

OPTIMIZE FreeRTOS WITH MCUXPRESSO SOFTWARE AND TOOLS

CLARK JARVIS

MCUXPRESSO SOFTWARE AND TOOLS

PRODUCT MARKETER

AMF-DES-T2634 | JUNE 2017



SECURE CONNECTIONS
FOR A SMARTER WORLD

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PUBLIC



AGENDA

- Overview MCUXpresso Software and Tools
 - MCUXpresso SDK
 - MCUXpresso Config Tools
 - MCUXpresso IDE
- Overview FreeRTOS
 - FreeRTOS
 - Segger RTT and SystemView
 - Percepio Tracealyzer
 - NXP Kernel and Thread Awareness
- Optimizing FreeRTOS





Overview: MCUXpresso Software and Tools



MCUXpresso Software and Tools

COMMON TOOLKIT
FOR THOUSANDS
OF KINETIS® & LPC
MICROCONTROLLERS



www.nxp.com/mcuxpresso



MCUXpresso Software and Tools

for Kinetis and LPC microcontrollers



MCUXpresso IDE

Edit, compile, debug and optimize in an intuitive and powerful IDE



MCUXpresso SDK

Runtime software including peripheral drivers, middleware, RTOS, demos and more



MCUXpresso Config Tools

Online and desktop tool suite for system configuration and optimization



MCUXpresso Software and Tools

- Common toolkit across Kinetis and LPC microcontrollers
- Easy to use
- High quality
- Shared software experience and broader portfolio support
- Offers easy migration and scalability
- Supports large ARM® Cortex®-M ecosystem
- Built on the 'best of' Kinetis SDK, LPCXpresso and Kinetis Design Studio IDEs



MCUXpresso Software and Tools

- IDE
- SDK
- Config Tools

For NXP's ARM® Cortex®-M controllers

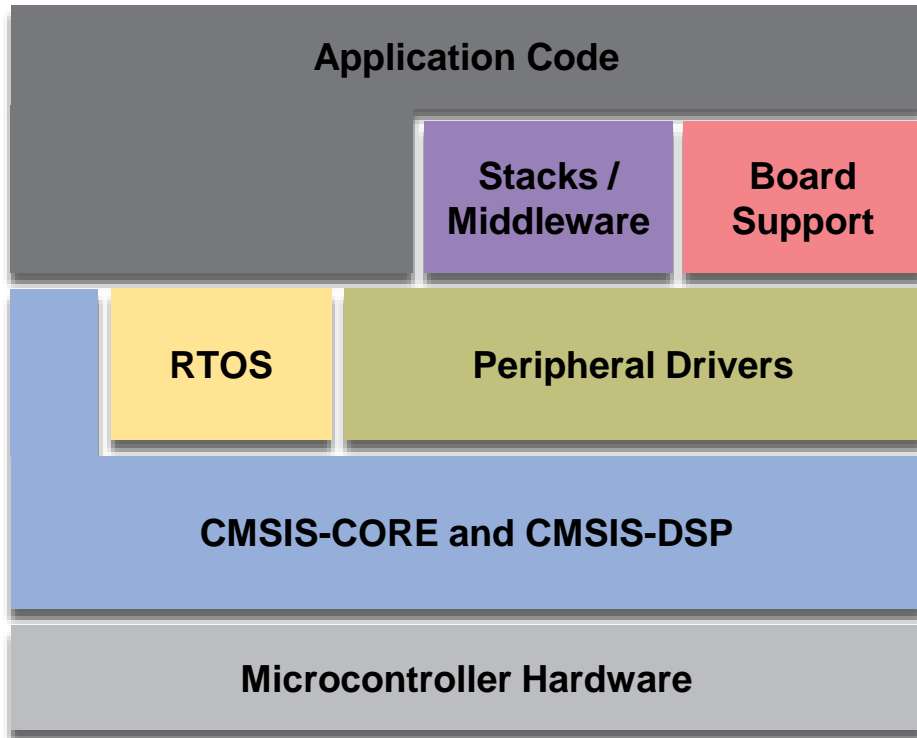
- Kinetis MCUs
- LPC Microcontrollers
- i.MX Application Processors



MCUXpresso SDK



The software framework and reference for Kinetis & LPC MCU application development



Product Features

Architecture:

- CMSIS-CORE compatible
- Single driver for each peripheral
- Transactional APIs w/ optional DMA support for communication peripherals

Integrated RTOS:

- FreeRTOS v9
- RTOS-native driver wrappers

Integrated Stacks and Middleware

- USB Host, Device and OTG
- lwIP, FatFS
- Crypto acceleration plus wolfSSL & mbedTLS
- SD and eMMC card support

Reference Software:

- Peripheral driver usage examples
- Application demos
- FreeRTOS usage demos

License:

- BSD 3-clause for startup, drivers, USB stack

Toolchains:

- MCUXpresso IDE
- IAR®, ARM® Keil®, GCC w/ Cmake

Quality

- Production-grade software
- MISRA 2004 compliance
- Checked with Coverity® static analysis tools

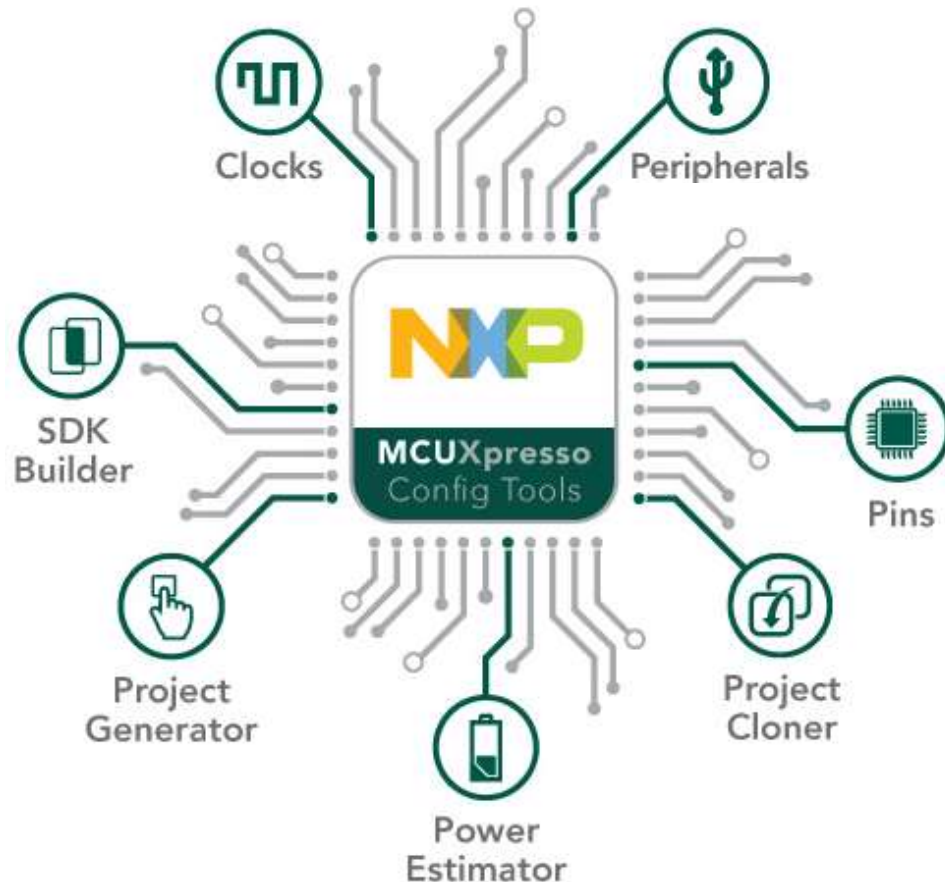




MCUXpresso Config Tools



Integrated configuration and development tools for LPC and Kinetis MCUs



MCUXpresso Config Tools is a suite of evaluation and configuration tools that helps guide users from first evaluation to production software development.



SDK Builder packages custom SDKs based on user selections of MCU, evaluation board, and optional software components.



Pins, **Clocks**, and **Peripheral** tools generate initialization C code for custom board support. Features validation of inputs and cross-tool conflict resolution.



Project Generator creates new SDK projects with generated Pins and Clocks source files.



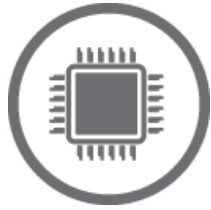
Project Cloning creates a standalone SDK project based on an example application available within SDK release.



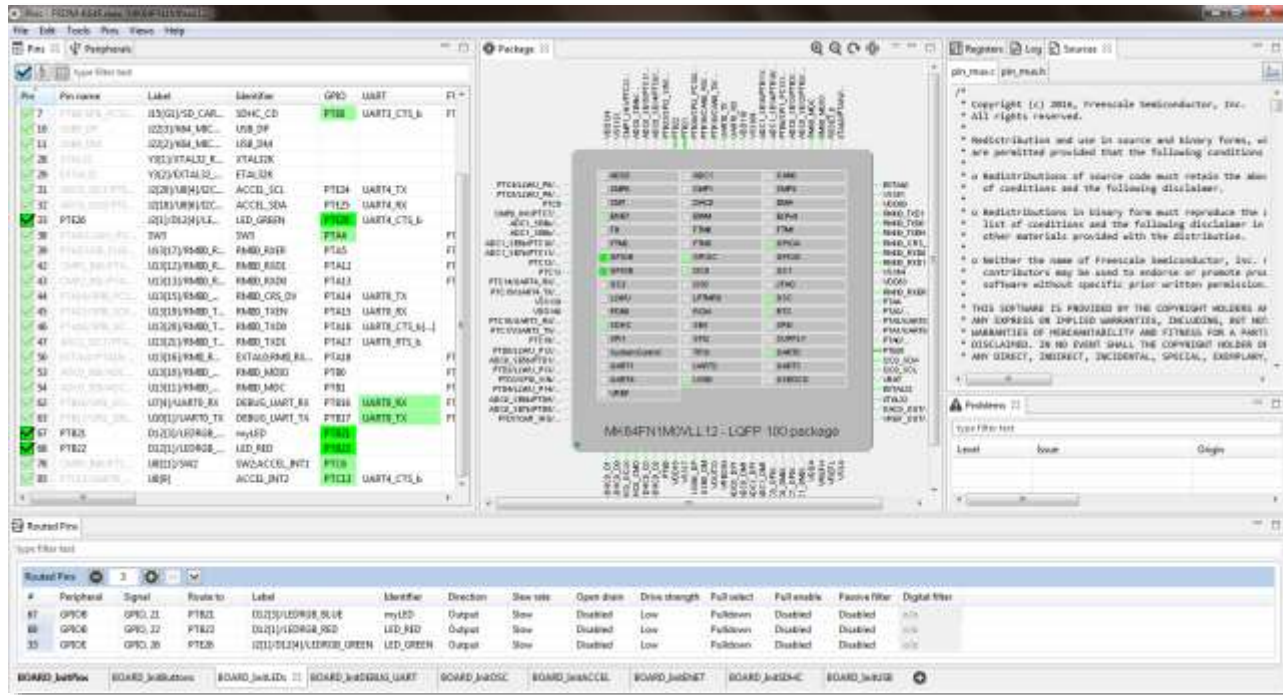
Power Estimation tool provides energy and battery-life estimates based on a user's application model.

Available as a standalone tool for select devices.

MCUXpresso Config - Pins Tool



Easy-to-use muxing and pin assignments for Kinetis & LPC microcontrollers



Product Features:

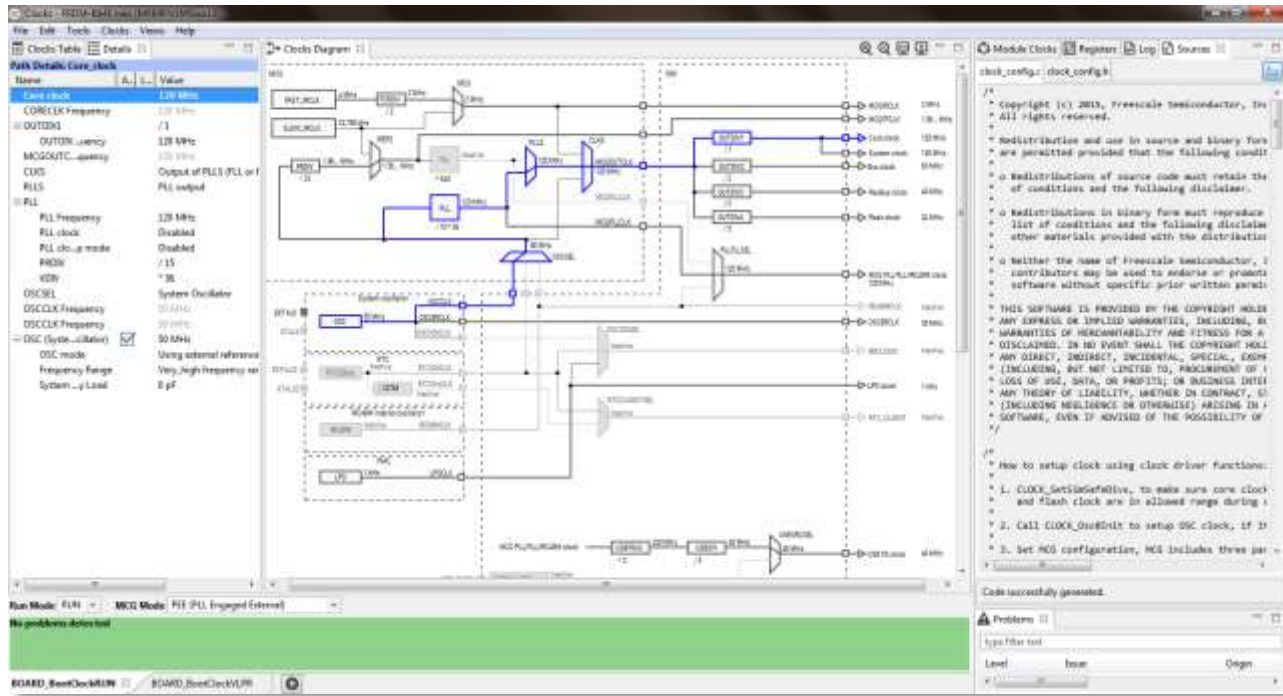
- Part of the MCUXpresso suite of system configuration tools
- Muxing and pin configuration with consistency checking
- ANSI-C configuration code
- Graphical processor package view
- Multiple configuration blocks/functions
- Wizard for optimized assignments of functionality to available pins
 - Selection of Pins and Peripherals
 - Package with IP blocks
 - Routed pins with electrical characteristics
 - Registers with configured and reset values
 - Source code for C/C++ applications
- Documented and easy to understand source code
- Report generation
- Integrates with any compiler and IDE



MCUXpresso Config - Clocks Tool



Easy-to-use clock configuration for Kinetis & LPC



Product Features:

- Part of the MCUXpresso system configuration tools
- System clock configuration with consistency checking
- ANSI-C initialization code
- Graphical clock diagrams
- Multiple configuration blocks/functions
- Easy-to-use guided graphical user interface
 - Selection of Clock Sources
 - Configuration of prescalers and clock outputs
 - Details and Full Diagram views with clock path
 - Registers with configured and reset values
 - Source code for C/C++ applications
- Documented and easy to understand source code
- Report generation



