Detecting and Avoiding Stack Overflow in IoT/Embedded Systems

ThreadX RTOS users have five powerful tools that are able to help embedded applications avoid this system-crippling problem

One of the toughest (and unfortunately common) problems in embedded systems is stack overflow and the collateral corruption or crash that it can cause. Often, the consequences of a stack overflow manifest themselves far removed from the cause of the overflow itself, making the cause that much more difficult to identify and fix. As a result, we have spent considerable effort inventing creative ways our customers can deal with this potential problem. ThreadX developers have an array of tools at their disposal to detect and even avoid stack overflow problems. These tools and techniques not only help developers avoid stack overflow due to inadequate stack memory allocation, they also help minimize RAM wasted by allocating excessive memory for thread stacks "just to be safe." The following tools and techniques are discussed in this white paper:

- Manual stack inspection
- Kernel awareness and ThreadX stack analysis
- ThreadX run-time stack analysis
- IAR EWARM stack usage analysis
- TraceX stack analysis

Overview

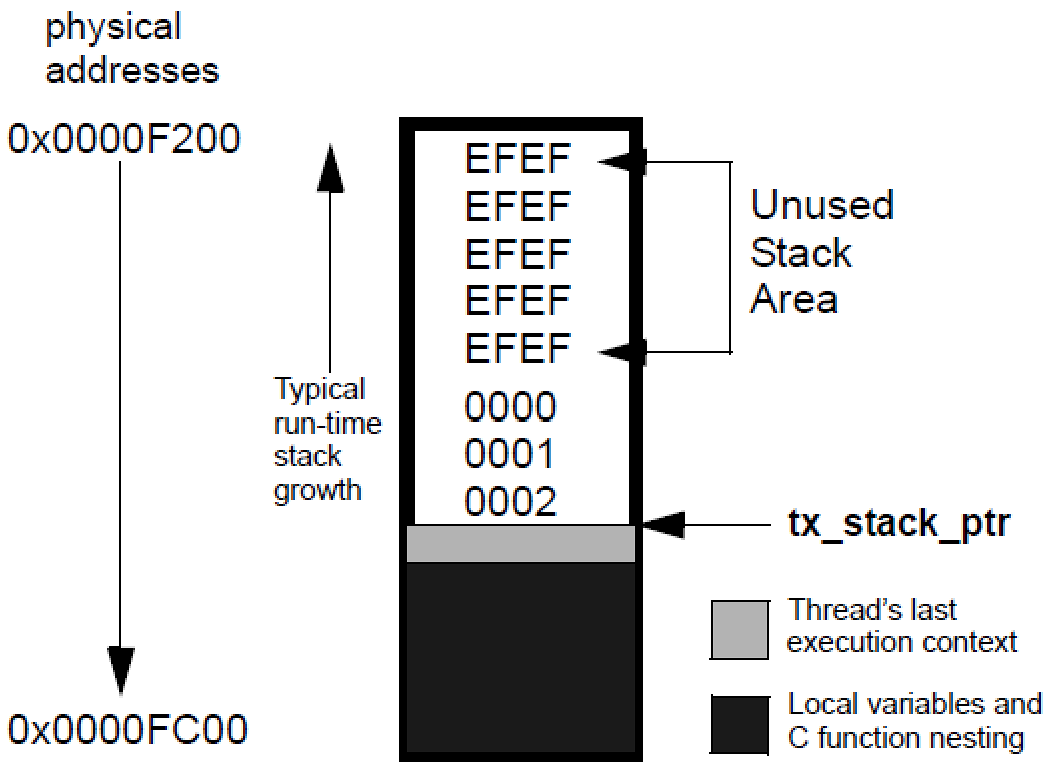
In the C programming language, the stack—a region of memory in which local variables are located and function arguments are passed—is allocated by the programmer, with the amount of memory allocated based on factors such as machine architecture, OS, application design, and amount of memory available. If the program should require more memory for its stack than has been allocated, the stack overflows—without warning in most cases—which can corrupt other memory areas and often results in a program malfunction or even a crash. Such problems are very difficult to trace back to the stack overflow, causing programmers to expend considerable time and energy to find the underlying cause of the problem that the application exhibits. As a result, they tend to over-allocate stack memory as a precaution, “just to be safe.”

Traditionally, deciding how much memory to allocate for the stack has been a trial and error process. As widely respected industry commentator and consultant, Jack Ganssle, has observed:

"*With experience, one learns the standard, scientific way to compute the proper size for a stack: Pick a size at random and hope*." -- Jack Ganssle, “The Art of Designing Embedded Systems,” Elsevier, 1999.

In an RTOS, there is a separate stack for each thread, and each thread might have drastically different stack size needs. Making things even more challenging, stack overflows often affect a somewhat unrelated memory area – global variables, allocated memory, or another thread's stack – and thus the subsequent problem does not manifest itself until much later than when the overflow occurred.

