ABSTRACT
This application report demonstrates the use of the Micrium \( \mu \)C/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 \( \mu \)C/OS-II to optimize a project are included. This report also explains how to effectively use MSP430 ultralow-power modes with \( \mu \)C/OS-II projects.

Sample application source code and other collateral can be downloaded from the \( \mu \)C/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).

![Select a Different Device](image)

Figure 1. Select a Different Device

2. Modify hal_board.h to reflect the new LED port settings.

3. It is highly recommended 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.
Memory Requirements for \( \mu \)C/OS-II on MSP430

---

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

---

Figure 2. Excerpt From Map File

<table>
<thead>
<tr>
<th>Module</th>
<th>CODE (Rel)</th>
<th>DATA (Rel)</th>
<th>CONST (Abs)</th>
<th>CONST (Rel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>?DivMod32u</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>?Mul32Hw32Loc2</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>?OneBitMask32</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_dbg_break</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>__exit</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_exit</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cstart</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exit</td>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>memzero</td>
<td>24</td>
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<td></td>
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<tr>
<td>reset_vector</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>app</td>
<td>188</td>
<td>744</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>+ shared</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bsp</td>
<td>22</td>
<td></td>
<td>4</td>
<td></td>
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<tr>
<td>hal_board</td>
<td>88</td>
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<td>36</td>
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<tr>
<td>os_core</td>
<td>1 060</td>
<td>823</td>
<td>272</td>
<td></td>
</tr>
<tr>
<td>os_cpu_a</td>
<td>208</td>
<td></td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>+ common</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>os_cpu_c</td>
<td>270</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>os_dbg</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>os_flag</td>
<td>92</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>os_mem</td>
<td>84</td>
<td></td>
<td>2</td>
<td></td>
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<tr>
<td>os_task</td>
<td>280</td>
<td></td>
<td></td>
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<tr>
<td>os_time</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A (command line)</td>
<td></td>
<td></td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>N/A (alignment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>2 736</td>
<td>1 731</td>
<td>44</td>
<td>290</td>
</tr>
<tr>
<td>+ common</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Configuration Constant</th>
<th>Value</th>
<th>What the Constant Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS_LOWEST_PRIO</td>
<td>4</td>
<td>Defines the lowest priority that can be assigned</td>
</tr>
<tr>
<td>OS_MAX_QS</td>
<td>0</td>
<td>Maximum number of queue control blocks in your application</td>
</tr>
<tr>
<td>OS_MAX_TASKS</td>
<td>4</td>
<td>Maximum number of tasks in your application, MUST be ≥ 2</td>
</tr>
<tr>
<td>OS_Q_EN</td>
<td>0</td>
<td>Enable (1) or Disable (0) code generation for QUEUES</td>
</tr>
<tr>
<td>OS_MAX_EVENTS</td>
<td>1</td>
<td>Maximum number of event control blocks in your application</td>
</tr>
<tr>
<td>OS_MBOX_EN</td>
<td>0</td>
<td>Enable (1) or Disable (0) code generation for MAILBOXES</td>
</tr>
<tr>
<td>OS_MUTEX_EN</td>
<td>0</td>
<td>Enable (1) or Disable (0) code generation for MUTEX</td>
</tr>
<tr>
<td>OS_SEM_EN</td>
<td>0</td>
<td>Enable (1) or Disable (0) code generation for SEMAPHORES</td>
</tr>
<tr>
<td>OS_MAX_MEM_PART</td>
<td>3</td>
<td>Maximum number of memory partitions</td>
</tr>
</tbody>
</table>

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

```c
/**********************************************************
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 disabled 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 is disabled.
  - DCO is enabled if sources ACLK.
  - 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

4. [http://msp430.com](http://msp430.com)
5. AN-TI-MSP430F5438.pdf ([http://micrium.com/page/home](http://micrium.com/page/home) as part of MSP430 port download)
Licensing

μC/OS-II is a source-available real-time kernel; it is not open source. Under the source-available model, which Micrium 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 Micrium; contact information is provided below.

12 Micrium Contact Information

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<td>OMAP Mobile Processors</td>
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<tr>
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