disabled after reset. To be able to use the sub-clock circuit, it needs to be enabled. The steps necessary to enable the sub-clock circuit are listed below and followed by sample code listing used in the demo.

1. Change Ports 8_6 (XCin) and 8_7 to inputs.

```
// Start the 32Khz crystal sub clock
pd8_7 = 0;              // setting GPIO to inputs (XCin/XCout)
pd8_6 = 0;
```

2. BDisable protection of clock control register.

```
prc0 = 1;               /* Unlock CM0 and CM1 */
```

3. Enable sub-clock circuit.

```
cm04 = 1;               // Start the 32KHz crystal
```

4. Enable protection of clock control register.

```
prc0 = 0;               // Lock the System Clock Control Register
```

3.3 Setting up the Real Time Clock Timer

Now that we have enabled the sub-clock circuit, we need to setup the second timer that will run the real-time clock function. As mentioned above, the sub-clock circuit generates fc and fc32. fc is the frequency of the crystal or oscillator connected to the sub-clock pins. On the other hand, fc32 is fc divided by 32. On the MSV30262 Board, a 32.768 KHz crystal is connected between Xcin and Xcout, making fc equal to 32.768KHz. The frequency fc32 then becomes, 1.024KHz.

A sample code, used in the demo, on setting up a timer (i.e. Timer B1) on the M16C/26 as the real-time clock timer is shown below.

```
/* Configure Timer B1 - RTC (second) timer*/
tb1mr = 0xc0;       // Timer mode, fc32 (32.768KHz/32 = 1024Hz)
tb1 = 1023;  // Set the counter to interrupt every second (1s = 1024 (0-1023) count).
```

Timer B1 is used in timer mode with fc32 as the clock source. In Timer mode the timer will count down every fc32 from a preset value (tb1) until it underflows. When the timer underflows it will generate an interrupt request and reload the preset value into the count register. It will then begin counting down again.

To generate a 1-second timer, Timer B1 count (tb1) must be set to count 1024 (1 second x fc32). But since the counter goes to 0, setting tb1 to 1023 will generate a 1024 count. The demo uses a 1 second timer but it can be setup as a 1-minute timer by setting tb1 to 61440 (60 seconds x fc32).

Once the timer is setup, setting the start flag (i.e. tb1s) to 1 will start the timer running. For the demo, the timer was not started until the clock has been preset.

3.4 The Real-time Clock Interrupt Routine

An interrupt is generated, every second, every time our timer underflows. And so, time must be calculated every time this interrupt routine is called. A sample code that calculates time in military time format is shown below.

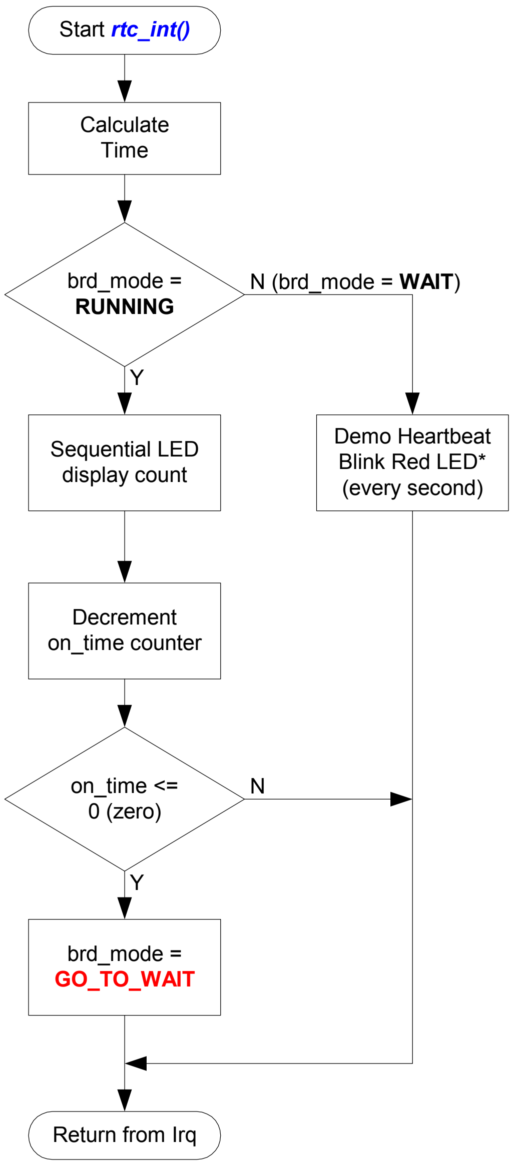
```
/*****************************************************************************
Name:           rtc_int
Parameters:     None
Returns:        None
Description: This is the RTC timer, Timer B1, interrupt routine. It is called
             every second.
*****************************************************************************/
void rtc_int(void)
{
        unsigned int i;

        /* time calculation (in military time mode) */
        if (++second >= 60){
                second = 0;
                if (++minute >= 60){
                        minute = 0;
                        ++hour;
                        if (hour > 23)
                                hour = 0;
                }
        }
```