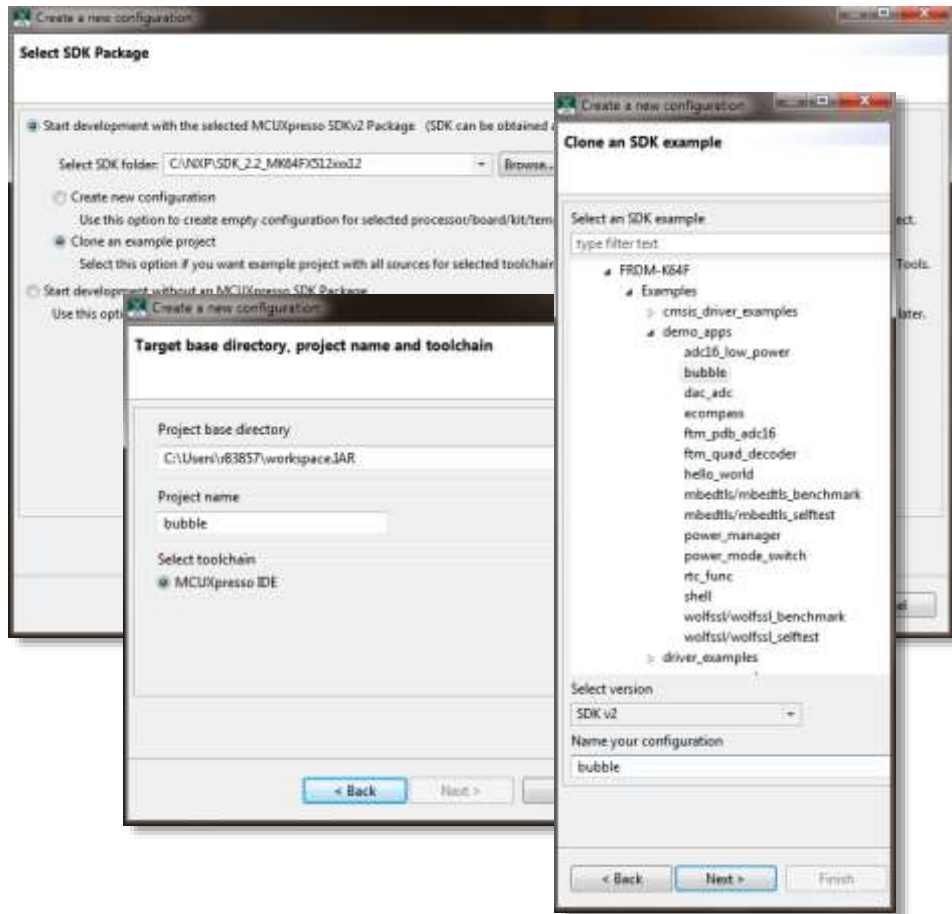
MCUXpresso Config – Project Cloner



Create a standalone copy of an MCUXpresso SDK example project

Product Features:

- Ability to generate a fully standalone MCUXpresso project cloned from one of the many included examples.
- Provide a native IDE project for any toolchain supported in your SDK configurations
- Available in the desktop version on the MCUXpresso Config Tool as part of the “New configuration dialog”
- Available in the online version of the MCUXpresso SDK Builder and webpage.
- Clones example projects can be downloaded directly from the MCUXpresso webpage. Online cloned projects provide all project and SDK files required to quickly have an application running on a support NXP development board in a single download.

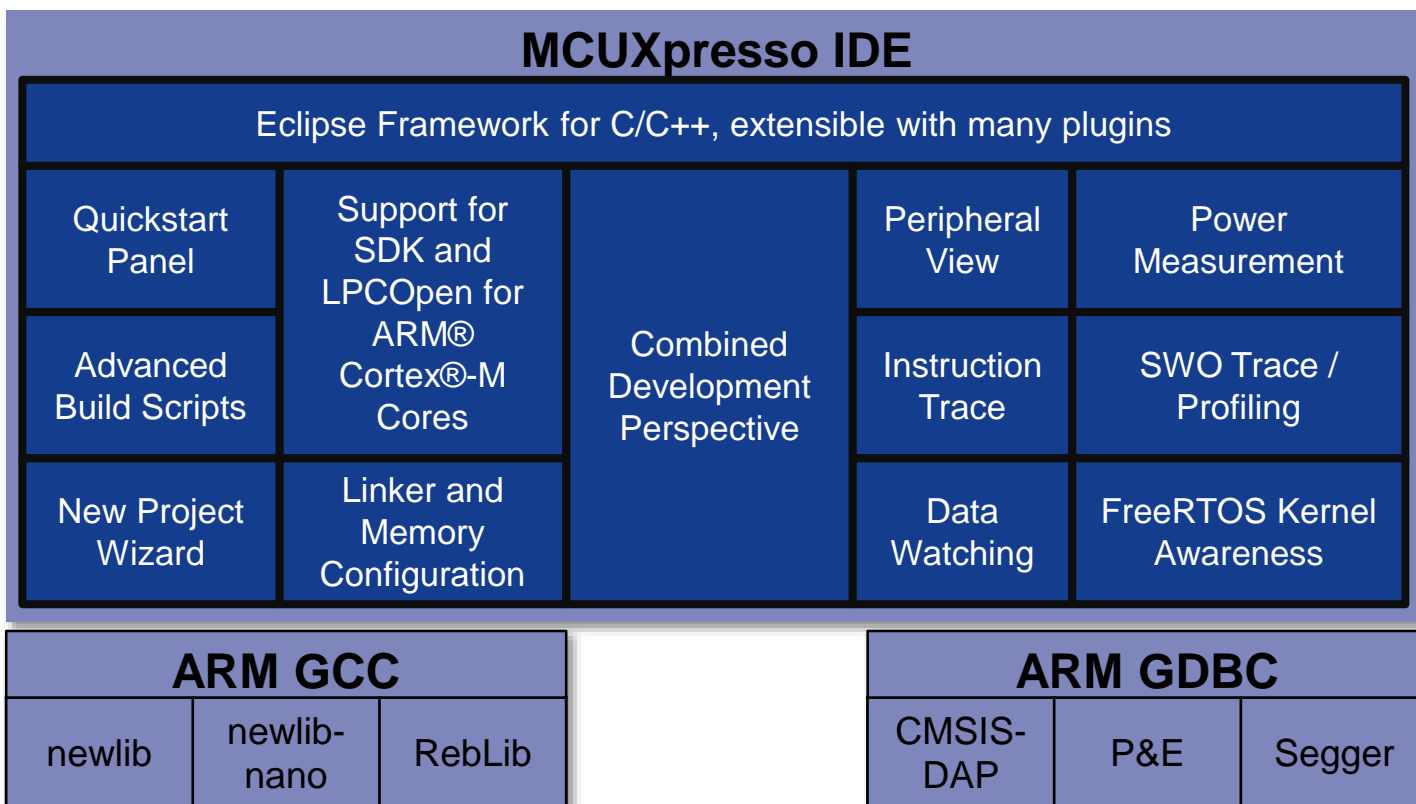




MCUXpresso IDE



Free Eclipse and GCC-based IDE for C/C++ development on Kinetis and LPC MCUs

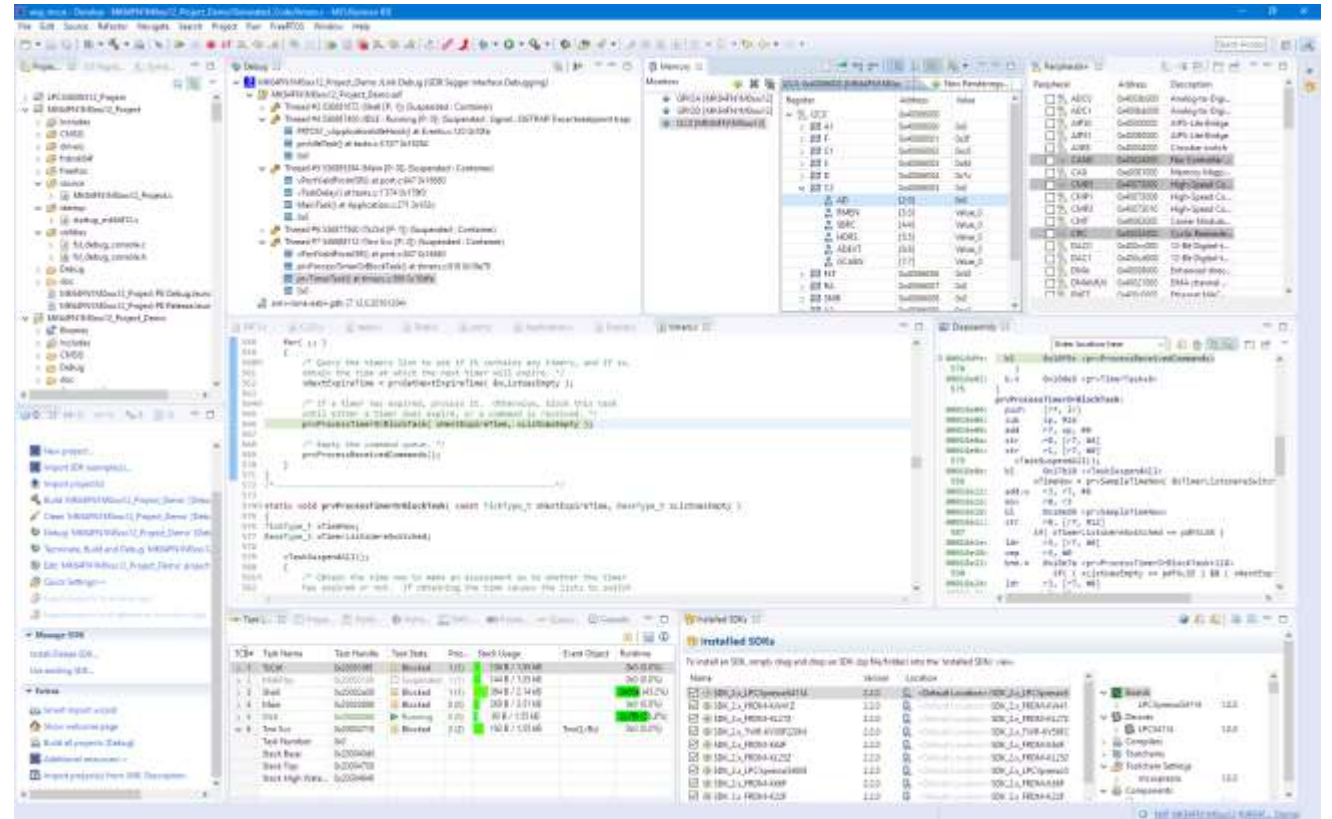


Product Features

- **Feature-rich, unlimited code size**, optimized for **ease-of-use**, based on **industry standard Eclipse** framework for **NXP's Kinetis and LPC MCUs**
- **Application development** with Eclipse and GCC-based IDE for advanced **editing, compiling and debugging**
- Supports **custom** development boards, **Freedom, Tower and LPCXpresso** boards with debug probes from **NXP, P&E and Segger**
- **Free Edition:** Full Featured, **unlimited Code Size**, no special activation needed, community based support
- **Pro Edition:** Email IDE support, **Advanced Trace Features**

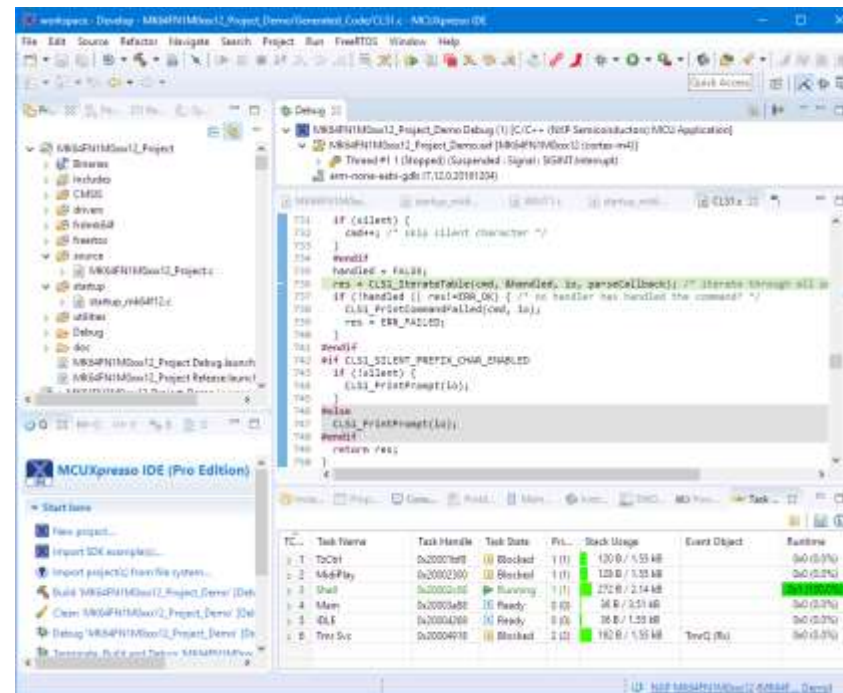
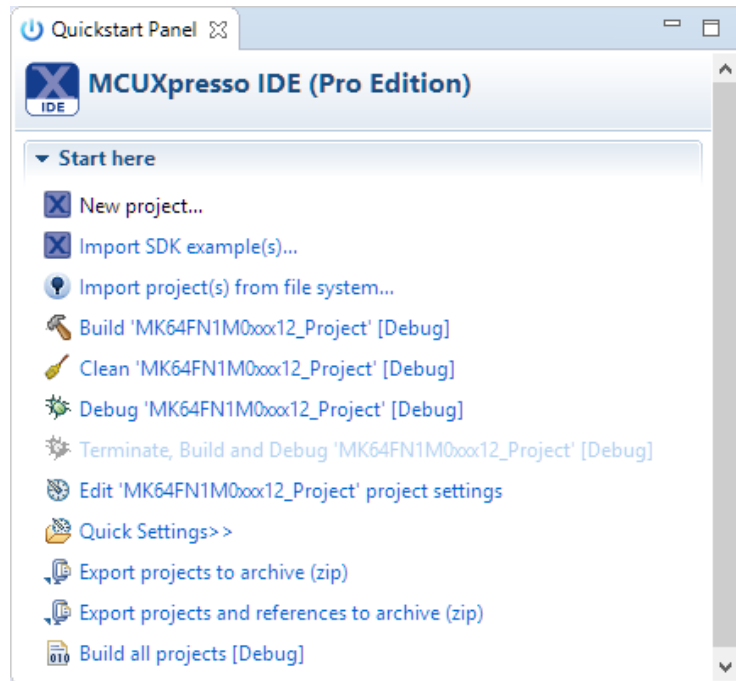
Eclipse Framework

- Eclipse 4.6 (NEON)
- CDT 9.1: Assembly, C, C++
- 1700+ Eclipse solutions available
- Optimized for ease-of-use
- Combined Development Perspective
- Quickstart Panel
- New Project Wizard with SDK and LPCOpen
- Advanced Debugging and Tracing
- Integrated ARM GCC and GDB



