Optimizing Memory on MSP430 for µC/OS-II

Kasthuri Annamalai   *MSP430 Applications*

ABSTRACT

This application report demonstrates the use of the Micrium µC/OS-II™ real-time kernel on an MSP430™ microcontroller with very low memory overhead. Suggestions on how to effectively use the features of MSP430 and µC/OS-II to optimize a project are included. This report also explains how to effectively use MSP430 ultralow-power modes with µC/OS-II projects.

Sample application source code and other collateral can be downloaded from the µC/OS-II (Small Footprint) link at this address: http://micrium.com/page/downloads/ports/ti/msp430.

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1 Details of the Sample Application

- The application blinks two LEDs on the MSP430F5438 Experimenter Board (MSP-EXP430F5438). Each of the LEDs is controlled by its own task.
- The application is built for the MSP430F5438A by default.
- The experimenter board software is configured to run at 1 MHz for this application.

2 To Modify This Application for Other MSP430F5xx/6xx Devices

1. Click IAR→Options→General Options→Target to select the new device (see Figure 1).
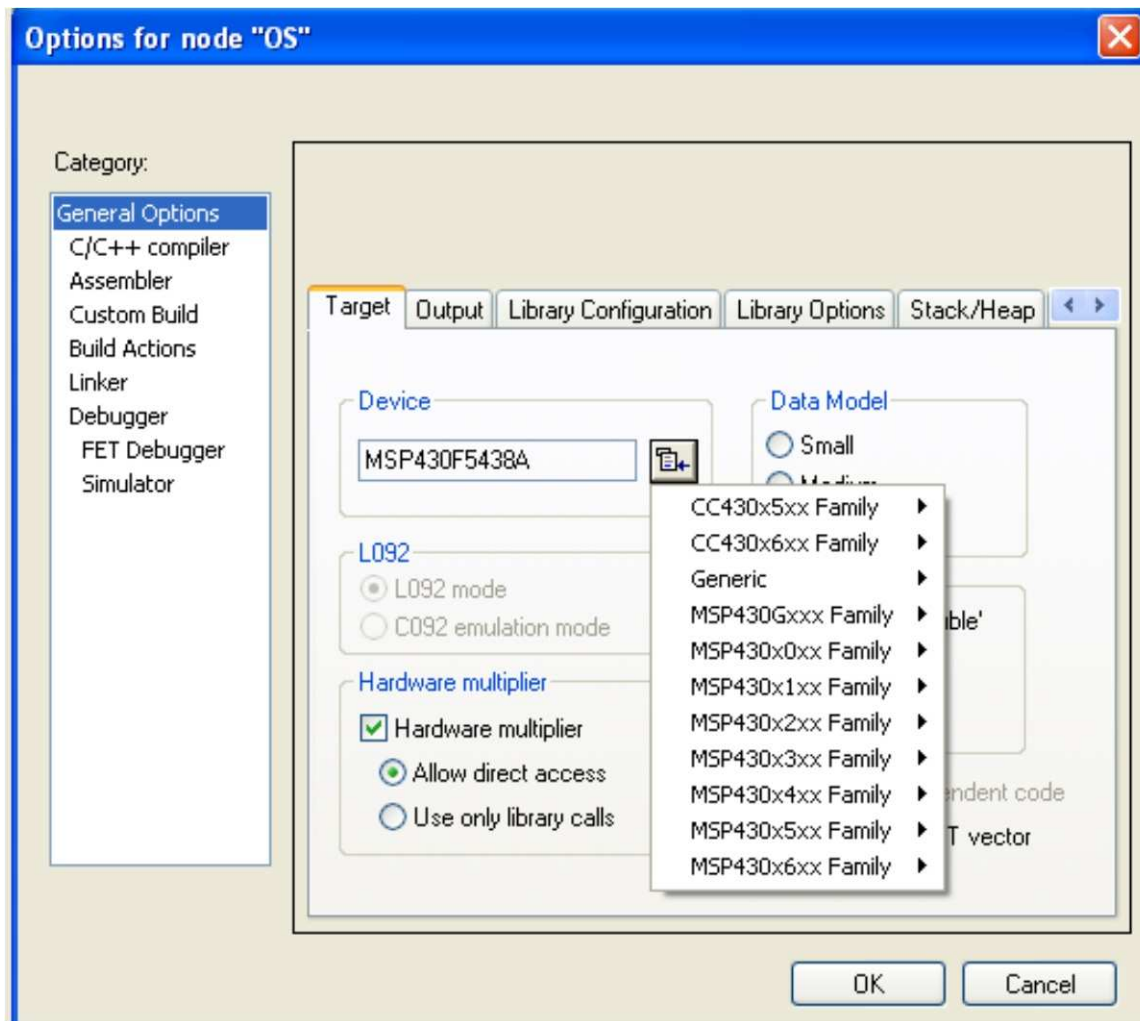
Figure 1. Select a Different Device

2. Modify hal_board.h to reflect the new LED port settings.
3. It is highly recommend to correctly terminate all unused pins as explained in the *MSP430x5xx/MSP430x6xx Family User's Guide* (SLAU208) and the device-specific data sheet. The halBoardInit() function in file hal_board.c ties the unused ports to the output direction for lower current consumption.