To tell the C compiler that the routine is an interrupt routine, a **'# pragma interrupt /B irq_rtn'** must be defined and where irq_rtn is the routine to be processed when the interrupt is generated. A sample definition used in the demo, and can be found in rtc.c, is shown below.

```
/* interrupt routine used for rtc - vectors modified in sect30_rtc.inc */
#pragma INTERRUPT /B rtc_int
```

To be able to jump to this **rtc_int** routine, the M16C/26 MCU needs to know its vector address. The vector is set in an include file, **sect30.inc** (in the demo, sect30_rtc.inc). Please see sample snippet below used in sect30_rtc.inc on how to setup the interrupt vector for our real time clock timer.

```
.lword dummy_int            ; TIMER A0 (for user)
.lword dummy_int            ; TIMER A1 (for user)
.lword dummy_int            ; TIMER A2 (for user)
.lword dummy_int            ; TIMER A3 (for user)
.lword  dummy_int           ; TIMER A4 (for user) (vector 25)
.lword dummy_int            ; TIMER B0 (for user) (vector 26)
.glb    _rtc_int
.lword _rtc_int             ; TIMER B1 (for user) (vector 27)
.lword dummy_int            ; TIMER B2 (for user) (vector 28)
.lword dummy_int            ; INT0 (for user) (vector 29)
```



NOTE:
1. Functions called are in blue letters. See **rtc.c** for details.
2. Board mode are shown in red letters.
3. Blinking Red LED is to show that a program is running.

Figure 3 Real-time clock timer (Timer B1) interrupt routine, rtc_int(), flowchart

3.5 WAIT Mode and Real-time Clock

In many applications the real-time clock is required to operate under very low power conditions. This can be accomplished by using a timer and the fc32 clock as the count source. The fc32 clock allows very low power operation by allowing the MCU to operate in WAIT mode with all peripherals except those supplied with the fc32 clock to be disabled.

In the demo, the real-time clock timer B1 is used in Timer mode to generate an interrupt every second. After the interrupt routine is serviced, the M16C/26 goes into WAIT mode. Every second, the real-time clock timer B1 interrupt occurs and triggers the M16C/26 out of WAIT mode, the timer B1 interrupt routine is serviced, and then, the M16C/26 goes back to WAIT mode. As a note, an interrupt (or a reset) is required to bring the M16C/26 back from a WAIT mode and so ensure that interrupts are enabled and the interrupt routine is set.

3.6 Entering WAIT Mode

When the WAIT instruction is executed, the BCLK stops and the M16C/26 go into WAIT mode. If the WAIT Peripheral Function Clock Stop bit, CM02, is set the peripheral device clocks are also stopped. The oscillation circuits continue to operate in WAIT mode. To minimize power requirements, the sub-clock can be selected as the system clock and the main clock oscillation circuit is stopped. When the sub-clock is selected as the system clock, the Peripheral Function Clock Stop bit should not be set to 1. The basic steps to enter WAIT mode are shown below.

1. Disable protection of the clock control registers.	prc0 = 1;
2. Switch the system clock to the sub-clock.	cm07 = 1;
3. To reduce the power requirement, stop the main clock.	cm05 = 1;
4. Enable protection of the clock control registers.	prc0 = 0;
5. Call the WAIT instruction.	asm (“wait”);