Built for Ease-of-Use

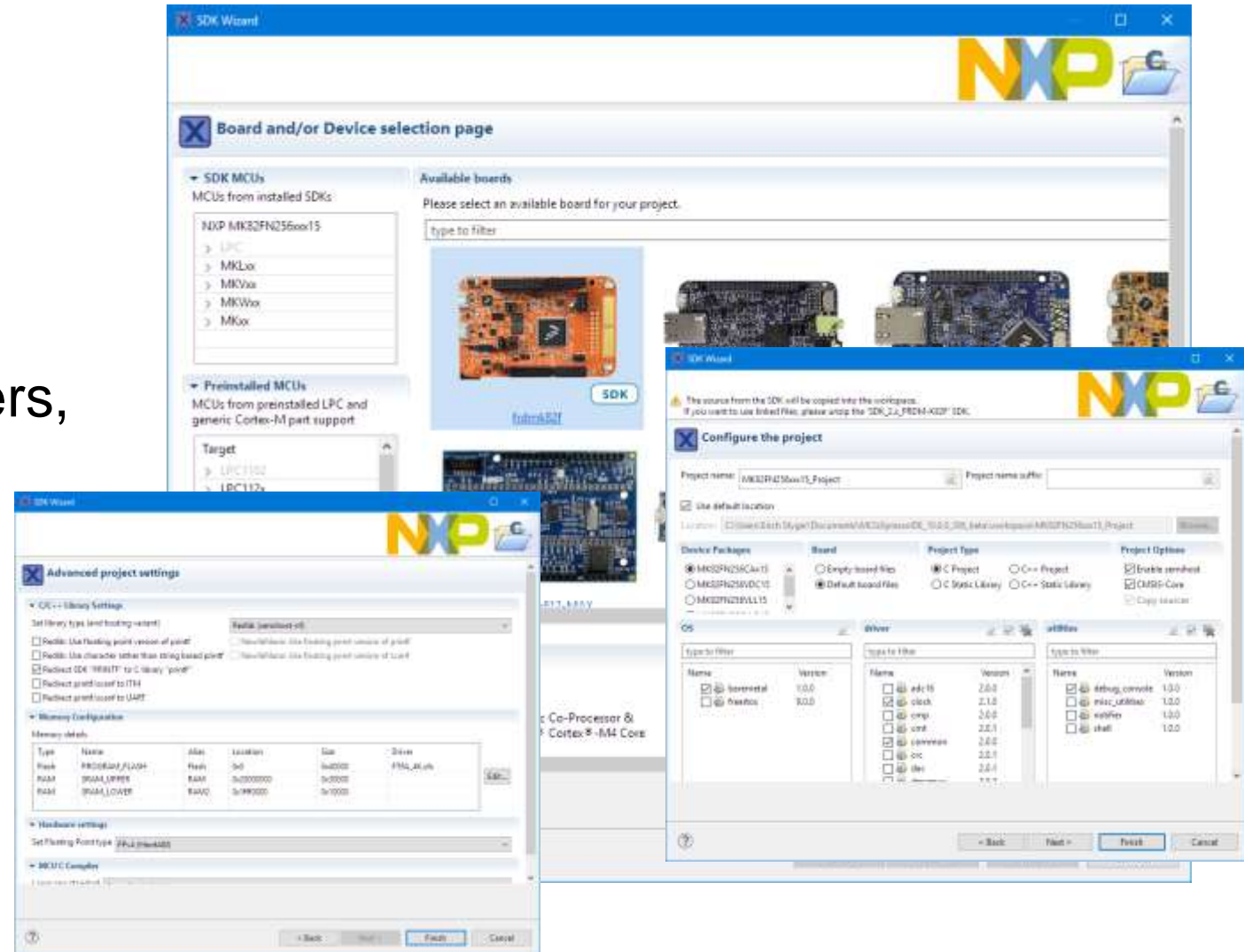
- **Quickstart Panel** guides users to most commonly used options
 - One-Click access to most used functions
- **Develop Perspective** for both project editing and debugging
 - Simplifies Eclipse usage





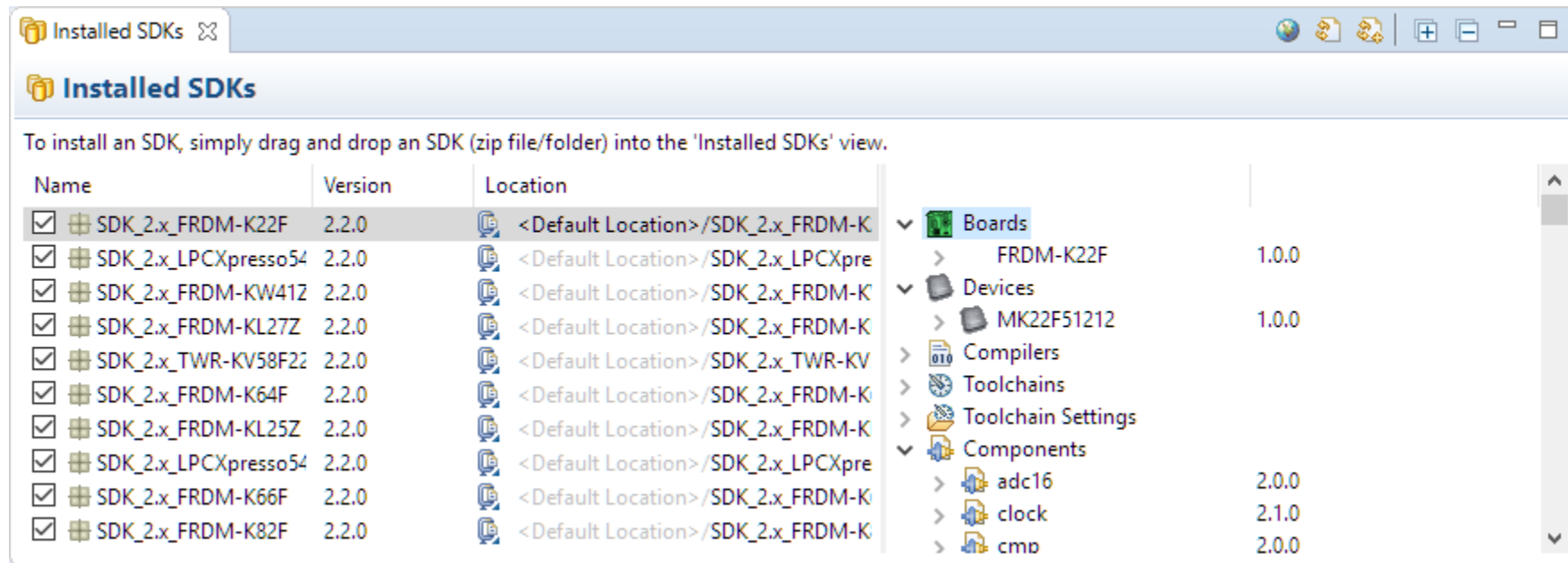
New Project Wizard: Data Driven Device Support

- SDK MCUs (LPC and Kinetis)
- Preinstalled LPC and generic Cortex-M
- Installable device support through SDK packages (data driven)
- Selection of package, RTOS, drivers, utilities
- Standalone and linked projects
- Advanced project settings



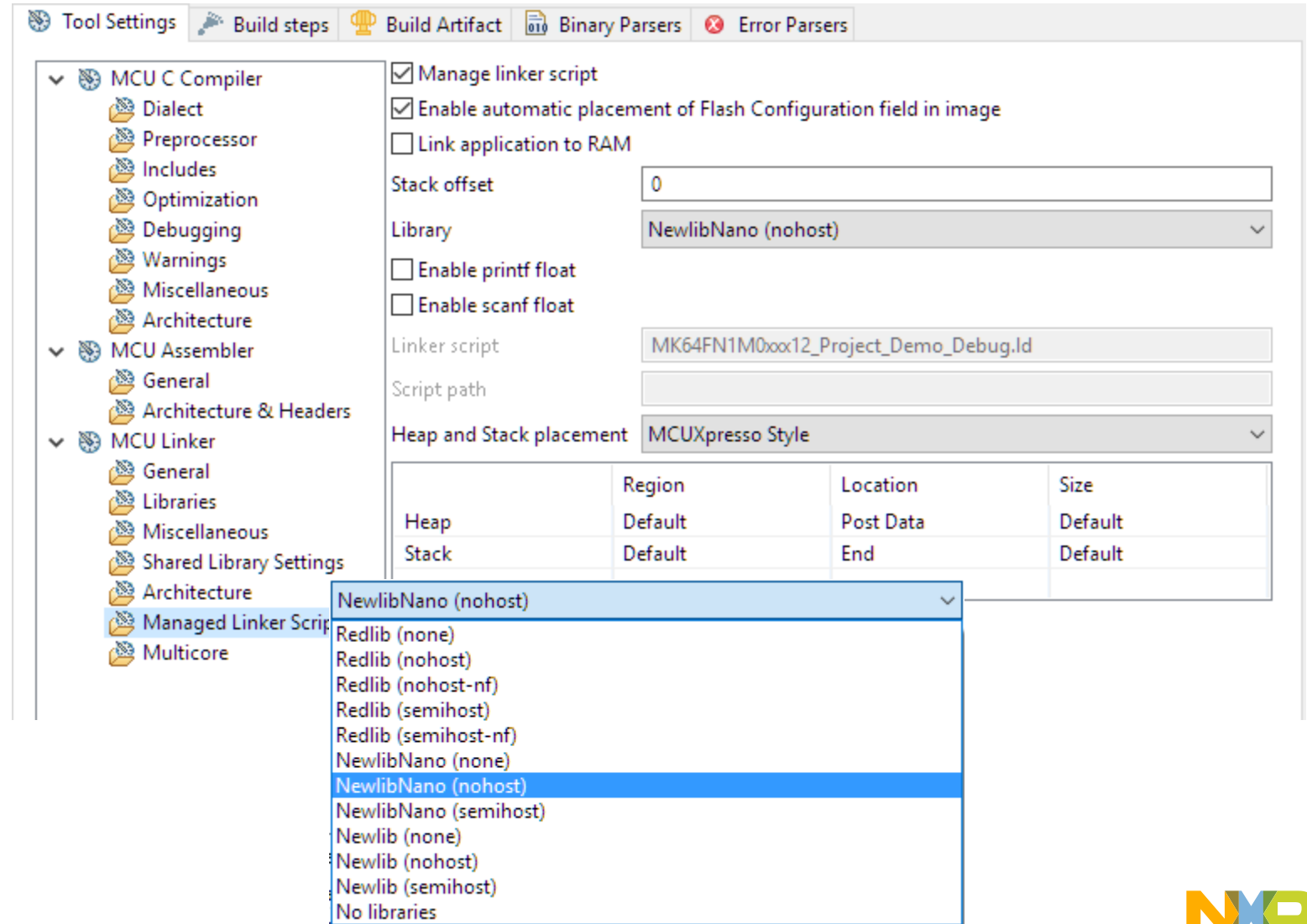
Device Support

- Preinstalled LPC/LPCOpen and Generic Cortex-M device support
- Additional LPC and Kinetis Device support with MCUXpresso SDK
 - Build and download from <http://mcuxpresso.nxp.com/>
 - Zip file(s) with manifest XML: standalone (default) or linked projects
 - Examples, peripheral drivers, startup code, linker files, toolchain support



Build System with Managed Linker Scripts

- Automatic Linker Script File Generation
- Heap and Stack management
- Selection of library
 - RedLib (optimized)
 - newlib
 - newlib-nano
- Semihosting with and without floating point support



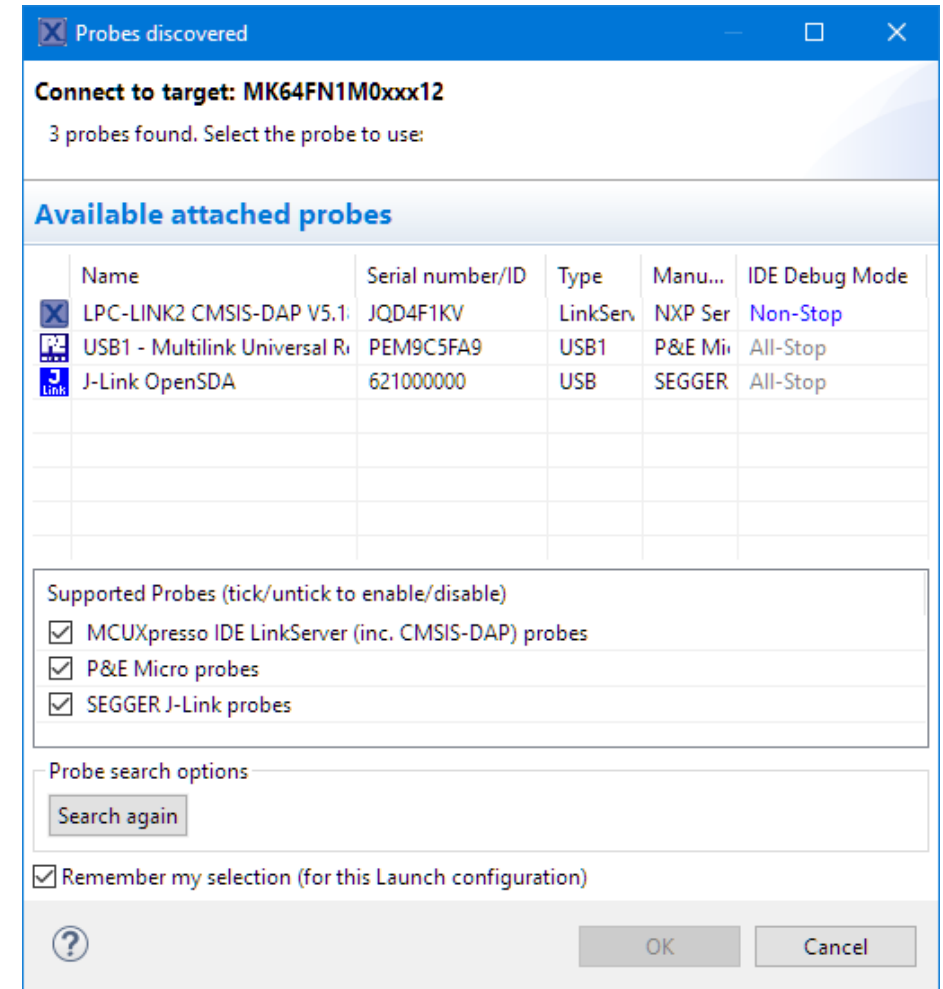
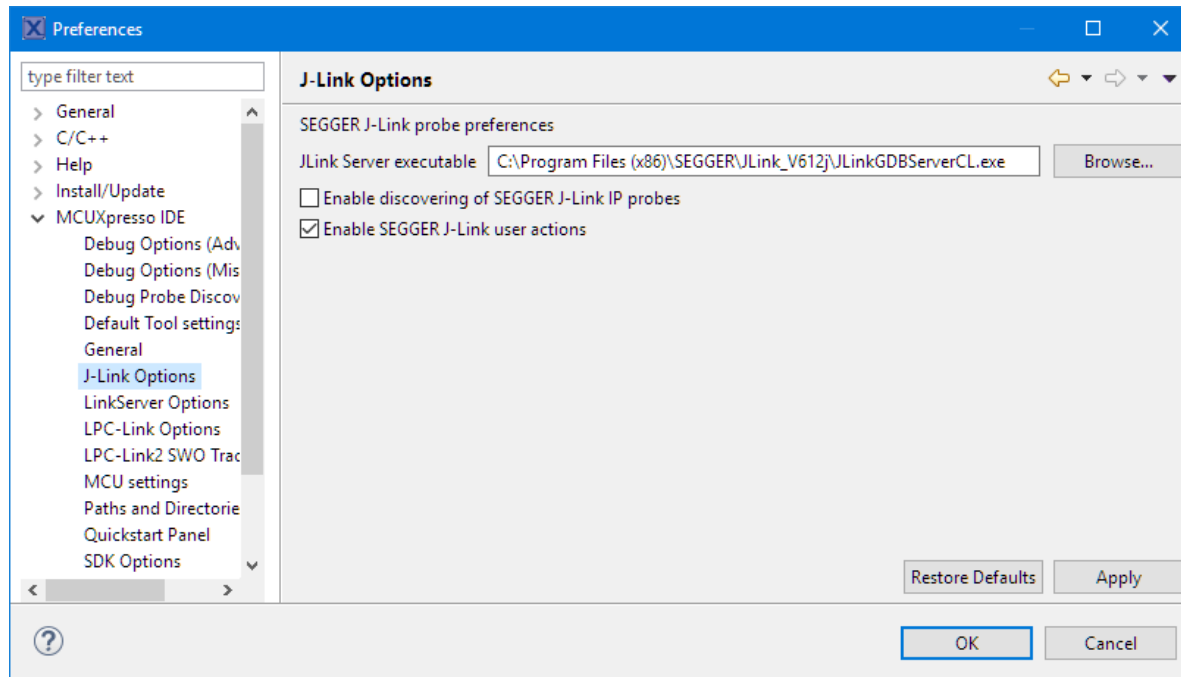
MCUXpresso Supported Debug Probes