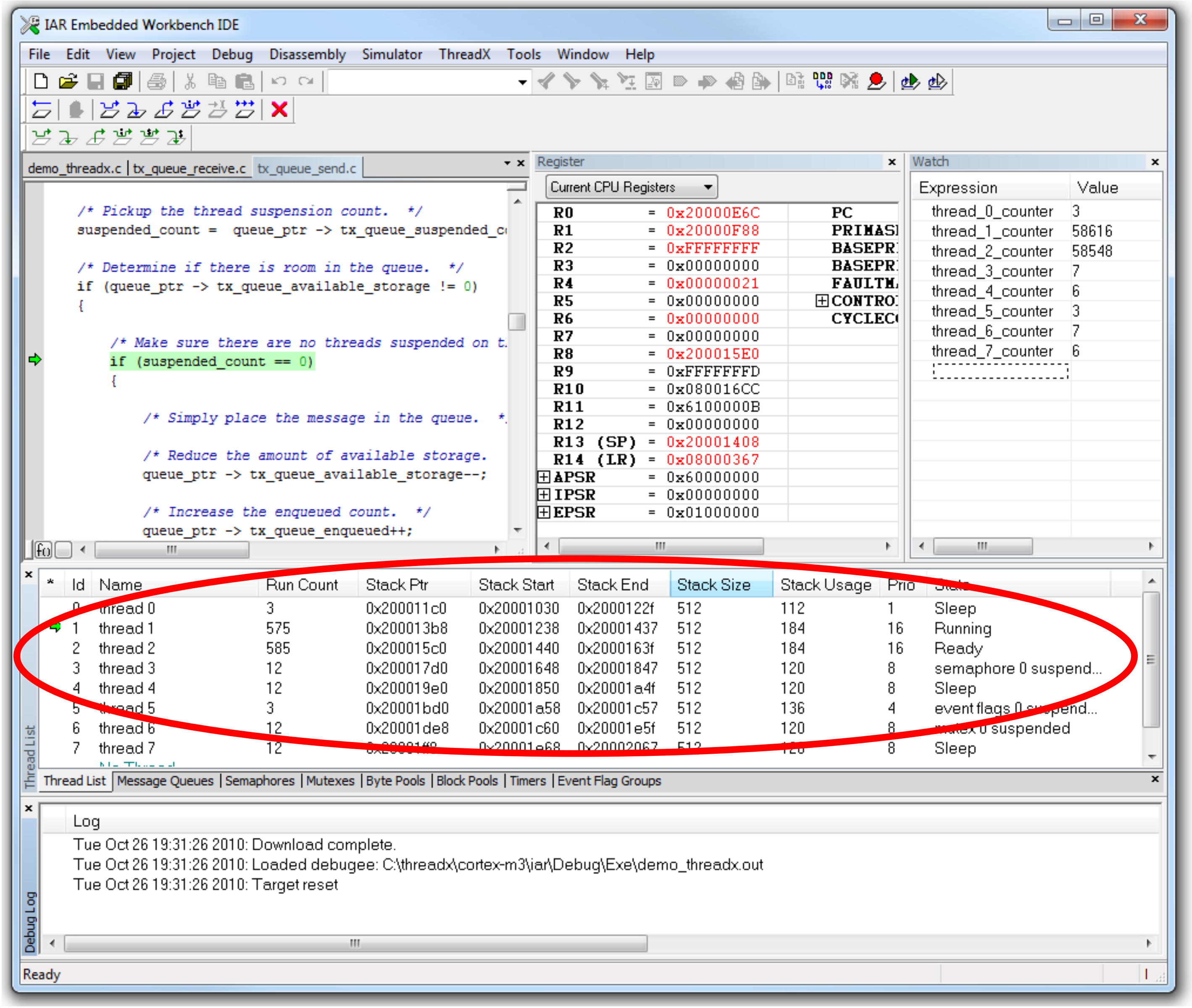
Manual Stack Inspection
The most obvious and basic technique to prevent stack overflows is to manually inspect the stack memory region and stack pointers for potential overflow. To facilitate this, ThreadX places a 0xEF data pattern throughout each thread's stack. The idea here is to run the thread through its validation tests and then review all of the thread stacks. The non-0xEF byte closest to the start of the stack represents the high-water mark of that thread's stack usage. Of course, if there are no remaining 0xEF data patterns in a thread's stack, there is a high-probability that a stack overflow has occurred. The following figure shows an example thread stack with the 0xEF data pattern:



In addition to detection of stack overflow, manual stack inspection can be used to tune the stack size. For example, if a large area of unused stack space is found, it may indicate that the size for that thread's stack is excessive. Of course, this analysis assumes that the test suite is exercising the worst case call tree depth for each thread. Note also that every thread stack must always have a minimum amount of unused memory in order to save its context if an interrupt occurs at the highest point of stack used. The exact amount needed varies by architecture, but is defined in each ThreadX port's ***readme_threadx.txt*** file.

ThreadX Kernel Awareness and Stack Analysis

Most major embedded development tools provide what is called ThreadX kernel awareness. Such awareness provides a single-click, system level view of ThreadX resources. Most of the ThreadX-aware debuggers also provide thread stack analysis, which effectively automates the manual inspection technique described above. The following screen shot shows an example of IAR's Embedded Workbench for ARM (EWARM), with its ThreadX kernel awareness for a Cortex-M3 target. Specifically, this illustration shows the information related to the "thread" object:


IAR Embedded Workbench IDE
File Edit View Project Debug Disassembly Simulator ThreadX Tools Window Help
demo_threadx.c | tx_queue_receive.c | tx_queue_send.c
Register
Current CPU Registers
Watch
Thread List | Message Queues | Semaphores | Mutexes | Byte Pools | Block Pools | Timers | Event Flag Groups
Debug Log
Ready

```
    /* Pickup the thread suspension count.  */
    suspended_count =  queue_ptr -> tx_queue_suspended_c

    /* Determine if there is room in the queue.  */
    if (queue_ptr -> tx_queue_available_storage != 0)
    {

        /* Make sure there are no threads suspended on t
        if (suspended_count == 0)
        {

            /* Simply place the message in the queue.  *

            /* Reduce the amount of available storage.
            queue_ptr -> tx_queue_available_storage--;

            /* Increase the enqueued count.  */
            queue_ptr -> tx_queue_enqueued++;
```

```
R0        = 0x20000E6C      PC
R1        = 0x20000F88      PRIMASI
R2        = 0xFFFFFFFF      BASEPR
R3        = 0x00000000      BASEPR
R4        = 0x00000021      FAULTM
R5        = 0x00000000     ⊞CONTRO
R6        = 0x00000000      CYCLEC
R7        = 0x00000000
R8        = 0x200015E0
R9        = 0xFFFFFFFD
R10       = 0x080016CC
R11       = 0x6100000B
R12       = 0x00000000
R13 (SP)  = 0x20001408
R14 (LR)  = 0x08000367
⊞APSR     = 0x60000000
⊞IPSR     = 0x00000000
⊞EPSR     = 0x01000000
```