In the demo, the wait_setup() function routine, shown below, makes the preparation for WAIT mode but does NOT execute the WAIT instruction. The WAIT instruction is executed in the main() loop List 1. For demo purposes, aside from the real-time clock timer interrupt, another interrupt (a key input interrupt) was added to allow the M16C/26 to exit WAIT mode. Pressing one of the three user pushbuttons S2, S3, or S4 on the MSV30262 Board generates a key input interrupt. The key input interrupt routine (wakeup_int()) must also be defined similar to the real-time clock timer B1 interrupt routine.

```
/*****************************************************************************
Name:          wait_setup
Parameters:    None
Returns:       None
Description: This prepares the MCU to enter wait mode. The application/demo runs
              and after a preset period, goes into wait mode.

              Aside from the real-time clock timer B1, the MCU can come out of
              wait mode by user intervention: pressing one of the three user
              pushbuttons S2-S4 (key input irq).

              The key input irq to wake MCU must be set prior to wait mode so
              it can be used to wakeup the MCU. This is disabled in the wakeup
              interrupt routine.
 *****************************************************************************/
void wait_setup(void)
{
       /* save power */
       ALL_LED_OFF;                // all LEDs off
       disp_ctrlw(LCD_CLEAR);      // clear LCD

       /* enable key input irq */
       asm("FCLR I");              // disable interrupts
       kupic = 6;                  // enable key-input irq
       asm("FSET I");              // enable interrupts

       /* Switch to XCin and then turn Xin off before going to wait mode */
       prc0 = 1;                   // unlock CM0
       cm07 = 1;                   // Switch from Xin to XCin
       cm05 = 1;                   // Stop Xin
       prc0 = 0;                   // lock CM0

       /* set our board mode to wait */
       brd_mode = WAIT;
}
```

WARNING: The WAIT instruction should never be called from within an interrupt handler. Calling a WAIT instruction within an interrupt routine may cause unexpected clock or MCU behavior. Ensure that the interrupt that will allow the M16C/26 MCU to exit is enabled. Otherwise, the MCU will be stuck in WAIT mode.

```
       while(1){                                  // infinite loop

              if (brd_mode == RUNNING){           // in RUNNING mode?
                     led_display(disp_count);     // display current count
                     if (temp_sec != second){     // LCD is to be updated every second
only
                            display(0, "RTC Time");      // RTC Header
                            disp_time(2);                // current time
                            temp_sec = second;
                     }
```

```
                }
                else if (brd_mode == GO_TO_WAIT)    // time to go wait mode?
                                wait_setup();       // yes, let's prepare for wait mode

                else{                               // let's wait here (brd_mode =
WAIT)
                        asm("WAIT");                // in wait mode
                        asm("NOP");                 // 4 NOPs required after wait
instruction
                        asm("NOP");                 // due to prefetch queue
                        asm("NOP");
                        asm("NOP");
                }
        }
```

List 1 Executing a Wait Instruction

3.7 Exiting WAIT mode

The MCU will exit WAIT mode when an interrupt or a reset occurs. After exiting WAIT mode the MCU will enter the interrupt service routine for that interrupt. After completion of the service routine the MCU will return to the instruction following the WAIT instruction.

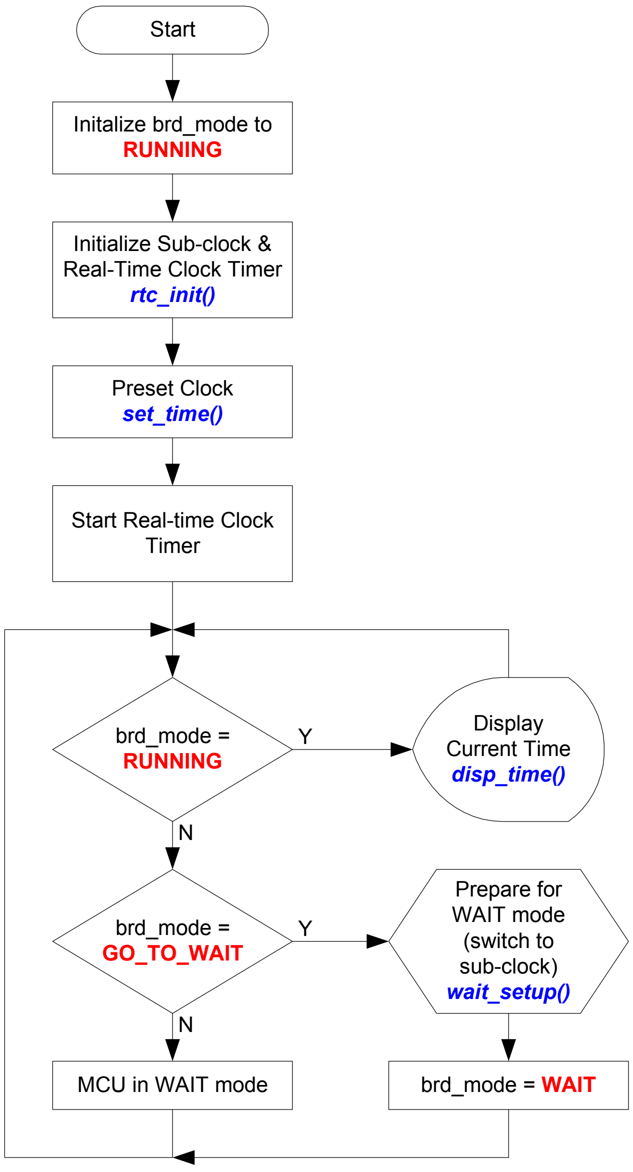
In the demo, there are two interrupts that will allow us to exit WAIT mode. One is the RTC interrupt service routine which occurs every second. The second is using a key-input interrupt by pressing one of the three user pushbuttons. The RTC interrupt is enabled during initialization and always remain enable. The key-input interrupt is enabled in the wait_setup() routine before the WAIT instruction is executed.