- **LinkServer MCUXpresso Probes**
 - LPC-Link, LPC-Link2, including debug probes on LPCXpresso V2/V3 boards
 - CMSIS-DAP (including CMSIS-DAP on Kinetis FRDM and TOWER boards)
- **Segger (J-Link)**
 - Native and OEM J-Link for Kinetis and LPC
 - OpenSDA Segger Firmware on FRDM/TOWER boards
 - LPC-Link2 Segger Firmware on LPC-Link/LPC-Link2
- **P&E (Multilink)**
 - Native Multilink for LPC and Kinetis
 - OpenSDA P&E Firmware on FRDM/TOWER boards



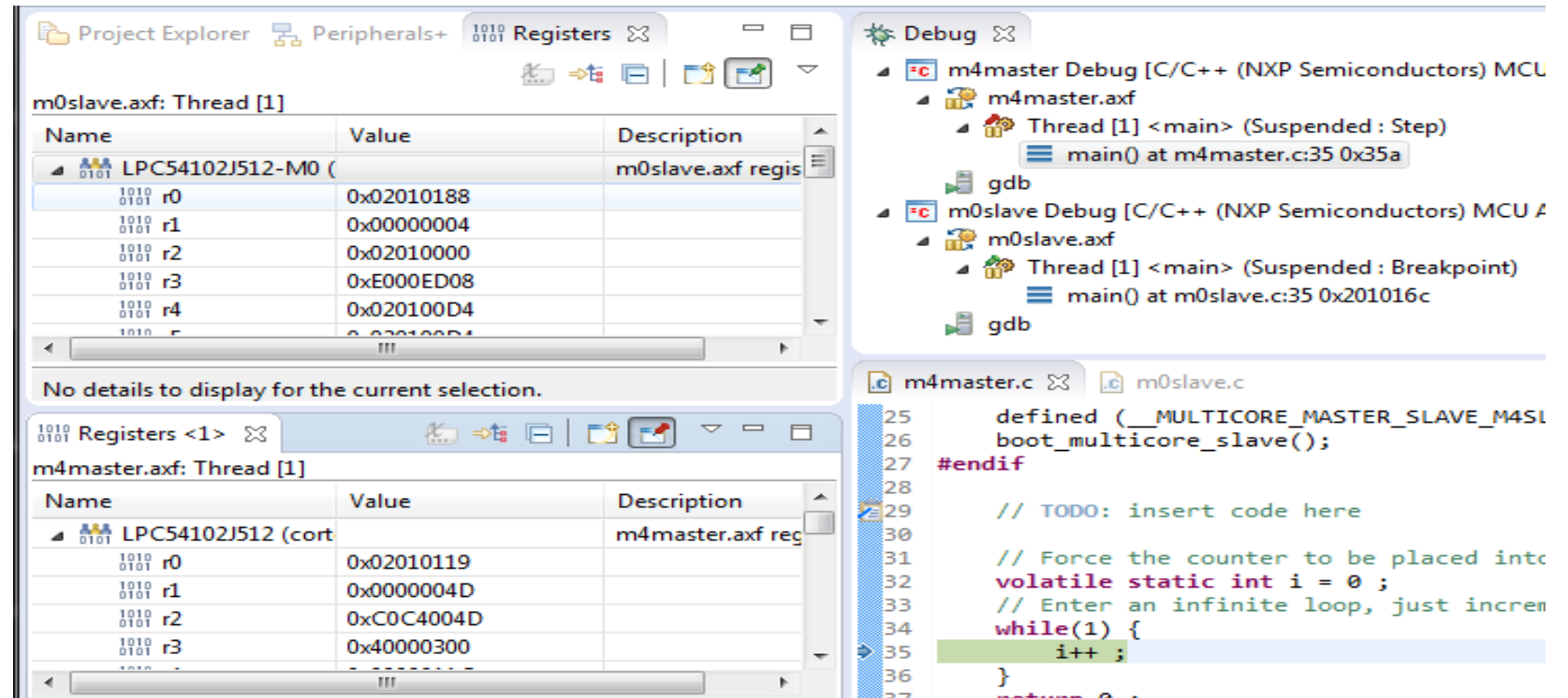
Automatic Probe Discovery and Configuration

- Discovery of attached supported probes
- Automatic creation of Debug Launch Configurations
- Setting to locate SEGGER GDB



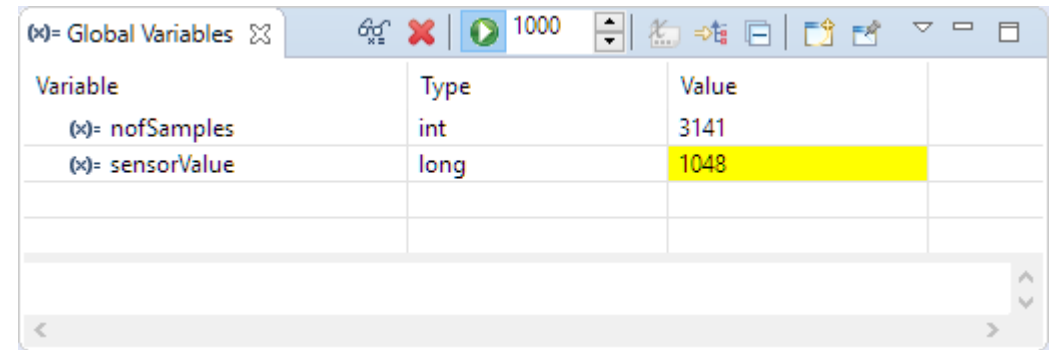
Multicore support

- One application project per CPU
- Links Master (M4) project to Slave (M0) project(s)
 - Master pulls in binary from Slave(s) to create single image to download
- Parallel debugging of all projects
 - Start Master debug connection first, then attach to Slave(s)
- Multiple instances of views
- Can pause / start CPUs in parallel (IDE not in HW)



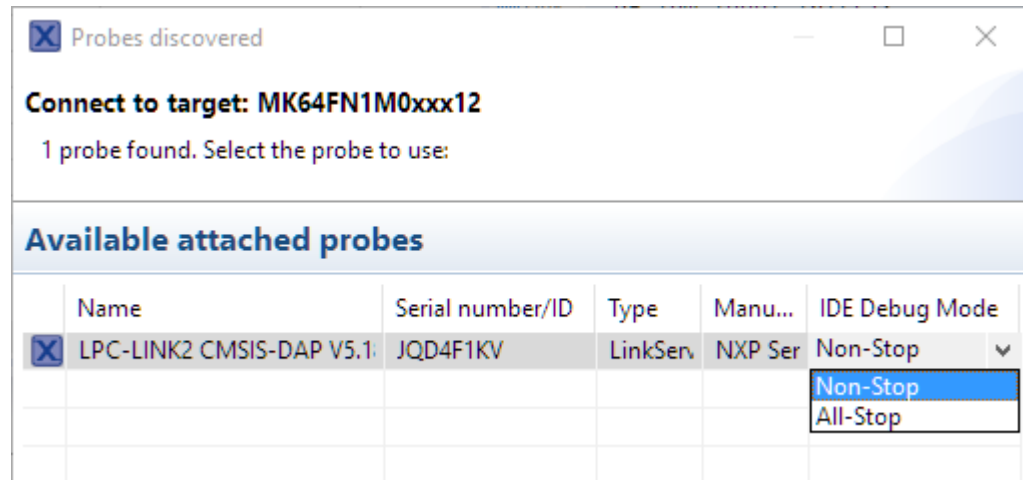
Live View (NXP LinkServer and P&E)

- Ability to watch variables/expressions while target is running
- Update can be paused/suspended
- LinkServer uses GDB Non-Stop mode



Global Variables

Variable	Type	Value
(x)- nofSamples	int	3141
(x)- sensorValue	long	1048



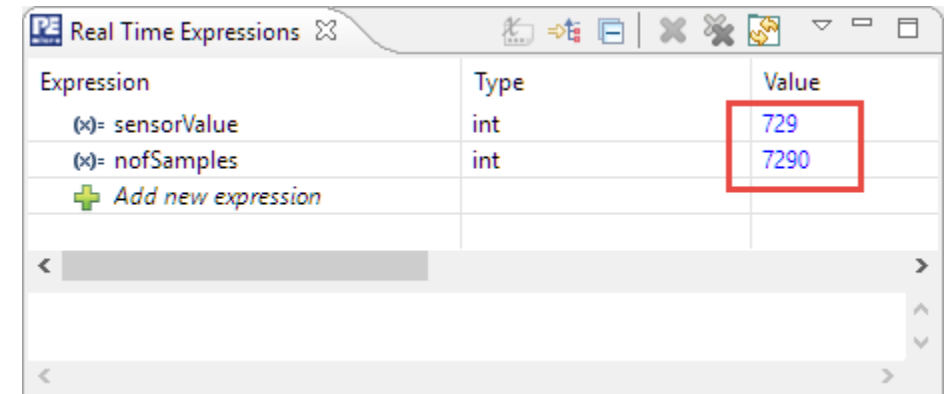
Probes discovered

Connect to target: MK64FN1M0xxx12

1 probe found. Select the probe to use:

Available attached probes

Name	Serial number/ID	Type	Manu...	IDE Debug Mode
<input checked="" type="checkbox"/> LPC-LINK2 CMSIS-DAP V5.1	JQD4F1KV	LinkSer.	NXP Ser	Non-Stop Non-Stop All-Stop



Real Time Expressions

Expression	Type	Value
(x)- sensorValue	int	729
(x)- nofSamples	int	7290
+ Add new expression		

Peripherals+ View

- Peripherals view based on extended Memory view
- Register view extended to highlight changes and show additional pseudo registers (including VectPC when exception occurs or cycle counter)

Peripherals+ View

Peripheral	Address	Description
<input type="checkbox"/> FTM0	0x40038000	FlexTimer Module
<input type="checkbox"/> FTM1	0x40039000	FlexTimer Module
<input type="checkbox"/> FTM2	0x4003a000	FlexTimer Module
<input type="checkbox"/> FTM3	0x400b9000	FlexTimer Module
<input type="checkbox"/> GPIOA	0x400ff000	General Purpose Input...
<input type="checkbox"/> GPIOB	0x400ff040	General Purpose Input...
<input checked="" type="checkbox"/> GPIOC	0x400ff080	General Purpose Input...
<input type="checkbox"/> GPIOD	0x400ff0c0	General Purpose Input...
<input type="checkbox"/> GPIOE	0x400ff100	General Purpose Input...
<input type="checkbox"/> I2C0	0x40066000	Inter-Integrated Circuit
<input type="checkbox"/> I2C1	0x40067000	Inter-Integrated Circuit
<input type="checkbox"/> I2C2	0x400e6000	Inter-Integrated Circuit
<input type="checkbox"/> I2S0	0x4002f000	Inter-IC Sound / Sync...
<input type="checkbox"/> LLWU	0x4007c000	Low leakage wakeup ...
<input type="checkbox"/> LPTMR0	0x40040000	Low Power Timer
<input type="checkbox"/> MCG	0x40064000	Multipurpose Clock ...
<input type="checkbox"/> MCM	0xe0080000	Core Platform Miscel...
<input type="checkbox"/> NVIC	0xe000e100	Nested Vectored Inter...

MK64FN1M0xxx12 Peripheral:
GPIOC [0x400ff080]
General Purpose Input/Output

Registers View

Name	Value	Description
0101 MK64FN1M0xxx12		MK64FN1M0x...
0101 r0	0x00000007	
0101 r1	0x00000000	
0101 r2	0x0000EA60	
0101 r3	0x00004DBC	
0101 r4	0xA5A5A5A5	
0101 r5	0xA5A5A5A5	
0101 r6	0xA5A5A5A5	
0101 r7	0x20002AB8	
0101 r8	0xA5A5A5A5	
0101 r9	0xA5A5A5A5	
0101 r10	0xA5A5A5A5	
0101 r11	0xA5A5A5A5	
0101 r12	0xA5A5A5A5	
0101 sp	0x20002AB4	
0101 lr	0x000129C1	
0101 pc	0x00012990	
0101 psr	0x81000000	
0101 flags	Nzcvq	
0101 epsr	none	
0101 ipsr	0 (Base)	
0101 msp	0x2002FFE0	
0101 control	0x00000002	
0101 cycle	0x07613A23	
0101 cycledelta	0x00E76F7B	
0101 vectpc	n/a	
0101 faults	n/a	
0101 basepri	0x00000000	
0101 primask	0x00000000	
0101 faultmask	0x00000000	

Memory View

Monitors

- GPIOC [MK64FN1M0xxx12]
- GPIOD [MK64FN1M0xxx12]
- I2C0 [MK64FN1M0xxx12]

GPIOD: 0x400ff0c0 [MK64F]

Register	Address	Value
GPIOD	0x400ff0c0	
> 0101 PDOR	0x400ff0c0	0x6
> 0101 PSOR	0x400ff0c4	<writeonly>
> 0101 PCOR	0x400ff0c8	<writeonly>
0101 PTCO	[31:0]	<writeonly>
> 0101 PTOR	0x400ff0cc	<writeonly>
> 0101 PDIR	0x400ff0d0	0x6
> 0101 PDDR	0x400ff0d4	0xf

Registers View (Detailed)

Register	Value
cycle	x:0x07613a23
cimal	123812387
tal	00730235043

Instruction Trace (NXP LinkServer)

- Requires MCU to provide internal RAM trace buffer (MTB or ETB)
- Buffer can be downloaded when MCU hits breakpoint

The screenshot displays the NXP LinkServer interface with three main panes:

- Source Code (main.c):** Lines 95-110 are visible. Line 98 is highlighted in blue, corresponding to the instruction trace entry 2347.
- Disassembly:** Shows assembly instructions for the selected line. The instruction `ldr r3, [pc, #56] ; (0x448 <main+328>)` is highlighted in blue.
- Instruction Trace Table:** A table listing instructions with columns for Inst No, PC, Disassembly, Info, function, filename, and line no.