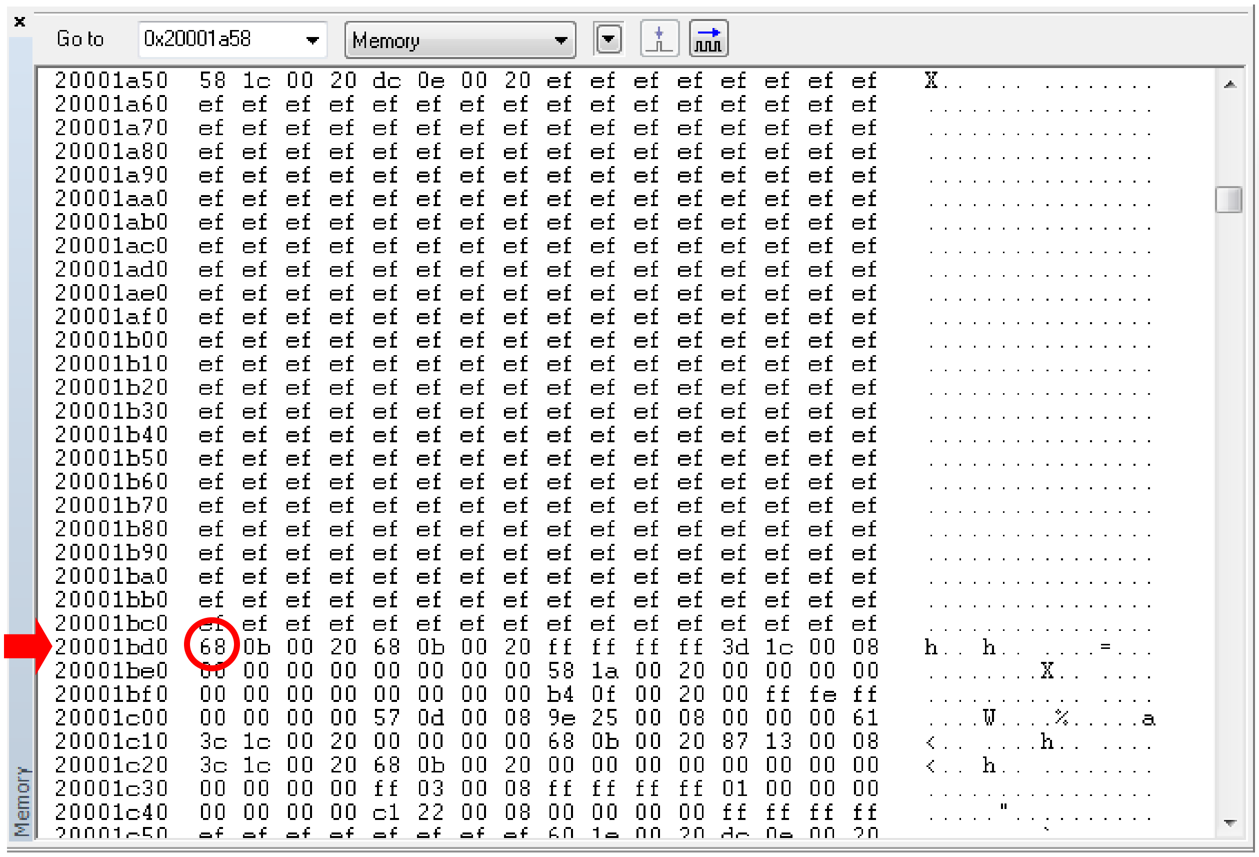
Expression	Value
thread_0_counter	3
thread_1_counter	58616
thread_2_counter	58548
thread_3_counter	7
thread_4_counter	6
thread_5_counter	3
thread_6_counter	7
thread_7_counter	6

*	Id	Name	Run Count	Stack Ptr	Stack Start	Stack End	Stack Size	Stack Usage	Prio	State
	0	thread 0	3	0x200011c0	0x20001030	0x2000122f	512	112	1	Sleep
	1	thread 1	575	0x200013b8	0x20001238	0x20001437	512	184	16	Running
	2	thread 2	585	0x200015c0	0x20001440	0x2000163f	512	184	16	Ready
	3	thread 3	12	0x200017d0	0x20001648	0x20001847	512	120	8	semaphore 0 suspend...
	4	thread 4	12	0x200019e0	0x20001850	0x20001a4f	512	120	8	Sleep
	5	thread 5	3	0x20001bd0	0x20001a58	0x20001c57	512	136	4	event flags 0 suspend...
	6	thread 6	12	0x20001de8	0x20001c60	0x20001e5f	512	120	8	mutex 0 suspended
	7	thread 7	12	[illegible]	0x20001e68	0x20002067	512	120	8	Sleep

```
Log
Tue Oct 26 19:31:26 2010: Download complete.
Tue Oct 26 19:31:26 2010: Loaded debugee: C:\threadx\cortex-m3\iar\Debug\Exe\demo_threadx.out
Tue Oct 26 19:31:26 2010: Target reset
```

The key column is the ***Stack Usage*** column. The difference between the ***Stack Size*** and the ***Stack Usage*** column yields the remaining stack size. For example, in the example shown ***thread 5*** has a stack size of 512 bytes, while its current usage is 136 bytes. This means that there are 376 free bytes on ***thread 5***'s stack.