4.0 The RTC (and Wait) Demo Program

The RTC-Wait demo program implemented all the topics discussed earlier. For demo purposes, the MSV30262 Board was used. Like any other clock, the current time must be preset before running the clock. The clock is displayed on the LCD and the LED's are blinking sequentially. After 10s, the LCD and LED's are switched off to lower power consumption. Every second, as the real-time clock timer B1 interrupt is generated, the Red LED is blinked so that it's visible that a program is running. Pressing one of the user pushbuttons S2, S3, or S4, will display the current time on the LCD and blink the LED's sequentially for 10s.

4.1 Setting Initial Time

After the RTC-Wait program has been downloaded, run the program. Banners are displayed and then Set Hour will be displayed on the LCD. Pressing S2 will increment the hour while pressing S3 will decrement the hour. After the hour has been set, press S4 to set the minutes. Similar to setting the hour, pressing S2 will increment minutes and pressing S3 decrements minutes. After minutes have been set, pressing S4 will start the clock. Preset time is displayed on the LCD and the LED's will be blinking sequentially. After 10s, LCD will be blank and the heartbeat Red LED blinks every second.


Start
Initalize brd_mode to RUNNING
Initialize Sub-clock & Real-Time Clock Timer rtc_init()
Preset Clock set_time()
Start Real-time Clock Timer
brd_mode = RUNNING
Y
N
Display Current Time disp_time()
brd_mode = GO_TO_WAIT
Y
N
Prepare for WAIT mode (switch to sub-clock) wait_setup()
MCU in WAIT mode
brd_mode = WAIT

NOTE:
1. Functions called are in blue letters. See **rtc.c** for details.
2. Board mode are shown in red letters.

Figure 4 RTC-Wait Demo Program Flowchart

4.2 Displaying Current Time on LCD

Pressing any of the user pushbuttons S2, S3, or S4, will display the current time on the LCD and cause the sequential blinking of the three LED's for 10s.

5.0 Conclusion

Real-time clock function is easily implemented in the M16C/26 MCU using any of its eight 16-bit timers. Some real-time clock function requires power conservation and can also be accomplished with the M16C/26 MCU by using WAIT mode.

6.0 Reference

Renesas Technology Corporation Semiconductor Home Page

http://www.renesas.com

E-mail Support

support_apl@renesas.com

Data Sheets

- M16C/26 datasheets, M30262eds.pdf

User's Manual

- M16C/20/60 C Language Programming Manual, 6020c.pdf
- M16C/20/60 Software Manual, 6020software.pdf
- Interrupt Handler App Note, M16C26_Interrupt_Handlers_in_C.doc
- MSV30262-SKP Users Manual, Users_Manual_MSV30262.pdf