3 Clock System

Conflicting requirements typically exist in battery-powered applications:

- Low clock frequency for energy conservation and time keeping
- High clock frequency for fast response times and fast burst-processing capabilities
- Clock stability over operating temperature and supply voltage
- Low-cost applications with less-constrained clock accuracy requirements

The Unified Clock System (UCS) module addresses these conflicting requirements by allowing the user to select from the three available clock signals: ACLK, MCLK, and SMCLK.

All three available clock signals can be sourced via any of the available clock sources (XT1CLK, VLOCLK, REFOCLK, DCOCLK, DCOCLKDIV, or XT2CLK), giving complete flexibility in the system clock configuration. A flexible clock distribution and divider system is provided to fine tune the individual clock requirements.

See the *MSP430x5xx/MSP430x6xx Family User's Guide* (SLAU208) for UCS details.

4 To Change the System Clock and Similar Settings

The Power Management Module (PMM), Unified Clock System (UCS), Port Map (PMAP), and Flash modules are flexible peripherals that require initialization within many applications. The MSP430F5xx and MSP430F6xx Core Library provide functions that implement the most common operations using the PMM, UCS, PMAP, and Flash modules, such as changing the core voltage to operate at higher frequencies, crystal/clock initialization, mapping port I/O, and write/erase flash operations. It is strongly recommended to use the core library calls to change UCS and PMM settings.

The core library files are available in this sample project in the \Software\EvalBoards\TI\MSP-EXP430F5438\IAR\BSP\F5xx_F6xx_Core_Lib folder.

For details on the core library, see the application report *MSP430F5xx and MSP430F6xx Core Libraries* (SLAA448).

5 Memory Requirements for µC/OS-II on MSP430

The sample "Low Memory Overhead" project demonstrates that µC/OS-II can run on MSP430 with minimal overhead. The application blinks two LEDs on the MSP-EXP430F5438 board, each controlled by its own task.

IAR version 5.20.1 was used to develop this project. The optimization level chosen is High [Balanced].

The memory usage details of this application are shown in Figure 2.

```
2 854 bytes of CODE  memory
1 731 bytes of DATA  memory (+ 44 absolute )
  290 bytes of CONST memory


          ******************************************
          *                                        *
          *            MODULE SUMMARY              *
          *                                        *
          ******************************************

Module               CODE      DATA       CONST
------               ----      ----       -----
                    (Rel)  (Rel)  (Abs)   (Rel)
?DivMod32u             68
?Mul32Hw32Loc2         34
?OneBitMask32          34
?__dbg_break            2
?__exit                22
?_exit                  4
?cstart                28
?exit                   4
?memzero               24
?reset_vector           2
app                   188    744            14
  + shared                           4
bsp                    22            4
hal_board              88           36
os_core             1 060    823           272
os_cpu_a              208
  + common            118
os_cpu_c              270      4
os_dbg                  2
os_flag                92                    2
os_mem                 84                    2
os_task               280
os_time               220
N/A (command line)            160
N/A (alignment)
----------           -----  -----    --    ---
Total:              2 736  1 731    44    290
  + common            118
```

Figure 2. Excerpt From Map File

6   New Values to OS Configuration Constants for This Application

Table 1 shows the new configuration constants that are used in the default sample application.

Table 1. Configuration Constants

Configuration Constant	Value	What the Constant Means
OS_LOWEST_PRIO	4	Defines the lowest priority that can be assigned
OS_MAX_QS	0	Maximum number of queue control blocks in your application
OS_MAX_TASKS	4	Maximum number of tasks in your application, MUST be ≥ 2
OS_Q_EN	0	Enable (1) or Disable (0) code generation for QUEUES
OS_MAX_EVENTS	1	Maximum number of event control blocks in your application
OS_MBOX_EN	0	Enable (1) or Disable (0) code generation for MAILBOXES
OS_MUTEX_EN	0	Enable (1) or Disable (0) code generation for MUTEX
OS_SEM_EN	0	Enable (1) or Disable (0) code generation for SEMAPHORES
OS_MAX_MEM_PART	3	Maximum number of memory partitions

If the application is modified to change the operation or to add additional tasks, the above constants should be increased according to the new requirements. It is advisable to increase these constants to reasonable values so that RAM use is kept optimal.

See the µC/OS-II Configuration Manual available in the \Software\uCOS-II\Doc folder for details about these constants.

7   Adding a New Task to The Sample Application

The sample application currently contains two tasks – AppTask1 and AppTask2. The tasks are created in app.c. This code may be used as a template for creating additional tasks to expand this sample application.

Adding a new task to this sample application involves the following steps.

1. Increase OS_MAX_TASKS by 1 for every additional task

2. Increase OS_LOWEST_PRIORITY by at least 1. Every task must have a different priority value. However this constant may be increased based on any priority required for the task.

3. If the new task uses a semaphore, mutex, queue or mailbox, set or enable OS_SEM_EN, OS_MUTEX_EN, OS_Q_EN or OS_MBOX_EN and OS_MAX_EVENTS as needed.