Inst No	PC	Disassembly	Info	function	filename	line no
2344	0x00000408	lsls r3, r3, #2		main	../src/main.c	98
2345	0x0000040a	cmp r2, r3		main	../src/main.c	98
2346	0x0000040c	bls.n 0x426 <...>		main	../src/main.c	98
2347	0x0000040e	ldr r3, [pc, #56...		main	../src/main.c	98
2348	0x00000410	ldr r2, [r3, #0]		main	../src/main.c	98
2349	0x00000412	movs r3, #150 ...		main	../src/main.c	98
2350	0x00000414	lsls r3, r3, #3		main	../src/main.c	98
2351	0x00000416	cmp r2, r3		main	../src/main.c	98
2352	0x00000418	bhi.n 0x426 <...>		main	../src/main.c	98

SWO Trace (NXP LinkServer)

STM> SWO ITM Console

```

Blinky example using timer 1!
Timer 1 clock      = 72000000 Hz
Timer 1 tick rate = 10 Hz
Enter your family name: LPCXpresso
Enter your age: 7
Mr. LPCXpresso , 7 years old.
Enter a hexadecimal number: |
    
```

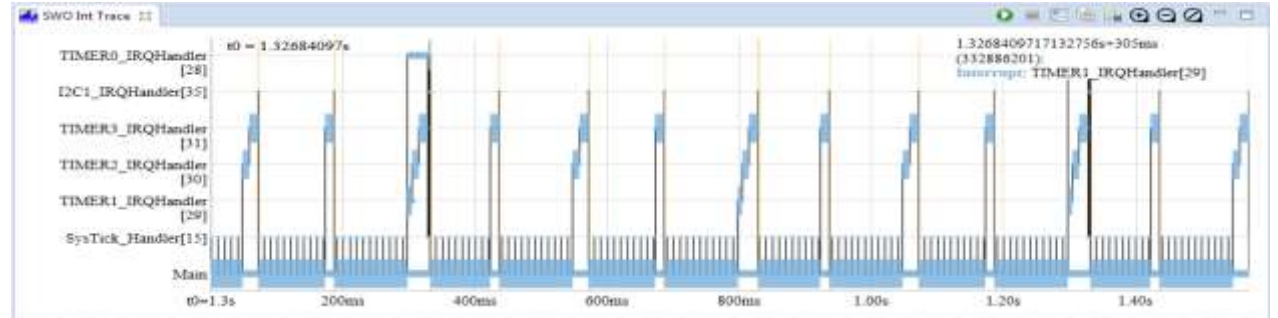
SWO Data

Enable Trace	Value	Format	Type	Access	Item	Value	Time	Access	Repeats
<input checked="" type="checkbox"/>	0x00000130	0x%08x	Value	Read	count_ct0	0x00000130	1.241m	W	0
<input checked="" type="checkbox"/>	0x0000025d	0x%08x	Value	Read	count_ct0	0x0000012f	1.241m	R	0
<input type="checkbox"/>	0x000076cb	0x%08x	Value	Read	count_ct1	0x0000025d	1.240m	W	0
					count_ct1	0x0000025c	1.240m	R	0
					count_ct1	0x0000025c	1.232m	W	0
					count_ct1	0x0000025b	1.232m	R	0
					count_ct0	0x0000012f	1.224m	W	0
					count_ct0	0x0000012e	1.224m	R	0

Note: this functionality is a [Technology Preview](#)

SWO Int Table

Index	ID	Event	Handler	Time	Ticks
3098	35	EXIT	I2C1_IRQHand...	16.048s	3273746073
3097	35	ENTRY	I2C1_IRQHand...	16.048s	3273745862
3096	0	RETURN		16.048s±3.294us	3273740833
3095	-3	OVERFLOW	SWO Overflow	16.048s±3.294us	3273740833
3094	0	RETURN		16.048s±3.294us	3273740833
3093	15	EXIT	SysTick_Handler	16.048s	3273740833
3092	15	ENTRY	SysTick_Handler	16.048s	3273740817
3091	31	EXIT	TIMER3_IRQH...	16.048s	3273740810
3090	31	ENTRY	TIMER3_IRQH...	16.034s	3270940679



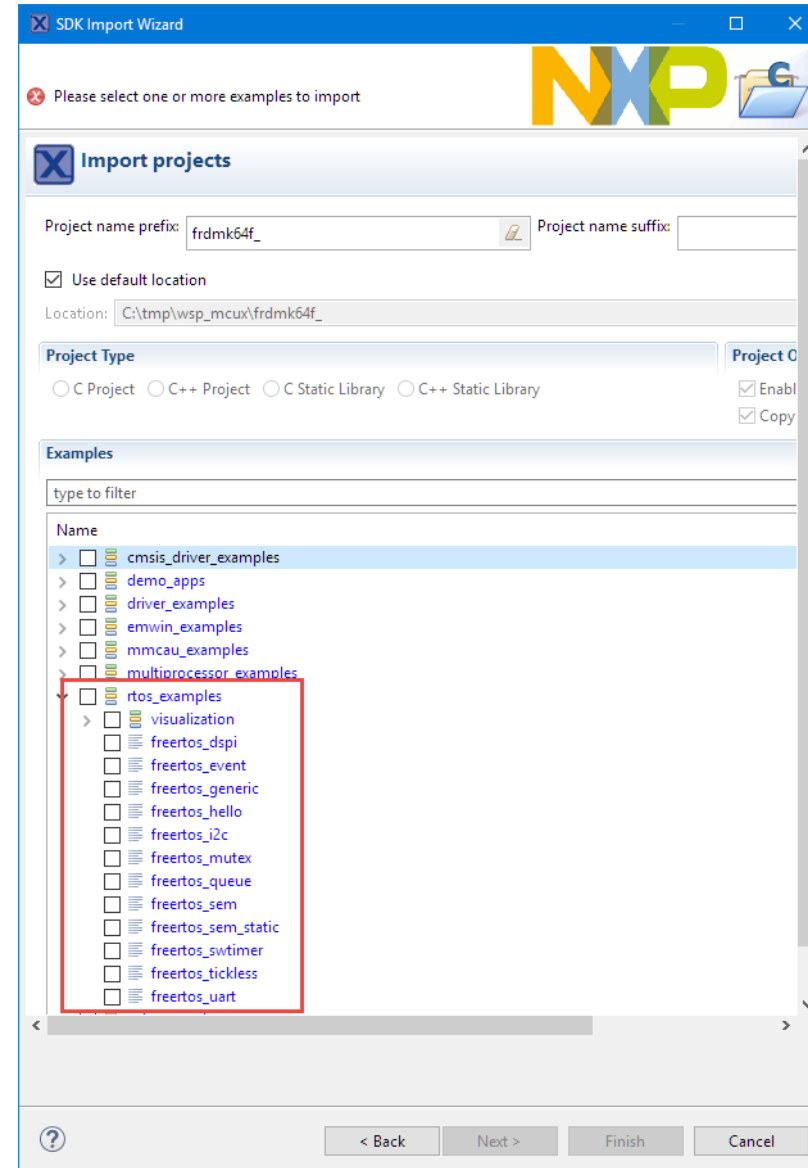
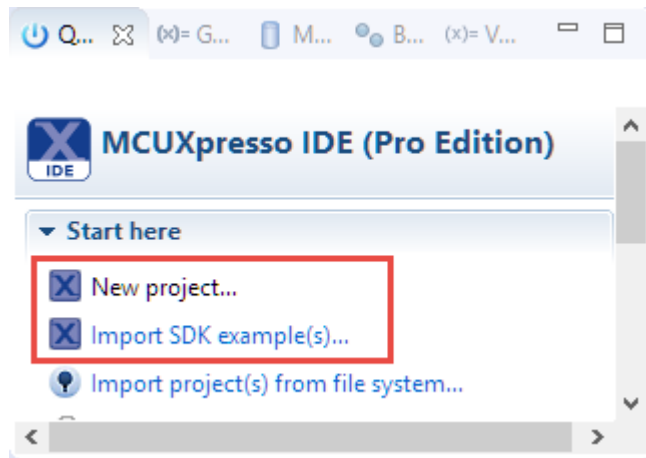
SWO Profile

Function	Cumulative samples	Cumulative samples %	Current samples %	Coverage %	First	Last	Since	Avg Between	Coverage bitmap
Board_LED_Toggle	82	0.0%	0.0%	22.7%	210...	25....	8.125s	303.719ms	0000000011110...
Chip_GPIO_SetPinToggle	25	0.0%	0.0%	12.5%	12....	16....	147....	154.913ms	001000000000000...
Chip_TIMER_ClearMatch	4	0.0%	0.0%	10.0%	1.5....	32....	529....	7.791s	000000000000000...
CT32B0_IRQHandler	2	0.0%	0.0%	11.5%	17....	25....	7.438s	4.128s	00101100000000...
Chip_TIMER_MatchPending	17	0.0%	0.0%	3.8%	2.0....	24....	8.549s	1.330s	0000000100000...
updateC	499256	30.8%	30.8%	90.0%	20....	33....	348....	66.579us	11111111111111...
SysTick_Handler	100	0.0%	0.0%	28.6%	280....	33....	158....	328.010ms	00000101101000
updateB	996882	61.4%	61.4%	90.0%	184....	33....	0.00...	33.344us	11111111111111...

Note: this functionality is a [Technology Preview](#)

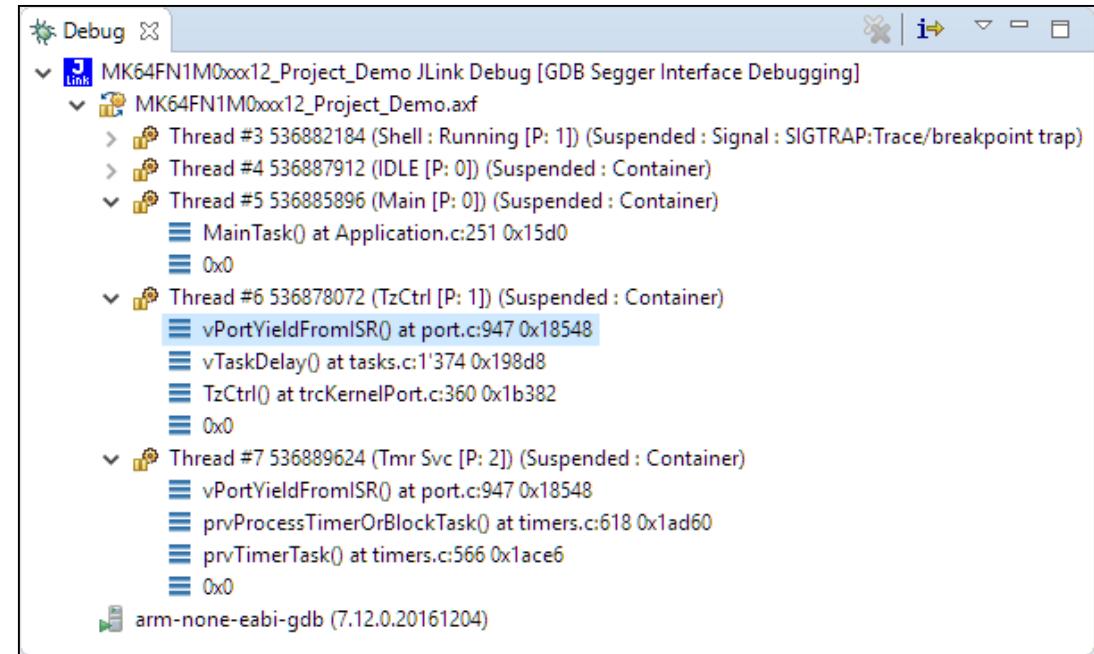
FreeRTOS with MCUXpresso Software and Tools

- MCUXpresso SDK includes FreeRTOS and Demo Applications
- Create new projects or import example projects



FreeRTOS Thread Aware Debugging

- Part of MCUXpresso IDE
- Show and debug FreeRTOS Tasks/Threads
- **LinkServer** (LPC-Link, LPC-Link2, CMSIS-DAP)
 - Uses 'freertos_tasks_c_additions.h'
 - Uses GDB 'all-stop mode'
 - See 'FreeRTOS_Thread_Aware_Setup.pdf'
- **P&E** (Multilink, OpenSDA)
 - automatically supported/enabled
- **Segger** (J-Link, OpenSDA)
 - Uses GDB server option:
 - rtos GDBServer/RTOSPlugin_FreeRTOS



NXP FreeRTOS Debug Views

- MCUXpresso IDE with FreeRTOS tasks, queues, timers and heap views

The screenshot displays the MCUXpresso IDE interface with several FreeRTOS debug views open. The 'FreeRTOS' menu is visible at the top left, listing 'Task List', 'Queue List', 'Timer List', and 'Heap Usage'. The 'Task List (FreeRTOS)' window shows a table of tasks, with 'Shell' currently running. The 'Heap Usage (FreeRTOS)' window shows a summary of heap usage, indicating 66.36% is used. The 'Queue List (FreeRTOS)' window shows a single queue named 'TmrQ'. The 'Timer List (FreeRTOS)' window shows a single timer named 'timer0'.

FreeRTOS Menu:

- Task List
- Queue List
- Timer List
- Heap Usage
- NXP Community
- About FreeRTOS TAD

Task List (FreeRTOS)

TCB#	Task Name	Task Handle	Task State	Priority	Stack Usage	Event Object	Runtime
> 1	TzCtrl	0x20001bf8	Blocked	1 (1)	120 B / 1.55 kB		0x0 (0.0%)
> 2	MidiPlay	0x20002300	Blocked	1 (1)	128 B / 1.55 kB		0x0 (0.0%)
> 3	Shell	0x20002c08	Running	1 (1)	368 B / 2.14 kB		0x161 (100.0%)
> 4	Main	0x20003a88	Ready	0 (0)	36 B / 3.51 kB		0x0 (0.0%)
> 5							
> 6							

Heap Usage (FreeRTOS)

Type	Heap Base	Heap End	Heap Usage	Free Space	Heap Usage Graph
2	0x200015a0	0x200063c0	12.96 kB / 19.53 kB	33.64% (6.57 kB)	66.36% Used

Queue List (FreeRTOS)

#	Queue Name	Address	Length	Item Size	# Tx ...	# Rx ...	Queue Type
1	TmrQ	0x20003b28	0/10	0x10 (16 B)	0	1	Queue

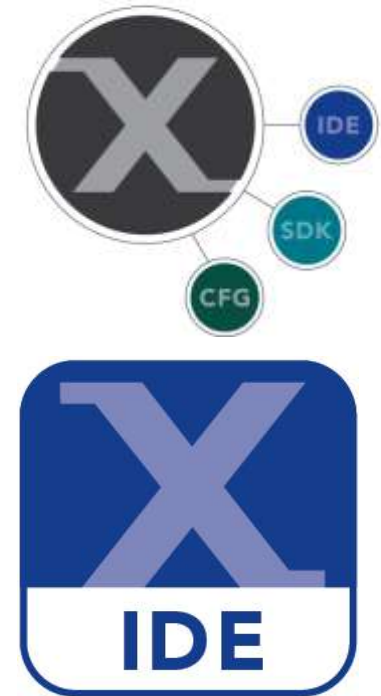
Timer List (FreeRTOS)

ID	Timer Name	Period [ti...	Auto relo...	Timer Number	Callback function
0x0	timer0	10	Yes	0x0	vTimerCallback (0x00000f6d)

Summary

- MCUXpresso is a full featured, state-of-the-art Eclipse based IDE for LPC and Kinetis Microcontrollers
- Free of charge, unlimited code size, easy-to-use
- Easy to use SDK with project generation and example cloning wizard
- GNU/GCC build system with Managed Linker Scripts
- LinkServer/CMSIS-DAP, P&E (Multilink) and Segger (J-Link) debug probe support
- FreeRTOS Kernel and Thread aware debugging
- LinkServer with SWO, ETM/ETB Trace and Power Measurement
- Advanced debugging features (watch variables, peripherals, semihosting, trace and profiling)
- Pro Edition with 1 Year of Email/Ticket support plus unlocked advanced trace features

MCUXpresso Software and Tools





FreeRTOS

FreeRTOS and Tools

- <http://www.freertos.org>
- Maintained by Real Time Engineers Ltd., London
- Open Source, free-of-charge, royalty free
- >35 architectures, >154,000 downloads in 2016
- Portable, simple to learn and use
- Ecosystem
 - OpenRTOS/SafeRTOS: commercial supported versions
 - **SEGGER SystemView**: System Visibility with Segger RTT
 - **PERCEPIO Tracalizer**: Powerful Analysis Views
 - **NXP MCUXpresso SDK** with FreeRTOS
 - **NXP MCUXpresso IDE** with advanced FreeRTOS views

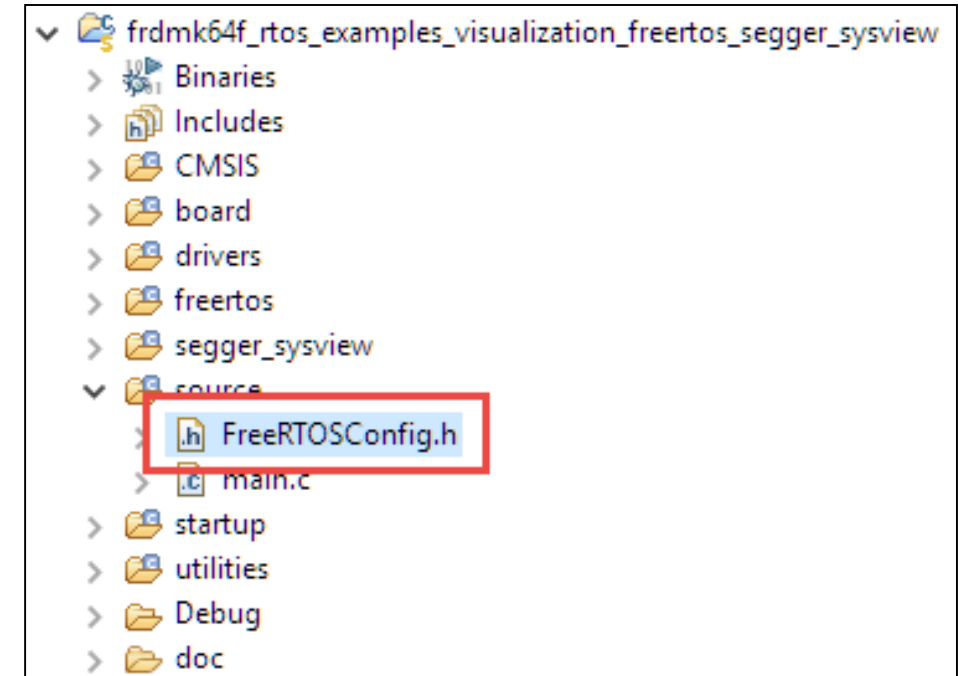


FreeRTOS Application Optimization Approach

- Static
 - FreeRTOS Configuration
 - Only enable what is necessary
 - Compiler/Linker
 - Enable higher level of optimizations (-O3, -flto)
 - Use optimized libraries (no semihosting/no-host, RedLib, newlib-nano)
- Dynamic
 - FreeRTOS Runtime Statistics
 - Segger SystemViewer
 - Percepio Tracealyzer

FreeRTOS Configuration File

- FreeRTOSConfig.h
- Header file configuring the RTOS
 - Features
 - API functionality
 - Diagnostics
 - Performance analysis
 - Hardware configuration and interrupts
- *Recommendation*
 - *Only enable what is needed!*
 - *Requires knowledge of application and RTOS functionality*



Examples in following slides....