7.0 Software Code

The rtc.c code used in the demo program is shown below. The whole source code/TM project for the RTC-WAIT demo can be requested from the your Renesas representative.

```
/***********************************************************************
*
*       File Name:  rtc.c
*
*       Content: Real Time Clock (RTC) functions for M16C that includes setting
*               initial time, displaying time, RTC, and wakeup interrupt routines.
*
*       Revision 1.1  2003-02-21
***********************************************************************/

#include "..\common\sfr262.h"  // M16C/26 special function register definitions
#include "..\common\skp26.h"   // MSV30262-SKP function definitions
#include "rtc.h"                       // RTC function definitions

/* interrupt routine used for rtc - vectors modified in sect30_rtc.inc */
#pragma INTERRUPT      rtc_int
#pragma INTERRUPT      wakeup_int

#define RUN_TIME               10      // preset demo run time before going into wait mode -
in seconds

int hour, minute, second;      // clock variables
char on_time;                  // demo run time and sleep time
char brd_mode;                 // Mode:
                               // Running - RTC displayed on LCD, LEDs flashing sequentially
                               // Go to Wait - Preparation for wait mode
                               // Wait - No LCD and LEDs, RTC Running

const char num_to_char[10] = {'0','1','2','3','4','5','6','7','8','9'};

extern char disp_count;

/*****************************************************************************
Name:           init_rtc
Parameters:     none
Returns:        none
Description: Initialize the real-time clock (RTC).
*****************************************************************************/
void init_rtc(void){

   /* Change XCin and XCout to inputs and start the 32Khz crystal sub clock   */
   pd8_7 = 0;           // setting GPIO to inputs (XCin/XCout)
   pd8_6 = 0;

   prc0 = 1;            // Unlock CM0 and CM1
   cm04 = 1;            // Start the 32KHz crystal
   prc0 = 0;            // Lock the System Clock Control Register
   /* Configure Timer B1 - RTC (second) timer*/
   tb1mr = 0xc0;    // Timer mode, fc32 (32.768KHz/32 = 1024Hz)
   tb1 = 1023;     // Set the counter to interrupt every second (1s = 1024 (0-1023) count).
}

/*****************************************************************************
Name:           set_time
Parameters:     none
Returns:        none
Description: Presets clock and starts clock (RTC).
*****************************************************************************/
void set_time(void){

        char set_flag = 1;              // variable to go to next setting by pressing S4
                                        // 1 - set hour, 2 - set minute, 3 - run RTC

        /* initialize clock variables */
        hour = 0;
        minute = 0;
        second = 0;

        while (set_flag < 3) {
                /* set Hour */
                if (set_flag == 1){
                        if(!S_S2){      // incrementing variable everytime S2 is pressed
                                while(!S_S2);           // wait for S2 to go back up
                                if (++hour > 23)        // max hour 12 (12 PM)
                                        hour = 0;
                                disp_time(2);
                        }

                        if(!S_S3){      // decrement variable everytime S3 is pressed
                                while(!S_S3);           // wait for S3 to go back up
                                if (--hour < 0) // min hour 0 (0 AM)
                                        hour = 23;
                                disp_time(2);
                        }

                        if (!S_S4){     // move to next setting (minutes) if S4 is pressed
                                while(!S_S4);           // wait for S4 to go back up
                                set_flag = 2;           // set minutes
                        }
                }

                /* set Minutes */
                if (set_flag == 2){
                        display(0, "Set Min "); // display Set Minute
                        if(!S_S2){      // incrementing variable everytime S2 is pressed
                                while(!S_S2);           // wait for S2 to go back up
                                if (++minute > 59)      // max minute 59
                                        minute = 0;
                                disp_time(2);
                        }
                        if(!S_S3){      // decrement variable everytime S3 is pressed
                                while(!S_S3);           // wait for S3 to go back up
                                if (--minute < 0)       // min minute 0
                                        minute = 59;
                                disp_time(2);
                        }

                        if (!S_S4){     // move to next setting (run RTC) if S4 is pressed
                                while(!S_S4);           // wait for S4 to go back up
                                set_flag = 3;           // run RTC
                        }
                }
        }

        /* clock has been preset, start RTC */
        tb1s = 1;

        /* set on_time */
        on_time = RUN_TIME;
}

/*****************************************************************************
Name:           disp_time
Parameters:     LCD_Line
                        1 - display on Line 1 (top)
                        2 - display on Line 2 (bottom)
Returns:        none
Description: Displays time on LCD.
*****************************************************************************/
void disp_time(char LCD_Line){