4. OS_MAX_MEM_PART may also be changed as needed

See the µC/OS-II Configuration Manual available in the \Software\uCOS-II\Doc folder for details about these constants.

8   Using MSP430 Ultralow-Power Options on μC/OS-II

When the OS is not busy doing application task and is blocked or waiting on an event, it is highly recommended to use the MSP430 low-power options to take the system to one of the low-power modes to conserve power. The designer must decide which low-power mode best suits the application.

Example 1 shows one way to enter a low-power mode.

Example 1. Entering LPM

```
/***************************************************************************
IDLE TASK HOOK
*
* Description: This function is called by the idle task.  This hook has been
* added to allow you to do such things as STOP the CPU to conserve power.
*
* Arguments: none
*
* Note(s): 1) Interrupts are enabled during this call.
*************************************************************************/
#if OS_CPU_HOOKS_EN > 0 && OS_VERSION >= 251
void  OSTaskIdleHook (void)
{
#if 1
    // Enter low power mode
    // Enable interrupts, enter LPM0
      __bis_SR_register(LPM0_bits + GIE);
      __no_operation();
#endif
}
```

After the microcontroller enters the low-power mode, it stays in the LPM until the tick timer or any application/peripheral enabled interrupts wakes it up.

In the sample application, the Watchdog Timer is configured to act as the tick timer. The tick timer interval and timer source may be modified to meet application requirements.

9   Low-Power Modes

The following operating modes that the software can configure are available on the MSP430F5438A.

- Active mode (AM): SCG1 = 0, SCG0 = 0, OSCOFF = 0, CPUOFF = 0
    - CPU, MCLK are active.
    - ACLK is active. SMCLK optionally active (SMCLKOFF = 0).
    - DCO is enabled if sources ACLK, MCLK, or SMCLK (SMCLKOFF = 0).
    - DCO bias is enabled if DCO is enabled or DCO sources MCLK or SMCLK (SMCLKOFF = 0).
    - FLL is enabled if DCO is enabled
- Low-power mode 0 (LPM0): SCG1 = 0, SCG0 = 0, OSCOFF = 0, CPUOFF = 1
    - CPU, MCLK are disabled
    - ACLK is active. SMCLK optionally active (SMCLKOFF = 0).
    - DCO is enabled if sources ACLK or SMCLK (SMCLKOFF = 0).
    - DCO bias is enabled if DCO is enabled or DCO sources MCLK or SMCLK (SMCLKOFF = 0).
    - FLL is enabled if DCO is enabled.
- Low-power mode 1 (LPM1): SCG1 = 0, SCG0 = 1, OSCOFF = 0, CPUOFF = 1
    - CPU, MCLK are disabled
    - ACLK is active. SMCLK optionally active (SMCLKOFF = 0).
    - DCO is enabled if sources ACLK or SMCLK (SMCLKOFF = 0).
    - DCO bias is enabled if DCO is enabled or DCO sources MCLK or SMCLK (SMCLKOFF = 0).
    - FLL is disabled
- Low-power mode 2 (LPM2): SCG1 = 1, SCG0 = 0, OSCOFF = 0, CPUOFF = 1
    - CPU, MCLK are disabled.
    - ACLK is active. SMCLK is disabled.
    - DCO is enabled if sources ACLK.
    - FLL is disabled
- Low-power mode 3 (LPM3): SCG1 = 1, SCG0 = 1, OSCOFF = 0, CPUOFF = 1
    - CPU, MCLK are disabled
    - ACLK is active. SMCLK is disabled
    - DCO is enabled if sources ACLK
    - FLL is disabled

A peripheral module requests its clock sources automatically from the UCS module if the clock is required for the module's proper operation, regardless of the device's current mode of operation. For example, if a timer selects ACLK as its clock source and the timer is enabled, the timer generates an ACLK_REQ signal to the UCS system. The UCS, in turn, enables ACLK regardless of the LPM settings. Any clock request from a peripheral module causes its respective clock off signal to be overridden.

Because the RTOS always requires a clock for timer tick, low-power modes beyond LPM3 are not possible.

10   References

1. http://micrium.com/page/home
2. *MSP430x5xx/MSP430x6xx Family User's Guide* (SLAU208)
3. *MSP430F5xx/MSP430F6xx Core Libraries* (SLAA448)
4. http://msp430.com
5. AN-TI-MSP430F5438.pdf (http://micrium.com/page/home as part of MSP430 port download)
6. Example Project (µC/OS-II (Small Footprint)) (http://micrium.com/page/downloads/ports/ti/msp430)

11 Licensing

µC/OS-II is a source-available real-time kernel; it is not open source. Under the source-available model, which Micriµm pioneered, the kernel's full source code can be evaluated at no cost. This code can also be used free of charge in academic projects. Developers planning to use the code to develop a product, however, must purchase a license. Additional licensing information can be obtained from Micriµm; contact information is provided below.

12 Micriµm Contact Information

Phone: +1 954 217 2036

Fax: +1 954 217 2037

E-Mail: sales@micrium.com

URL: http://www.micrium.com

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