Tick Rate

```
#define configTICK_RATE_HZ          ((TickType_t)1000)
```

- Typical tick rates of 100 Hz, 50 Hz or 1 kHz
- All RTOS timing depends on it
- Too high: higher interrupt load
- Too low: bigger timing granularity

- *Recommendation*
 - *Tick rate as low as possible*
 - *Impact: System interrupt load*

Tickless IDLE Mode

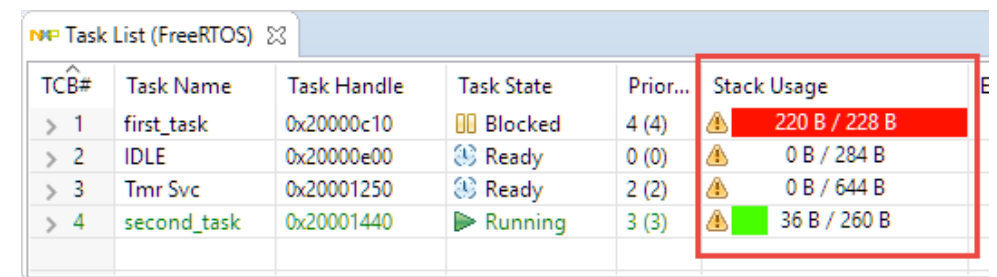
```
#define configUSE_TICKLESS_IDLE 0
```

- SysTick wakes up CPU from low power mode (timing, preemption)
- Extends interrupt periods to reduce interrupts for low-power applications
- *Recommendation*
 - *Enable for low power applications*
 - *Impact: reduced power consumption, time slippage*

Task Stack Size

```
#define configMINIMAL_STACK_SIZE      ((unsigned short)90)
#define configTIMER_TASK_STACK_DEPTH (configMINIMAL_STACK_SIZE * 2)
```

- Stack units on ARM: 32bits!
 - Used by IDLE task, dedicated macro for timer task
 - Often used for task stacks
- *Recommendation*
 - Use *configMINIMAL_STACK_SIZE* for IDLE task only
 - *Timer Task: use dedicated size*
 - *Value as small as possible (use Stack Usage)*
 - *Impact: reduced RAM and Heap*



TCB#	Task Name	Task Handle	Task State	Prior...	Stack Usage
> 1	first_task	0x20000c10	Blocked	4 (4)	220 B / 288 B
> 2	IDLE	0x20000e00	Ready	0 (0)	0 B / 284 B
> 3	Tmr Svc	0x20001250	Ready	2 (2)	0 B / 644 B
> 4	second_task	0x20001440	Running	3 (3)	36 B / 260 B

Application Hooks

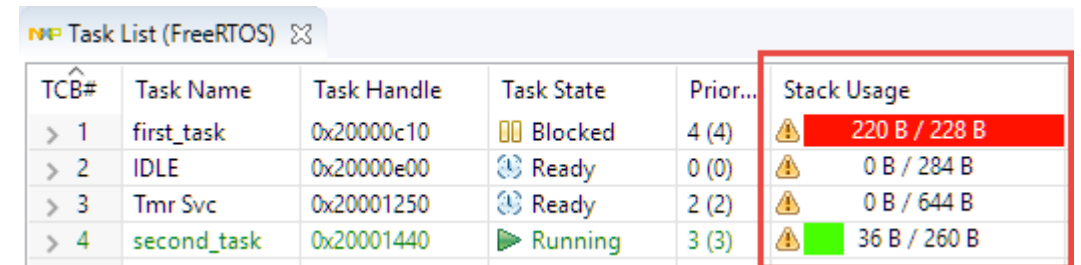
```
#define configUSE_IDLE_HOOK      1
#define configUSE_TICK_HOOK      1
#define configUSE_DAEMON_TASK_STARTUP_HOOK 1
```

- Application hooks for IDLE, tick interrupt or timer daemon startup
- *Recommendation*
 - *Use IDLE hook to enter low power mode*
 - *Use tick hook instead of periodic timer interrupt*
 - *Disable Daemon hook if not used*
 - *Impact: reduced code size, reduced hardware timer usage*

Error Hooks

```
#define configCHECK_FOR_STACK_OVERFLOW 1
#define configUSE_MALLOC_FAILED_HOOK 1
```

- Trap errors stack overflows
 - disabled (0), Method1 (1) and Method2 (2)
- Trap for 'out of heap'
- *Recommendation*
 - Turn on during development
 - Disable for 'release' version
 - Impact: reduced code size, improved context switch time



TCB#	Task Name	Task Handle	Task State	Prior...	Stack Usage
> 1	first_task	0x20000c10	Blocked	4 (4)	220 B / 228 B
> 2	IDLE	0x20000e00	Ready	0 (0)	0 B / 284 B
> 3	Tmr Svc	0x20001250	Ready	2 (2)	0 B / 644 B
> 4	second_task	0x20001440	Running	3 (3)	36 B / 260 B

Assertions

```
#define configASSERT(x) if((x) == 0) \  
    {taskDISABLE_INTERRUPTS(); for (;;);}}
```

- Trap errors during development
- *Recommendation*
 - *Turn on during development*
 - *Disable for 'release' version (define as 'empty')*
 - *Impact: reduced code size*

Maximum Task Priorities

```
#define configMAX_PRIORITIES 5
```

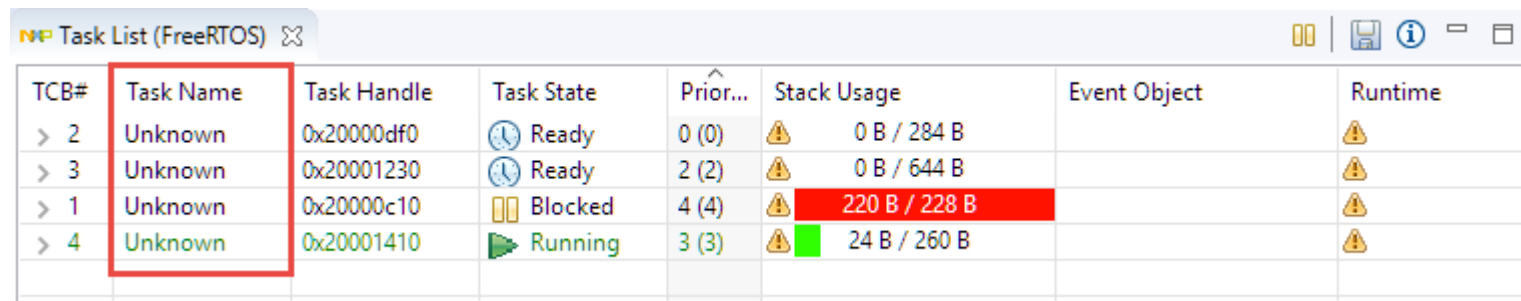
- Task priorities from 0 up to N-1
- Kernel maintains a list for each priority
- *Recommendation*
 - *As small as possible*
 - *No gaps in task priorities*
 - *Share priorities*
 - *Impact: reduced RAM size*

TCB#	Task Name	Task Handle	Task State	Prior...	Stack Usage	Event Object	Runtime
> 2	IDLE	0x20000e00	Ready	0 (0)	0 B / 284 B		
> 3	Tmr Svc	0x20001250	Ready	2 (2)	0 B / 644 B		
> 4	second_task	0x20001440	Running	3 (3)	36 B / 260 B		
> 1	first_task	0x20000c10	Blocked	4 (4)	220 B / 228 B		

Task Name Length

```
#define configMAX_TASK_NAME_LEN 20
```

- Used as name for tasks at creation time
- Name stored in task descriptor
- *Recommendation*
 - *As small as possible, or 1 to disable*
 - *Impact: reduced RAM size*
Limited or no task name in Task List

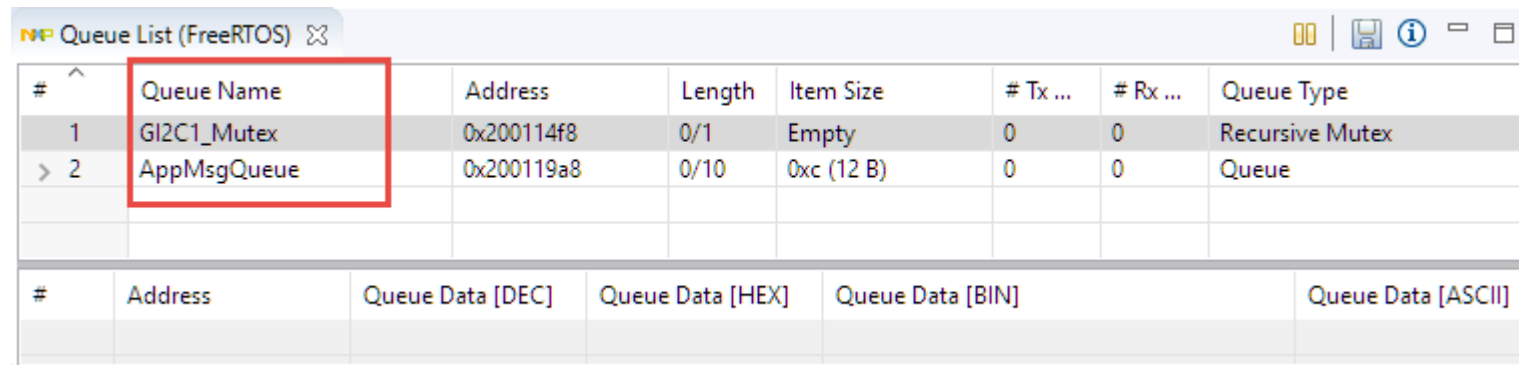


TCB#	Task Name	Task Handle	Task State	Prior...	Stack Usage	Event Object	Runtime
> 2	Unknown	0x20000df0	Ready	0 (0)	0 B / 284 B		
> 3	Unknown	0x20001230	Ready	2 (2)	0 B / 644 B		
> 1	Unknown	0x20000c10	Blocked	4 (4)	220 B / 228 B		
> 4	Unknown	0x20001410	Running	3 (3)	24 B / 260 B		

Queue Registry

```
#define configQUEUE_REGISTRY_SIZE 8
```

- Registry to store names for queues, semaphore and mutex
- *Recommendation*
 - *As small as possible, or 0 to disable*
 - *Impact: reduced RAM size, reduced code size, no names for queues/semaphore/mutex*



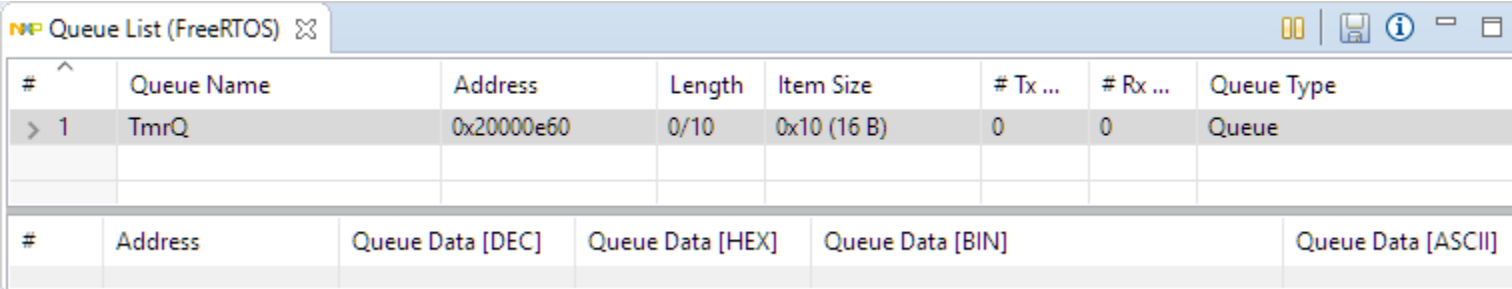
#	Queue Name	Address	Length	Item Size	# Tx ...	# Rx ...	Queue Type
1	GI2C1_Mutex	0x200114f8	0/1	Empty	0	0	Recursive Mutex
> 2	AppMsgQueue	0x200119a8	0/10	0xc (12 B)	0	0	Queue

#	Address	Queue Data [DEC]	Queue Data [HEX]	Queue Data [BIN]	Queue Data [ASCII]

RTOS Timers

```
#define configUSE_TIMERS 1
#define configTIMER_TASK_PRIORITY 2
#define configTIMER_QUEUE_LENGTH 10
#define configTIMER_TASK_STACK_DEPTH (configMINIMAL_STACK_SIZE * 2)
```

- Software timer, implemented with Daemon task and message queue
- *Recommendation*
 - *Disable if not used, or use values as small as possible*
 - *Use FreeRTOS timers for low power applications instead of HW timers*
 - *Impact: reduced RAM size, reduced code size*



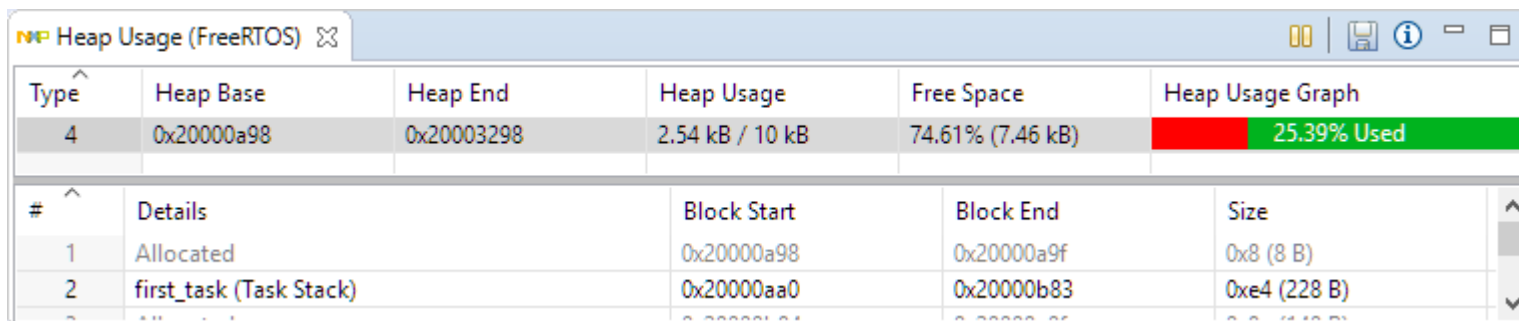
#	Queue Name	Address	Length	Item Size	# Tx ...	# Rx ...	Queue Type
> 1	TmrQ	0x20000e60	0/10	0x10 (16 B)	0	0	Queue

#	Address	Queue Data [DEC]	Queue Data [HEX]	Queue Data [BIN]	Queue Data [ASCII]
---	---------	------------------	------------------	------------------	--------------------

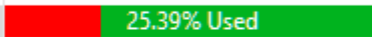
Heap Scheme

```
#define configFRTOS_MEMORY_SCHEME 4
```

- 0: allocate only, 1: no block merge, 3: malloc()/free(), 4: merges blocks, 5: multiple memory areas
- *Recommendation*
 - Use scheme 0, 3 if middleware uses malloc()/free(), otherwise 4
 - Use static allocation (configSUPPORT_STATIC_ALLOCATION 1) with no dynamic allocation (configSUPPORT_DYNAMIC_ALLOCATION 0)
 - Impact: reduced RAM size, reduced code size



The screenshot shows the NXP Heap Usage (FreeRTOS) tool interface. It displays a summary table and a detailed view of heap blocks.