        unsigned  char  hr1_LCD,  hr2_LCD,  min1_LCD,  min2_LCD,  sec1_LCD,  sec2_LCD;    //
characters for display
        unsigned int clk_var;

        /* get hour to display */
        clk_var = (unsigned int) hour/10;
        hr1_LCD = num_to_char[clk_var];
        hr2_LCD = num_to_char[(unsigned int) hour - (clk_var) * 10];

        /* get minutes to display */
        clk_var = (unsigned int) minute/10;
        min1_LCD = num_to_char[clk_var];
        min2_LCD = num_to_char[(unsigned int) minute - (clk_var) * 10];

        /* get seconds to display */
        clk_var = (unsigned int) second/10;
        sec1_LCD = num_to_char[clk_var];
        sec2_LCD = num_to_char[(unsigned int) second - (clk_var) * 10];

        /* display time on LCD */
        if (LCD_Line == 1)
                disp_ctrlw(0x80);          // top line of LCD, first char
        else
                disp_ctrlw(0xC0);          // bottom line of LCD, first char
        disp_dataw(hr1_LCD);
        disp_dataw(hr2_LCD);

        disp_dataw(':');

        disp_dataw(min1_LCD);
        disp_dataw(min2_LCD);

        disp_dataw(':');
        disp_dataw(sec1_LCD);
        disp_dataw(sec2_LCD);
}

/*****************************************************************************
Name:           rtc_int
Parameters:     None
Returns:        None
Description: This is the RTC timer, Timer B1, interrupt routine. It is called
                every second.
*****************************************************************************/
void rtc_int(void)
{
        unsigned int i;

        /* time calculation (in military time mode) */
        if (++second >= 60){
                second = 0;
                if (++minute >= 60){
                        minute = 0;
                        ++hour;
                        if (hour > 23)
                                hour = 0;
                }
        }

        if (brd_mode == RUNNING){               // in running mode?
                ++disp_count;                   // increment display counter
                if (disp_count > 4)
                        disp_count = 1;

                --on_time;                      // decrement our on_time

                if (on_time <= 0)                       // time to go to wait mode?
                        brd_mode = GO_TO_WAIT;  // if so, let's prepare for it
        }

        /* Make a heartbeat LED so it's visible that the program is running. */
        /* This is only for demo purposes. For actual applications, you can  */
        /* omit this routine.
                                 */
        else{                                           // in wait mode
                RED_LED = 0;                            // Flash Red LED
                for (i = 0xFF; i > 0; i--);     // add some delay
                RED_LED = 1;                            // turn off Red LED
        }
}

/*****************************************************************************
Name:           wakeup_int
Parameters:     None
Returns:        None
Description: This interrupt routine will wake us up from wait mode due to user
                intervention by pressing any of the three user pushbuttons, S2-S4.
*****************************************************************************/
void wakeup_int(void)
{
        unsigned int i;

        /* wakeup from wait mode - turn Xin back-on*/
        prc0 = 1;                       // unlock CM0
        cm05 = 0;                       // Enable Xin

        for (i = 0; i <= 0x0F; ++i)     // delay routine to allow Xin oscillator to stabilize
                asm ("NOP");

        cm06 = 0;       // No div - need to be set again - goes back to div by 8 in wait mode
        cm07 = 0;                       // Switch from XCin to Xin
        prc0 = 0;                       // lock CM0

        /* disable key-input irq */
        asm("FCLR I");                  // disable interrupts
        kupic = 0;                              // disable key input irq
        asm("FSET I");                  // enable interrupts

        /* switch brd_mode to RUNNING */
        brd_mode = RUNNING;

        /* reset our demo run time every time we wake up */
        on_time = RUN_TIME;
}

/*****************************************************************************
Name:           wait_setup
Parameters:     None
Returns:        None
Description:    This prepares the MCU to enter wait mode. The application/demo runs
                and after a preset period, goes into wait mode.

                Aside from the real-time clock timer B1, the MCU can come out of
                wait mode by user intervention: pressing one of the three user
                pushbuttons S2-S4 (key input irq).

                The key input irq to wake MCU must be set prior to wait mode so
                it can be used to wakeup the MCU. This is disabled in the wakeup
                interrupt routine.
 *****************************************************************************/
void wait_setup(void)
{
        /* save power */
        ALL_LED_OFF;                                // all LEDs off
        disp_ctrlw(LCD_CLEAR);          // clear LCD

        /* enable key input irq */
        asm("FCLR I");          // disable interrupts
        kupic = 6;                      // enable key-input irq
        asm("FSET I");          // enable interrupts

        /* Switch to XCin and then turn Xin off before going to wait mode */
        prc0 = 1;                       // unlock CM0
        cm07 = 1;                       // Switch from Xin to XCin
        cm05 = 1;                       // Stop Xin
        prc0 = 0;                       // lock CM0

        /* set our board mode to wait */
        brd_mode = WAIT;
}
```