This information is obtained by the debugger automatically examining the thread's stack memory for the 0xEF data pattern. The stack memory for ***thread 5*** ranges from address 0x20001a58 through 0x20001c57. The figure below shows the memory dump of this stack area:



```
20001a50  58 1c 00 20 dc 0e 00 20 ef ef ef ef ef ef ef ef   X...............
20001a60  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001a70  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001a80  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001a90  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001aa0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001ab0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001ac0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001ad0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001ae0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001af0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b00  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b10  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b20  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b30  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b40  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b50  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b60  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b70  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b80  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001b90  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001ba0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001bb0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001bc0  ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef ef   ................
20001bd0  68 0b 00 20 68 0b 00 20 ff ff ff ff 3d 1c 00 08   h...h.......=...
20001be0  00 00 00 00 00 00 00 00 58 1a 00 20 00 00 00 00   ........X.......
20001bf0  00 00 00 00 00 00 00 00 b4 0f 00 20 00 ff fe ff   ................
20001c00  00 00 00 00 57 0d 00 08 9e 25 00 08 00 00 00 61   ....W...%......a
20001c10  3c 1c 00 20 00 00 00 00 68 0b 00 20 87 13 00 08   <.......h.......
20001c20  3c 1c 00 20 68 0b 00 20 00 00 00 00 00 00 00 00   <...h...........
20001c30  00 00 00 00 ff 03 00 08 ff ff ff ff 01 00 00 00   ................
20001c40  00 00 00 00 c1 22 00 08 00 00 00 00 ff ff ff ff   ....."..........
20001c50  ef ef ef ef ef ef ef ef 60 1e 00 20 dc 0e 00 20
```

Manual inspection of the thread's stack memory area shows that the lowest address not having the 0xEF data pattern is 0x20001bd0. Subtracting this from the ending stack address of 0x20001c57 yields the reported used stack size of 136 bytes. Of course, the IAR debugger takes care of all this manual work, providing this valuable information via a simple mouse click.

ThreadX Run-time Stack Checking

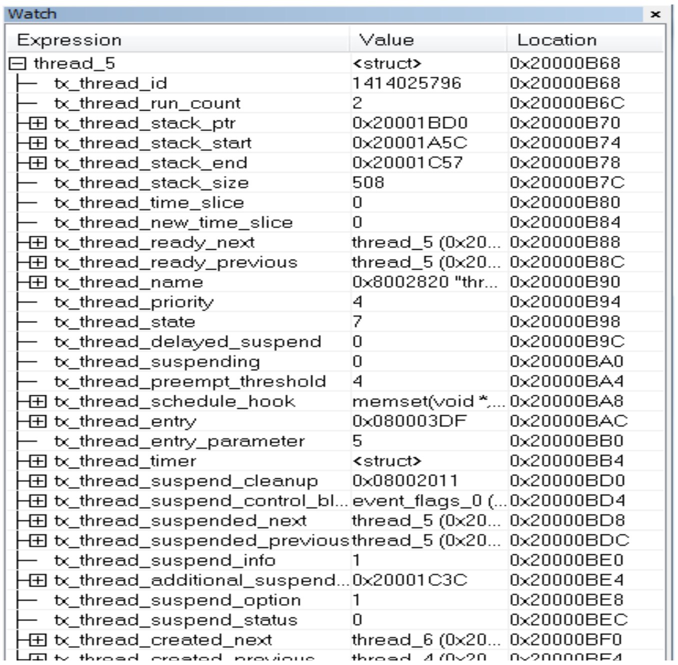
The automated debugger stack checking is a powerful feature, but it does have some shortcomings. One such shortcoming is that the stack overflow detection is still made by the developer. If the developer doesn't see the overflow, the problem may go undetected. Also, there is no mechanism to stop the system immediately when the overflow occurs. This is where ThreadX run-time stack checking comes into play.

By default, the run-time stack checking in ThreadX is disabled. To enable run-time stack checking, simply build the ThreadX library with ***TX_ENABLE_STACK_CHECKING*** defined. With stack checking enabled, ThreadX examines the stack of every thread being scheduled prior to execution. In addition, every suspending thread's stack is analyzed. If an overflow condition exists, ThreadX immediately calls the internal ThreadX default stack error handler ***_tx_thread_stack_error_handler***.

Alternatively, the application may register its own stack error handler by supplying a callback function to ***tx_thread_stack_error_notify***.

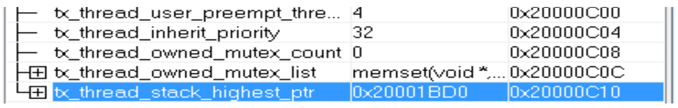
In addition to detecting overflow conditions, ThreadX run-time stack checking keeps track of the high water mark of stack usage. This address subtracted from the ending address yields the amount of stack spaced used. The following figure shows the thread control block for thread 5. The last structure member (named ***tx_thread_stack_highest_ptr***) contains the highest used address of the thread's stack. In this example, it matches the same value derived by the IAR kernel awareness.

The principal advantage of ThreadX run-time stack checking is that overflow detection occurs closer to the point where the overflow occurred and it does not rely on a developer spotting the overflow condition. It also provides the high water mark so that stack size tuning is possible. Finally, there are some environments that simply don't have automated debugger stack analysis, making ThreadX run-time checking the only option.