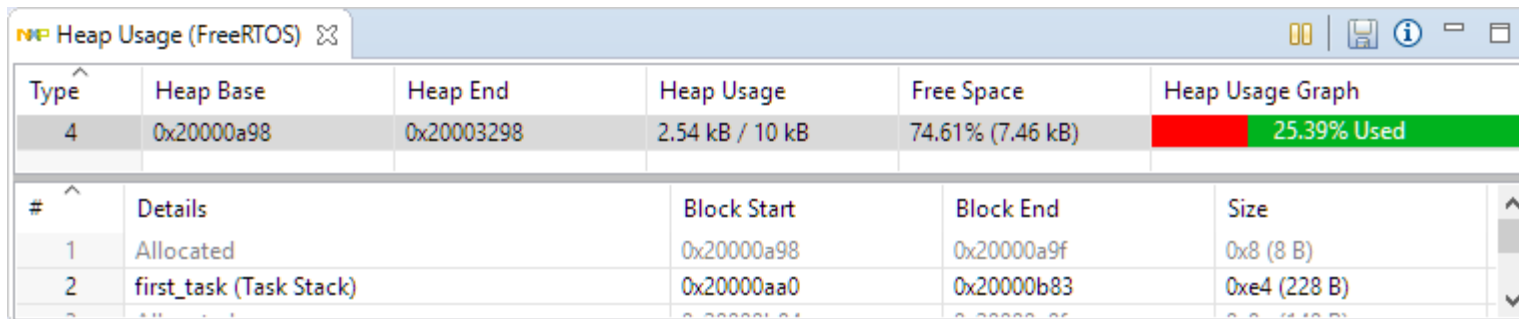
Type	Heap Base	Heap End	Heap Usage	Free Space	Heap Usage Graph
4	0x20000a98	0x20003298	2.54 kB / 10 kB	74.61% (7.46 kB)	

#	Details	Block Start	Block End	Size
1	Allocated	0x20000a98	0x20000a9f	0x8 (8 B)
2	first_task (Task Stack)	0x20000aa0	0x20000b83	0xe4 (228 B)


Heap Size

```
#define configSUPPORT_STATIC_ALLOCATION      0
#define configSUPPORT_DYNAMIC_ALLOCATION    1
#define configTOTAL_HEAP_SIZE              ((size_t)(10 * 1024))
```

- Dynamic memory for task stack, queues, semaphore, ...
- *Recommendation*
 - *As small as possible, static allocation (configSUPPORT_STATIC_ALLOCATION 1) with no dynamic allocation (configSUPPORT_DYNAMIC_ALLOCATION 0)*
 - *Impact: reduced RAM size, reduced code size*



The screenshot shows the NXP Heap Usage (FreeRTOS) tool interface. The main window displays a summary table with the following data:

Type	Heap Base	Heap End	Heap Usage	Free Space	Heap Usage Graph
4	0x20000a98	0x20003298	2.54 kB / 10 kB	74.61% (7.46 kB)	 25.39% Used

Below the summary table, a detailed view of heap blocks is shown:

#	Details	Block Start	Block End	Size
1	Allocated	0x20000a98	0x20000a9f	0x8 (8 B)
2	first_task (Task Stack)	0x20000aa0	0x20000b83	0xe4 (228 B)

Runtime Statistics

```
#define configGENERATE_RUN_TIME_STATS 0
#define configUSE_TRACE_FACILITY 1
#define configUSE_STATS_FORMATTING_FUNCTIONS 0
```

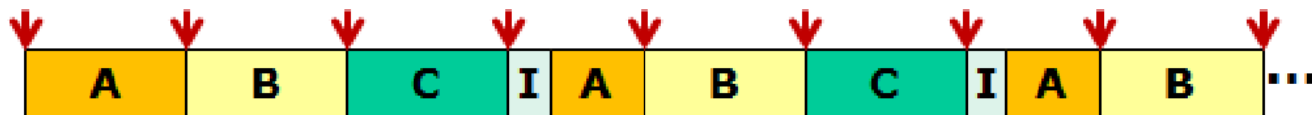
- Collects runtime statistics
- *Recommendation*
 - Turn off for release
 - Impact: reduced RAM size, reduced code size, improved performance, no statistics

TCB#	Task Name	Task Handle	Task State	Prior...	Stack Usage	Event Object	Runtime
> 1	Shell	0x20011490	Blocked	1 (1)	172 B / 4.88 kB		0x0 (0.0%)
> 3	App	0x200139c0	Running	1 (1)	1.79 kB / 7.8 kB		0x1190 (100.0%)
> 2	Accel	0x20011940	Ready	1 (1)	372 B / 992 B		0x0 (0.0%)
> 4	IDLE	0x20013bc0	Ready	0 (0)	36 B / 392 B		0x0 (0.0%)

Idle Yielding

```
#define configIDLE_SHOULD_YIELD 1
```

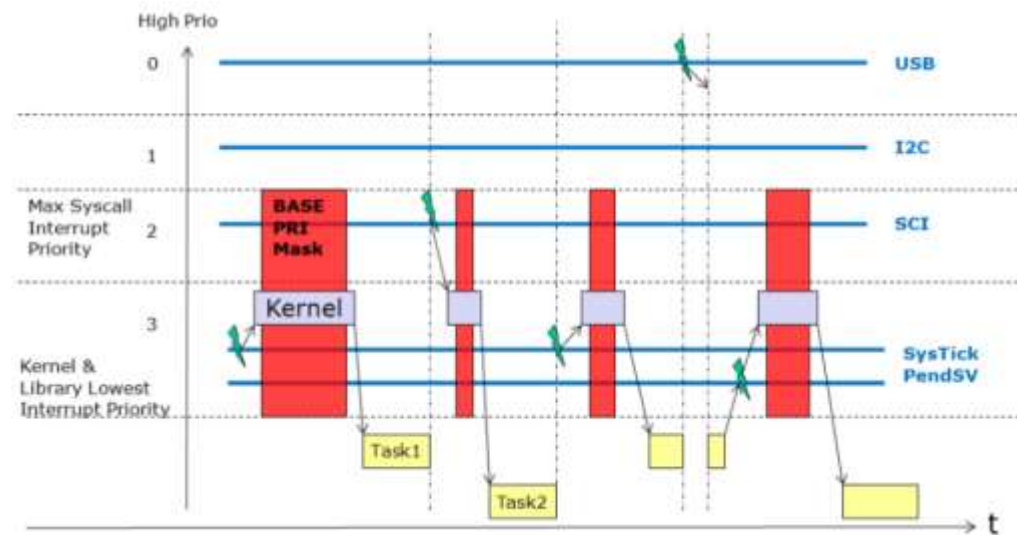
- In preemptive mode allows IDLE task to give back time to tasks
- *Recommendation*
 - *Enable IDLE yielding*
 - *Impact: improved application performance*



Cortex-M Interrupts

```
#define configLIBRARY_MAX_SYSCALL_INTERRUPT_PRIORITY 2
```

- Cortex-M0+: Scheduler masks all interrupts; Cortex-M4(F): only SYSCALL and below (less urgent)
- *Recommendation*
 - *Put interrupts which do **not** use RTOS API above SYSCALL level*
 - *Impact: improved application performance, less interrupt latency*



Cortex-M Interrupts

```
#define configUSE_PORT_OPTIMISED_TASK_SELECTION 1
```

- Optimized task selection using bit instructions
- Supports up to 32bit task priorities

- *Recommendation*
 - *Enable for Cortex-M4/M7*
 - *Impact: improved application performance (~1%)*

FreeRTOS Trace Hooks

```
#ifndef traceTASK_SWITCHED_OUT
    /* Called before a task has been selected to run.  pxCurrentTCB holds a pointer
    to the task control block of the task being switched out. */
    #define traceTASK_SWITCHED_OUT()
#endif
```

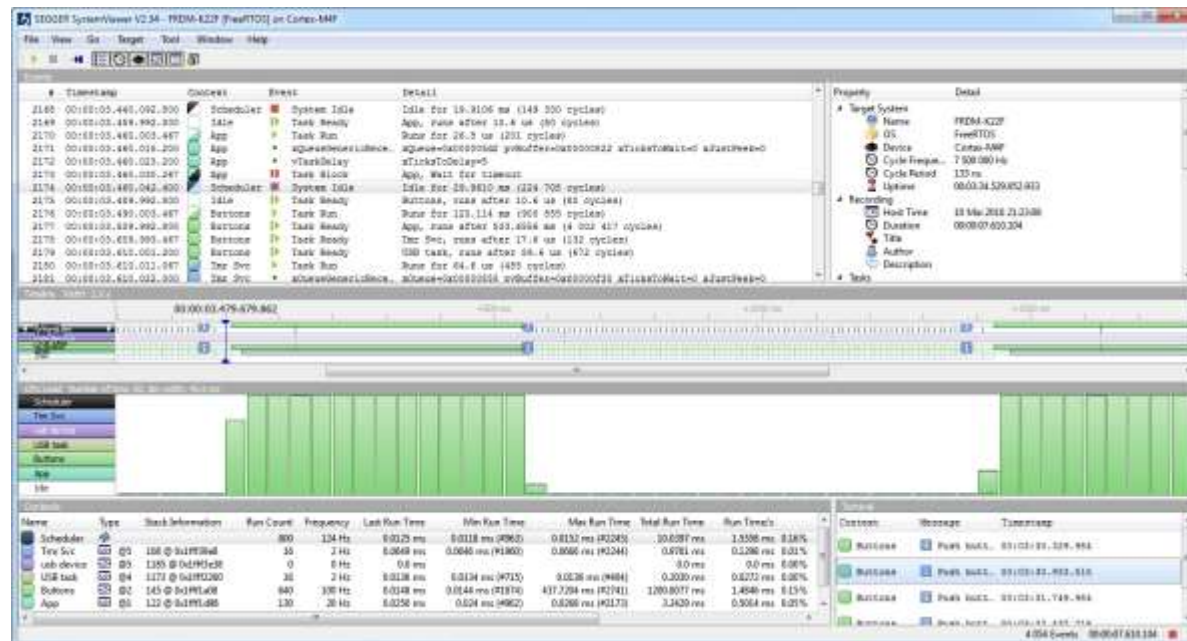
- Instruments Kernel with additional trace hooks
- Macros provided by user or trace library
 - Percepio Tracalyzer
 - Segger SystemView
- *Recommendation*
 - *Disable for release version, use for application tuning and debugging*
 - *Impact: improved application performance*



Ecosystem around FreeRTOS Optimization

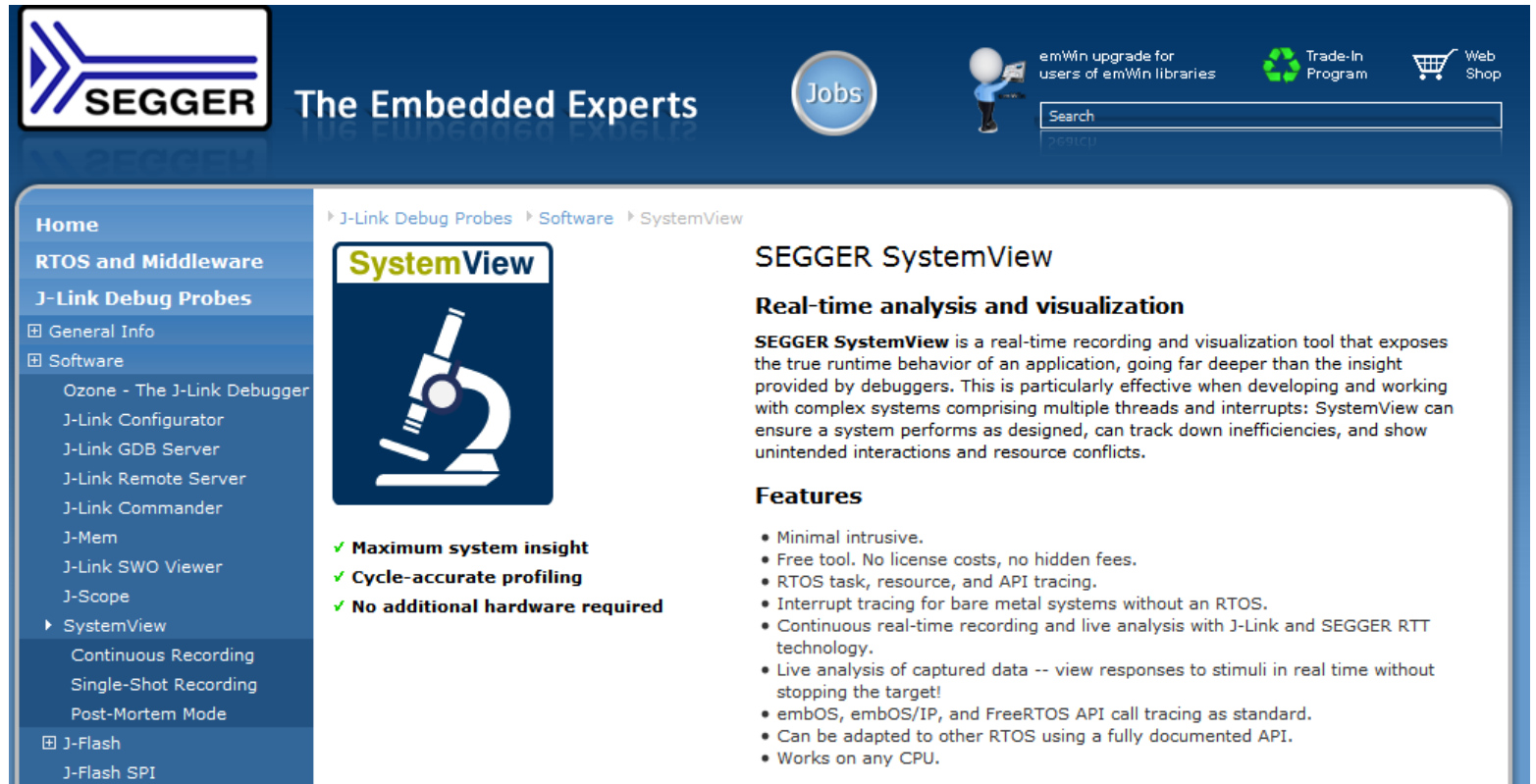
Segger SystemView

- Free-of-Charge, requires Segger debug interface
- Uses Segger RTT (Real Time Transfer)
- Realtime data recording and time measurement
- Continuous, Single-Shot and Post-Mortem recording
- Uses Cortex M4 Cycle count register, SysTick on M0+
- <http://mcuoneclipse.com/2015/11/16/segger-systemview>



Segger SystemView

- <https://www.segger.com/link-software.html>
- <https://www.segger.com/systemview.html>



The screenshot shows the Segger website's product page for SystemView. The header features the Segger logo and tagline 'The Embedded Experts', along with navigation links for 'Jobs', 'emWin upgrade for users of emWin libraries', 'Trade-In Program', and 'Web Shop'. A search bar is also present. The left sidebar contains a navigation menu with categories like 'Home', 'RTOS and Middleware', 'J-Link Debug Probes', 'General Info', 'Software', 'Ozone - The J-Link Debugger', 'J-Link Configurator', 'J-Link GDB Server', 'J-Link Remote Server', 'J-Link Commander', 'J-Mem', 'J-Link SWO Viewer', 'J-Scope', 'SystemView', 'Continuous Recording', 'Single-Shot Recording', 'Post-Mortem Mode', 'J-Flash', and 'J-Flash SPI'. The main content area displays the SystemView logo (a microscope icon) and lists three key features: 'Maximum system insight', 'Cycle-accurate profiling', and 'No additional hardware required'. The right side of the page provides a detailed description of SystemView as a real-time recording and visualization tool, followed by a list of features such as minimal intrusiveness, being a free tool, and support for various RTOS and APIs.

