

# Optimizing Memory on MSP430 for $\mu$ C/OS-II

Kasthuri Annamalai

MSP430 Applications

## 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>.

## Contents

1	Details of the Sample Application .....	2
2	To Modify This Application for Other MSP430F5xx/6xx Devices .....	2
3	Clock System .....	3
4	To Change the System Clock and Similar Settings .....	3
5	Memory Requirements for $\mu$ C/OS-II on MSP430 .....	3
6	New Values to OS Configuration Constants for This Application .....	5
7	Adding a New Task to The Sample Application .....	5
8	Using MSP430 Ultralow-Power Options on $\mu$ C/OS-II .....	6
9	Low-Power Modes .....	7
10	References .....	7
11	Licensing .....	8
12	Micrium Contact Information .....	8

## List of Figures

1	Select a Different Device.....	2
2	Excerpt From Map File .....	4

## List of Tables

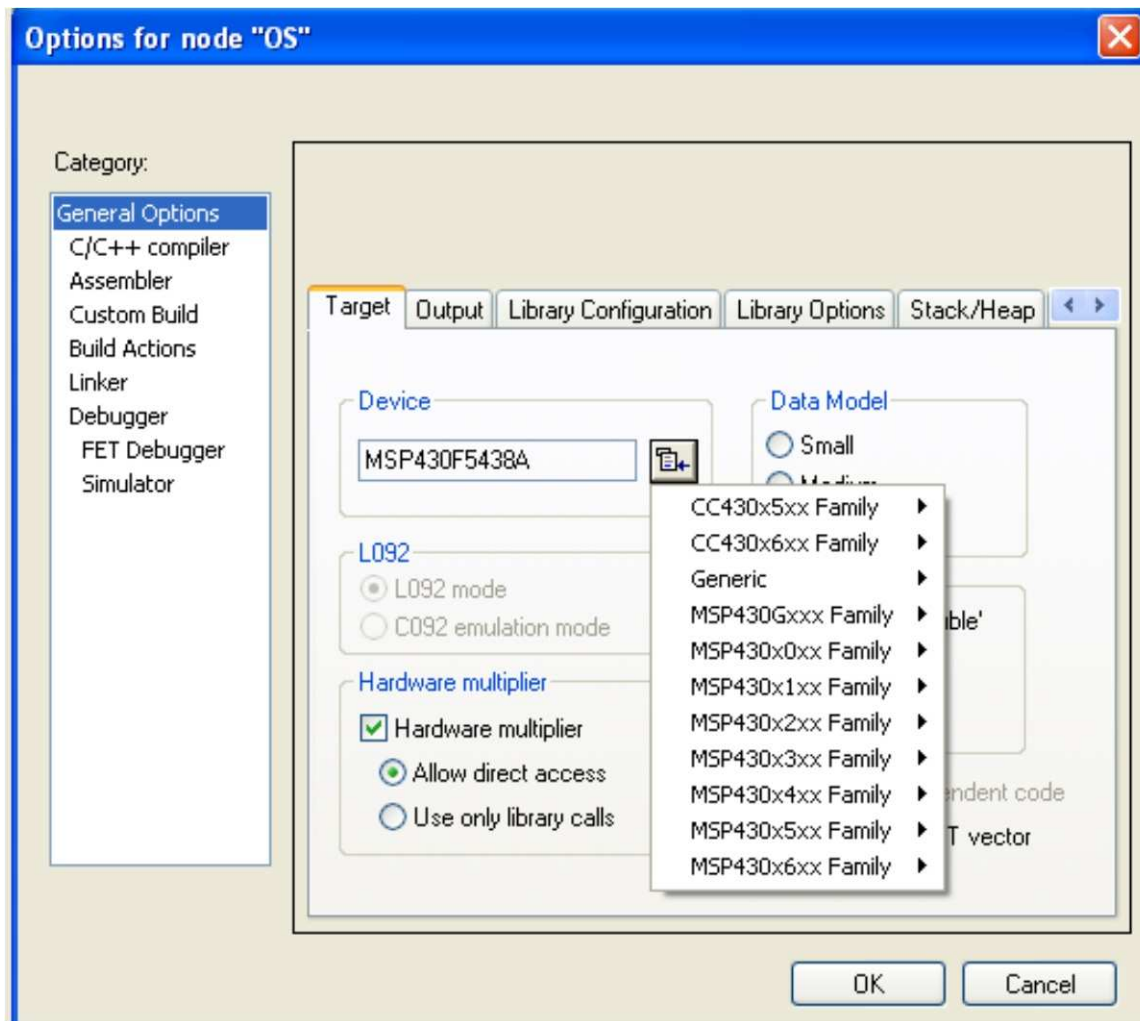
1	Configuration Constants .....	5
---	-------------------------------	---

## 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 $\mu$ C/OS-II on MSP430

The sample "Low Memory Overhead" project demonstrates that  $\mu$ C/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 $\geq 2$
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  $\mu$ C/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  $\mu$ C/OS-II Configuration Manual available in the \Software\uCOS-II\Doc folder for details about these constants.

## 8 Using MSP430 Ultralow-Power Options on $\mu$ C/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 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

Phone: +1 954 217 2036

Fax: +1 954 217 2037

E-Mail: [sales@micrium.com](mailto:sales@micrium.com)

URL: <http://www.micrium.com>



## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Transportation and Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

TI E2E Community Home Page

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011, Texas Instruments Incorporated