Expression	Value	Location
thread_5	<struct>	0x20000B68
tx_thread_id	1414025796	0x20000B68
tx_thread_run_count	2	0x20000B6C
tx_thread_stack_ptr	0x20001BD0	0x20000B70
tx_thread_stack_start	0x20001A5C	0x20000B74
tx_thread_stack_end	0x20001C57	0x20000B78
tx_thread_stack_size	508	0x20000B7C
tx_thread_time_slice	0	0x20000B80
tx_thread_new_time_slice	0	0x20000B84
tx_thread_ready_next	thread_5 (0x20...	0x20000B88
tx_thread_ready_previous	thread_5 (0x20...	0x20000B8C
tx_thread_name	0x8002820 "thr...	0x20000B90
tx_thread_priority	4	0x20000B94
tx_thread_state	7	0x20000B98
tx_thread_delayed_suspend	0	0x20000B9C
tx_thread_suspending	0	0x20000BA0
tx_thread_preempt_threshold	4	0x20000BA4
tx_thread_schedule_hook	memset(void *,...	0x20000BA8
tx_thread_entry	0x080003DF	0x20000BAC
tx_thread_entry_parameter	5	0x20000BB0
tx_thread_timer	<struct>	0x20000BB4
tx_thread_suspend_cleanup	0x08002011	0x20000BD0
tx_thread_suspend_control_bl...	event_flags_0 (...	0x20000BD4
tx_thread_suspended_next	thread_5 (0x20...	0x20000BD8
tx_thread_suspended_previous	thread_5 (0x20...	0x20000BDC
tx_thread_suspend_info	1	0x20000BE0
tx_thread_additional_suspend...	0x20001C3C	0x20000BE4
tx_thread_suspend_option	1	0x20000BE8
tx_thread_suspend_status	0	0x20000BEC
tx_thread_created_next	thread_6 (0x20...	0x20000BF0
tx_thread_created_previous	thread_4 (0x20	0x20000BF4

Thread Control Block for thread_5



Expression	Value	Location
tx_thread_user_preempt_thre...	4	0x20000C00
tx_thread_inherit_priority	32	0x20000C04
tx_thread_owned_mutex_count	0	0x20000C08
tx_thread_owned_mutex_list	memset(void *,...	0x20000C0C
tx_thread_stack_highest_ptr	0x20001BD0	0x20000C10

IAR EWARM Stack Usage Analysis
Another useful tool for determining proper stack memory use and allocation is IAR EWARM's Stack Usage Analysis. Under the right circumstances, the IAR EWARM linker can accurately calculate the maximum stack usage for each call graph, starting from the program start, interrupt functions, tasks etc. (each function that is not called from another function, in other words, a root). If you enable stack usage analysis, a stack usage chapter will be added to the linker map file, listing for each call graph root the particular call chain which results in the maximum stack depth.

In general, the compiler will generate this information for each C function, but if there are indirect calls (calls using function pointers) in your application, you must supply a list of possible functions that can be called from each calling function. If you use a stack usage control file, you can also supply stack usage information for functions in modules that do not have stack usage information.

Result of an Analysis—The Map File Contents
When stack usage analysis is enabled, the linker map file contains a stack usage chapter with a summary of the stack usage for each call graph root category, and lists the call chain that results in the maximum stack depth for each call graph root. This is an example of what the stack usage chapter in the map file might look like:

```
*** STACK USAGE ***
Call Graph Root Category      Max Use     Total Use
------------------------      -------     ---------
interrupt                     104         136
Program entry                 168         168

Program entry
  "__iar_program_start": 0x000085ac
  Maximum call chain                      168 bytes

        "__iar_program_start"             0
        "__cmain"                         0
        "main"                            8
        "printf"                          24
        "_PrintfTiny"                     56
        "_Prout"                          16
        "putchar"                         16
        "__write"                         0
        "__dwrite"                        0
        "__iar_sh_stdout"                 24
        "__iar_get_ttio"                  24
        "__iar_lookup_ttioh"              0

interrupt
  "FaultHandler": 0x00008434
  Maximum call chain                      32 bytes
    "FaultHandler"                        32

interrupt
  "IRQHandler": 0x00008424
  Maximum call chain                      104 bytes

    "IRQHandler"                          24
    "do_something" in suexample.o [1]     80
```

The summary contains the depth of the deepest call chain in each category as well as the sum of the depths of the deepest call chains in that category. Each call graph root belongs to a call graph root category to enable convenient calculations in check that directives.

Call Graph Log

To help you interpret the results of the stack usage analysis, there is a log output option that produces a simple text representation of the call graph (--log call_graph).

Example output:

```
Program entry:
0 __iar_program_start [168]
  0 __cmain [168]
    0 __iar_data_init3 [16]
      8 __iar_zero_init3 [8]
        16 - [0]
      8 __iar_copy_init3 [8]
        16 - [0]
    0 __low_level_init [0]
    0 main [168]
      8 printf [160]
        32 _PrintfTiny [136]
          88 _Prout [80]
            104 putchar [64]
              120 __write [48]
                120 __dwrite [48]
                  120 __iar_sh_stdout [48]
                    144 __iar_get_ttio [24]
                      168 __iar_lookup_ttioh [0]
                  120 __iar_sh_write [24]
                    144 - [0]
          88 __aeabi_uidiv [0]
            88 __aeabi_idiv0 [0]
          88 strlen [0]
    0 exit [8]
      0 _exit [8]
        0 __exit [8]
          0 __iar_close_ttio [8]
            8 __iar_lookup_ttioh [0] ***
    0 __exit [8] ***
```

Each line consists of the following information:

- The stack usage at the point of call of the function
- The name of the function, or a single '-' to indicate usage in a function at a point with no function call (typically in a leaf function)
- The stack usage along the deepest call chain from that point. If no such value could be calculated, "[---]" is output instead. "***" marks functions that have already been shown.

ThreadX Stack Usage Analysis

Here is a linker map chapter for Stack Usage Anaylsis performed on the ThreadX standard demo application, “demo_threadx”

```
*** STACK USAGE ***
```

```
  Call Graph Root Category  Max Use  Total Use
  ------------------------  -------  ---------
  Program entry                300        300
  thread                       276      1 544
  Uncalled function            260        264


Program entry
  "__iar_program_start": 0x000029cd

  Maximum call chain                                 300  bytes

    "__iar_program_start"                              0
    "__cmain"                                          0
    "main"                                             8
    "_tx_initialize_kernel_enter"                      8
    "tx_application_define"                           32
    "_tx_byte_allocate"                               32
    "_tx_thread_system_suspend"                       16
    "_tx_thread_system_return"                       204

thread
  "thread_0_entry": 0x00000655

  Maximum call chain                                 260  bytes

    "thread_0_entry"                                   8
    "_tx_event_flags_set"                             40
    "_tx_thread_system_preempt_check"                  8
    "_tx_thread_system_return"                       204


thread
  "thread_1_entry": 0x00000679

  Maximum call chain                                 252  bytes

    "thread_1_entry"                                   8
    "_tx_queue_send"                                  24
    "_tx_thread_system_suspend"                       16
    "_tx_thread_system_return"                       204

thread
  "thread_2_entry": 0x000006a5

  Maximum call chain                                 252  bytes

    "thread_2_entry"                                   8
    "_tx_queue_receive"                               24
    "_tx_thread_system_suspend"                       16
    "_tx_thread_system_return"                     204

thread
  "thread_3_and_4_entry": 0x000006d9

  Maximum call chain                               244  bytes

    "thread_3_and_4_entry"                           8
    "_tx_semaphore_get"                             16
    "_tx_thread_system_suspend"                     16
    "_tx_thread_system_return"                     204

thread
  "thread_5_entry": 0x00000719

  Maximum call chain                               260  bytes

    "thread_5_entry"                                16
    "_tx_event_flags_get"                           24
    "_tx_thread_system_suspend"                     16
    "_tx_thread_system_return"                     204

thread
  "thread_6_and_7_entry": 0x00000745

  Maximum call chain                               276  bytes

    "thread_6_and_7_entry"                           8
    "_tx_mutex_put"                                 24
    "_tx_mutex_priority_change"                     24
    "_tx_thread_system_suspend"                     16
    "_tx_thread_system_return"                     204

Uncalled function
  "SysTick_Handler": 0x00001929

  Maximum call chain                                 4  bytes

    "SysTick_Handler"                                4

Uncalled function
  "_tx_thread_time_slice": 0x00002409

  Maximum call chain                                 0  bytes

    "_tx_thread_time_slice"                          0

Uncalled function
  "_tx_timer_expiration_process": 0x000022ed

  Maximum call chain                               260  bytes
```

```
    "_tx_timer_expiration_process"                    24
    "_tx_thread_timeout"                               8
    "_tx_event_flags_cleanup"                         16
    "_tx_thread_system_resume"                         8
    "_tx_thread_system_return"                       204

The following functions were excluded from stack usage calculations:

  "_tx_mutex_thread_release": 0x000024e3
  "_tx_thread_schedule": 0x000019dd
  "_tx_thread_shell_entry": 0x000027a9
```

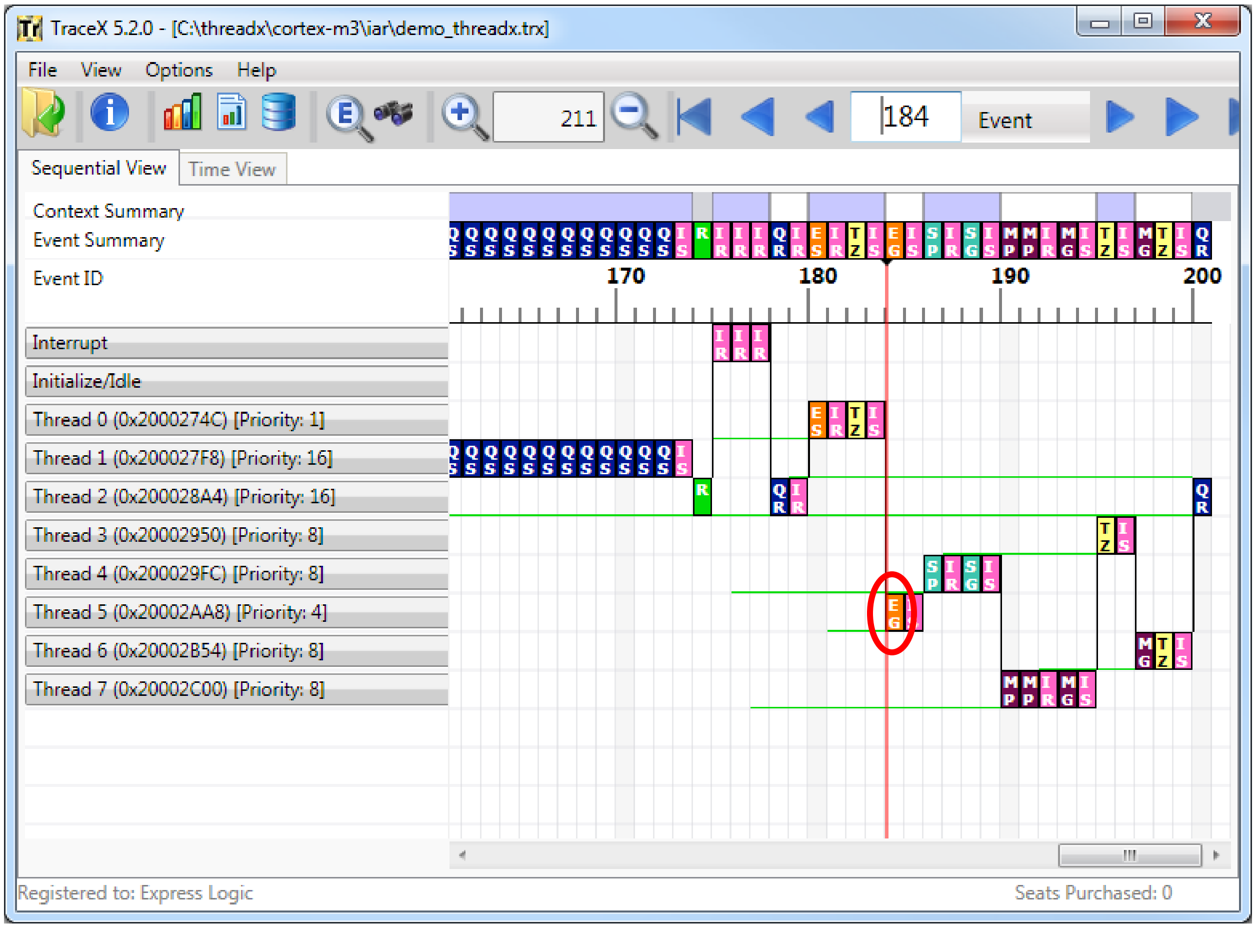
IAR EWARM Call Graph Output for demo_threadx

```
  thread:
  0 thread_0_entry [260]
    8 _tx_event_flags_set [252]
      48 _tx_thread_system_preempt_check [212]
        56 _tx_thread_system_return [204]
          260 - [0]
      48 _tx_thread_system_resume [212]
        56 _tx_thread_system_return [204] ***
        56 _tx_timer_system_deactivate [4]
          60 - [0]
    8 _tx_thread_sleep [228]
      16 _tx_thread_system_suspend [220]
        32 _tx_thread_system_return [204] ***
        32 _tx_timer_system_activate [4]
          36 - [0]

  thread:
  0 thread_1_entry [252]
    8 _tx_queue_send [244]
      32 _tx_thread_system_resume [212] ***
      32 _tx_thread_system_suspend [220] ***

  thread:
  0 thread_2_entry [252]
    8 _tx_queue_receive [244]
      32 _tx_thread_system_resume [212] ***
      32 _tx_thread_system_suspend [220] ***

  thread:
  0 thread_3_and_4_entry [244]
    8 _tx_semaphore_get [236]
      24 _tx_thread_system_suspend [220] ***
    8 _tx_semaphore_put [228]
      24 _tx_thread_system_resume [212] ***
    8 _tx_thread_sleep [228] ***
```

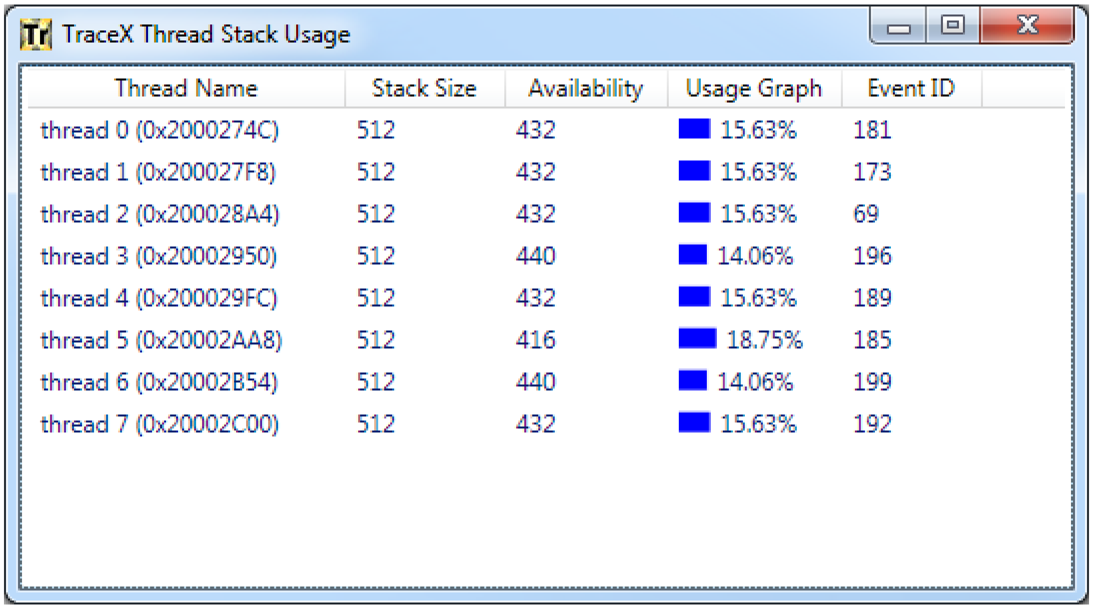
```
thread:
0 thread_5_entry [260]
  16 _tx_event_flags_get [244]
    40 _tx_thread_system_suspend [220] ***

thread:
0 thread_6_and_7_entry [276]
  8 _tx_mutex_get [260]
    24 _tx_mutex_priority_change [244]
      48 _tx_thread_system_resume [212] ***
      48 _tx_thread_system_suspend [220] ***
    24 _tx_thread_system_suspend [220] ***
  8 _tx_mutex_put [268]
    32 _tx_mutex_prioritize [236]
      56 _tx_thread_system_preempt_check [212] ***
    32 _tx_mutex_priority_change [244] ***
    32 _tx_thread_system_preempt_check [212] ***
    32 _tx_thread_system_resume [212] ***
  8 _tx_thread_sleep [228] ***

Uncalled:
0 SysTick_Handler [4]
  4 - [0]

Uncalled:
0 _tx_thread_schedule [---] (no info)

Uncalled:
0 _tx_mutex_thread_release [-excluded-]
  8 _tx_mutex_put [268] ***

Uncalled:
0 _tx_thread_shell_entry [---]
  8 Indirect call [---]
  8 _tx_thread_system_suspend [220] ***

Uncalled:
0 _tx_thread_time_slice [0]

Uncalled:
0 _tx_timer_expiration_process [260]
  24 _tx_thread_timeout [236]
    32 _tx_queue_cleanup [220]
      40 _tx_thread_system_resume [212] ***
    32 _tx_semaphore_cleanup [220]
      40 _tx_thread_system_resume [212] ***
    32 _tx_mutex_cleanup [220]
      40 _tx_thread_system_resume [212] ***
    32 _tx_block_pool_cleanup [220]
      40 _tx_thread_system_resume [212] ***
    32 _tx_byte_pool_cleanup [220]
      40 _tx_thread_system_resume [212] ***
    32 _tx_event_flags_cleanup [228]
      48 _tx_thread_system_resume [212] ***
    32 _tx_thread_system_resume [212] ***
  24 _tx_timer_system_activate [4] ***

Program entry:
0 __iar_program_start [300]
  0 __cmain [300]
    0 __iar_data_init3 [12]
      8 __iar_zero_init3 [0]
      8 __iar_copy_init3 [4]
        12 - [0]
    0 __low_level_init [0]
    0 main [300]
      8 _tx_initialize_kernel_enter [292]
        16 _tx_initialize_high_level [24]
          24 _tx_thread_initialize [16]
            32 __iar_Memset [8]
              32 __iar_Memset_word [8]
                40 - [0]
          24 _tx_timer_initialize [16]
            32 __iar_Memset [8] ***
        16 _tx_initialize_low_level [0]
        16 _tx_thread_schedule [---] (no info) ***
        16 tx_application_define [284]
          48 _tx_block_allocate [236]
            64 _tx_thread_system_suspend [220] ***
          48 _tx_block_pool_create [32]
            72 __iar_Memset [8] ***
          48 _tx_block_release [220]
            56 _tx_thread_system_resume [212] ***
          48 _tx_byte_allocate [252]
            80 _tx_byte_pool_search [28]
              108 - [0]
            80 _tx_thread_system_suspend [220] ***
          48 _tx_byte_pool_create [32]
            72 __iar_Memset [8] ***
          48 _tx_event_flags_create [24]
            64 __iar_Memset [8] ***
          48 _tx_mutex_create [24]
            64 __iar_Memset [8] ***
          48 _tx_queue_create [32]
            72 __iar_Memset [8] ***
          48 _tx_semaphore_create [24]
            64 __iar_Memset [8] ***
          48 _tx_thread_create [244]
            80 __iar_Memset [8] ***
            80 _tx_thread_stack_build [0]
            80 _tx_thread_system_preempt_check [212] ***
            80 _tx_thread_system_resume [212] ***
          48 _tx_thread_create [244] ***
          48 _tx_thread_create [244] ***
          48 _tx_thread_create [244] ***
          48 _tx_thread_create [244] ***
          48 _tx_thread_create [244] ***
    0 exit [8]
      0 _exit [8]
        0 __exit [8]
          8 - [0]
```

TraceX Stack Analysis

Another stack analysis tool available to ThreadX users is TraceX. Although the main purpose of TraceX is to provide a system level, graphical view of what the application is doing, TraceX also analyzes the stack usage for each thread represented in the trace buffer. TraceX does not provide a worst-case stack size for the entire thread execution, but only the worst case stack usage within the captured trace. For example, the following trace shows thread 5's execution in the trace buffer:


TraceX 5.2.0 - [C:\threadx\cortex-m3\iar\demo_threadx.trx]
File View Options Help
211
184
Event
Sequential View
Time View
Context Summary
Event Summary
Event ID
170
180
190
200
Interrupt
Initialize/Idle
Thread 0 (0x2000274C) [Priority: 1]
Thread 1 (0x200027F8) [Priority: 16]
Thread 2 (0x200028A4) [Priority: 16]
Thread 3 (0x20002950) [Priority: 8]
Thread 4 (0x200029FC) [Priority: 8]
Thread 5 (0x20002AA8) [Priority: 4]
Thread 6 (0x20002B54) [Priority: 8]
Thread 7 (0x20002C00) [Priority: 8]
Registered to: Express Logic
Seats Purchased: 0

Event number 184 is ***thread 5***'s call to ***tx_event_flag_get***, which in turn suspends as shown by event 185 and the subsequent execution of other threads. The stack analysis of this trace buffer, selected by ***View -> Thread Stack Usage***:


TraceX Thread Stack Usage

Thread Name	Stack Size	Availability	Usage Graph	Event ID
thread 0 (0x2000274C)	512	432	15.63%	181
thread 1 (0x200027F8)	512	432	15.63%	173
thread 2 (0x200028A4)	512	432	15.63%	69
thread 3 (0x20002950)	512	440	14.06%	196
thread 4 (0x200029FC)	512	432	15.63%	189
thread 5 (0x20002AA8)	512	416	18.75%	185
thread 6 (0x20002B54)	512	440	14.06%	199
thread 7 (0x20002C00)	512	432	15.63%	192

The TraceX view of thread stack usage shows that thread 5 has a minimal available stack of 416 bytes (or used stack of 96 bytes). The reason TraceX shows less stack used than the other methods is that the stack sampled in the trace buffer does not include the stack required to save the thread's context. However, it still provides a useful cross checking of the stack usage for thread execution captured within the trace buffer.

Summary

ThreadX users must still deal with stack overflow issues as well as attempting to ascertain the minimal amount of stack space required for each thread. However, ThreadX users have unparalleled stack analysis tools at their disposal – eliminating much of the guesswork and hope!