SEGGER The Embedded Experts

Jobs

emWin upgrade for users of emWin libraries

Trade-In Program

Web Shop

Search

Home

RTOS and Middleware

J-Link Debug Probes

General Info

Software

Ozone - The J-Link Debugger

J-Link Configurator

J-Link GDB Server

J-Link Remote Server

J-Link Commander

J-Mem

J-Link SWO Viewer

J-Scope

SystemView

Continuous Recording

Single-Shot Recording

Post-Mortem Mode

J-Flash

J-Flash SPI

J-Link Debug Probes Software SystemView

SystemView

- ✓ **Maximum system insight**
- ✓ **Cycle-accurate profiling**
- ✓ **No additional hardware required**

SEGGER SystemView

Real-time analysis and visualization

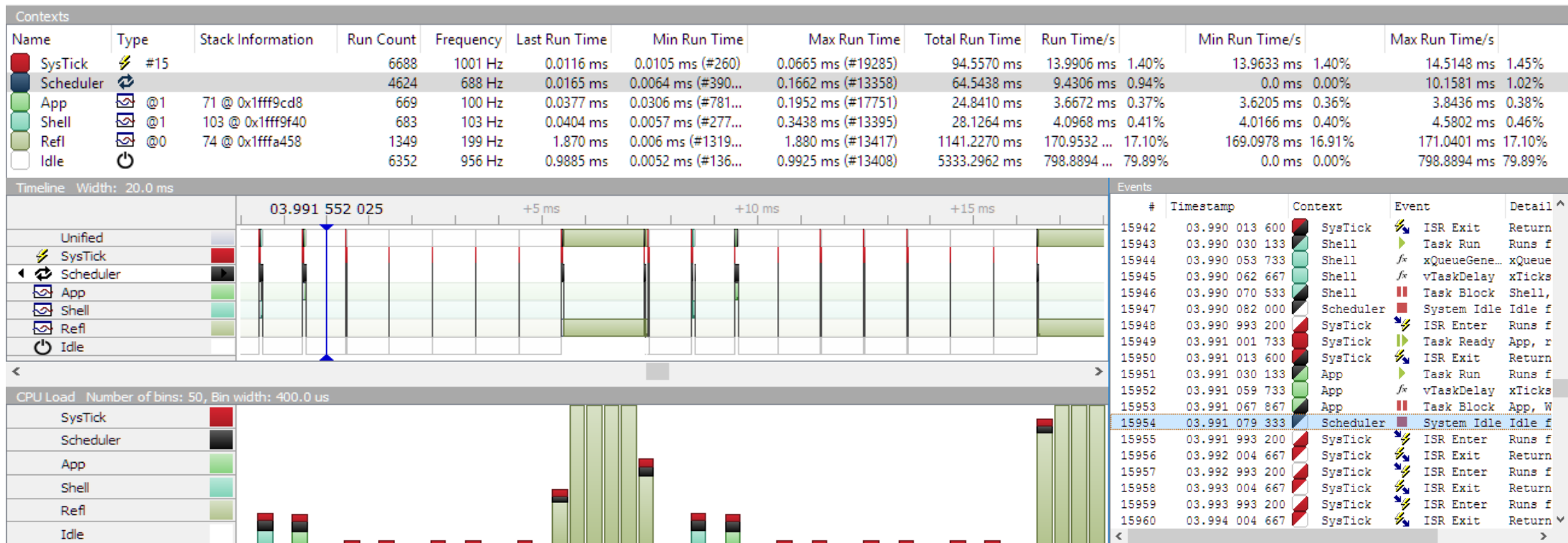
SEGGER SystemView is a real-time recording and visualization tool that exposes the true runtime behavior of an application, going far deeper than the insight provided by debuggers. This is particularly effective when developing and working with complex systems comprising multiple threads and interrupts: SystemView can ensure a system performs as designed, can track down inefficiencies, and show unintended interactions and resource conflicts.

Features

- Minimal intrusive.
- Free tool. No license costs, no hidden fees.
- RTOS task, resource, and API tracing.
- Interrupt tracing for bare metal systems without an RTOS.
- Continuous real-time recording and live analysis with J-Link and SEGGER RTT technology.
- Live analysis of captured data -- view responses to stimuli in real time without stopping the target!
- embOS, embOS/IP, and FreeRTOS API call tracing as standard.
- Can be adapted to other RTOS using a fully documented API.
- Works on any CPU.

SEGGER SystemView

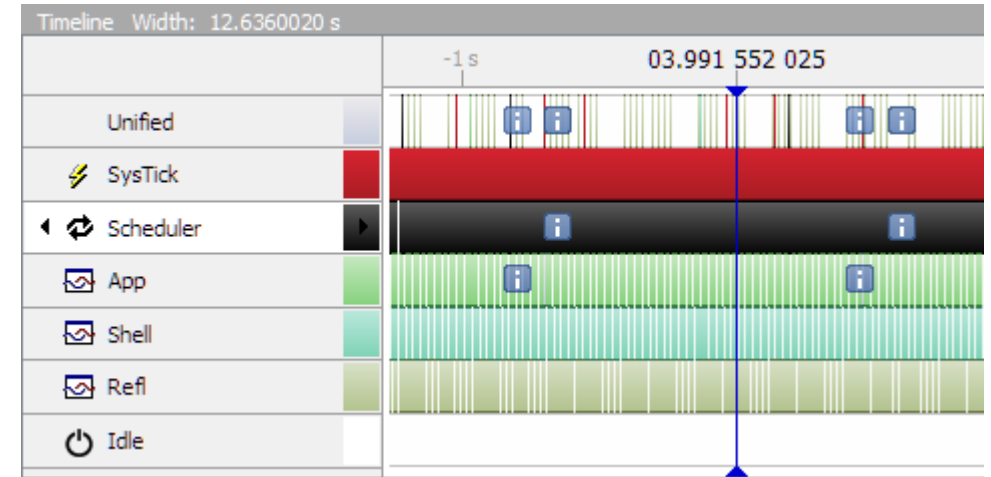
- Detailed Application plus RTOS trace
- Understand and Optimize!



User SystemViewer Events

```
SEGGER_SYSVIEW_RecordEnterISR();  
...  
SEGGER_SYSVIEW_RecordExitISR();
```

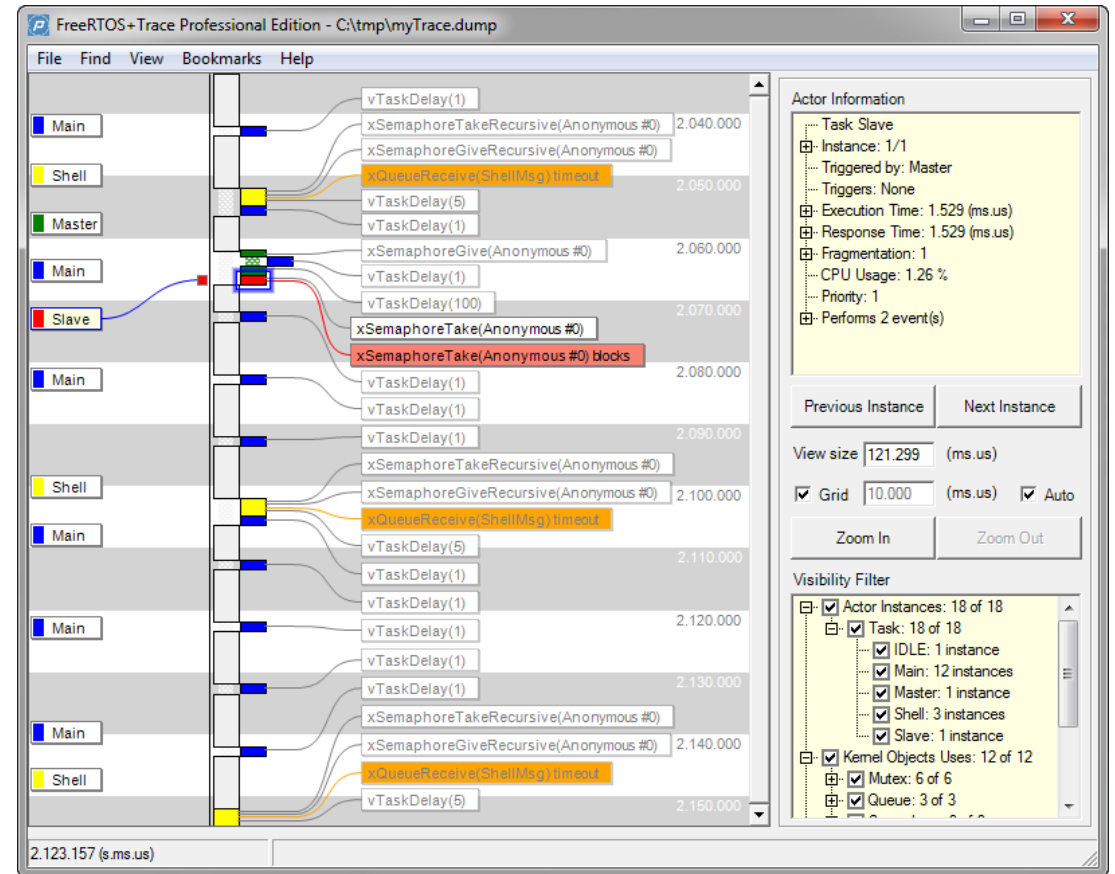
- Ability to instrument application and interrupts
- Log messages and event markers
- *Recommendation*
 - Use for measurement and debugging
 - Turn off for release
 - Impact: improved application



Timestamp	Context	Message
19.119 032	App	KEYDBNC
19.269 011	Scheduler	KEYDBNC
19.269 087	Scheduler	KEYDBNC
20.369 032	App	KEYDBNC
20.519 011	Scheduler	KEYDBNC
20.519 087	Scheduler	KEYDBNC

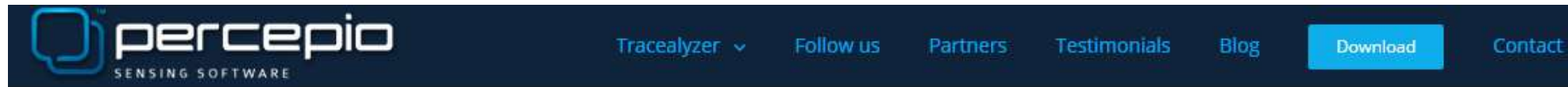
Percepio Tracealyzer

- Percepio (<http://www.percepio.com>)
- Free/Professional (Paid) edition
- Hosts: Windows, Linux
- Over 20 graphical views
- Tasks, System Calls and User Events
- CPU Load
- Timing Variations
- Communication Flow
- Kernel Object History
- User Events, Signal Plots
- Eclipse launcher plugin



FreeRTOS+Trace Tracealyzer from Percepio

- Tracealyzer for FreeRTOS: <http://percepio.com/download/>
- Free version (task scheduling only)
- 30 day evaluation (Professional Edition) license



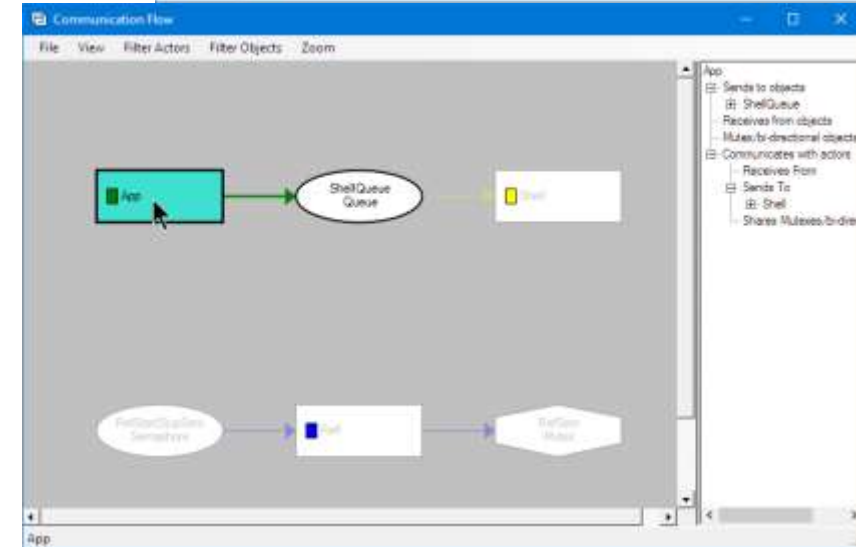
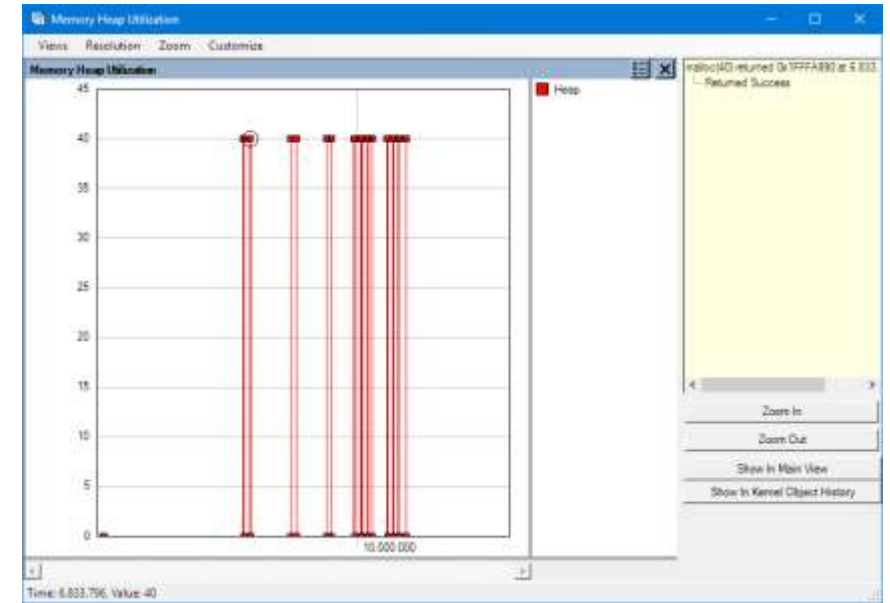
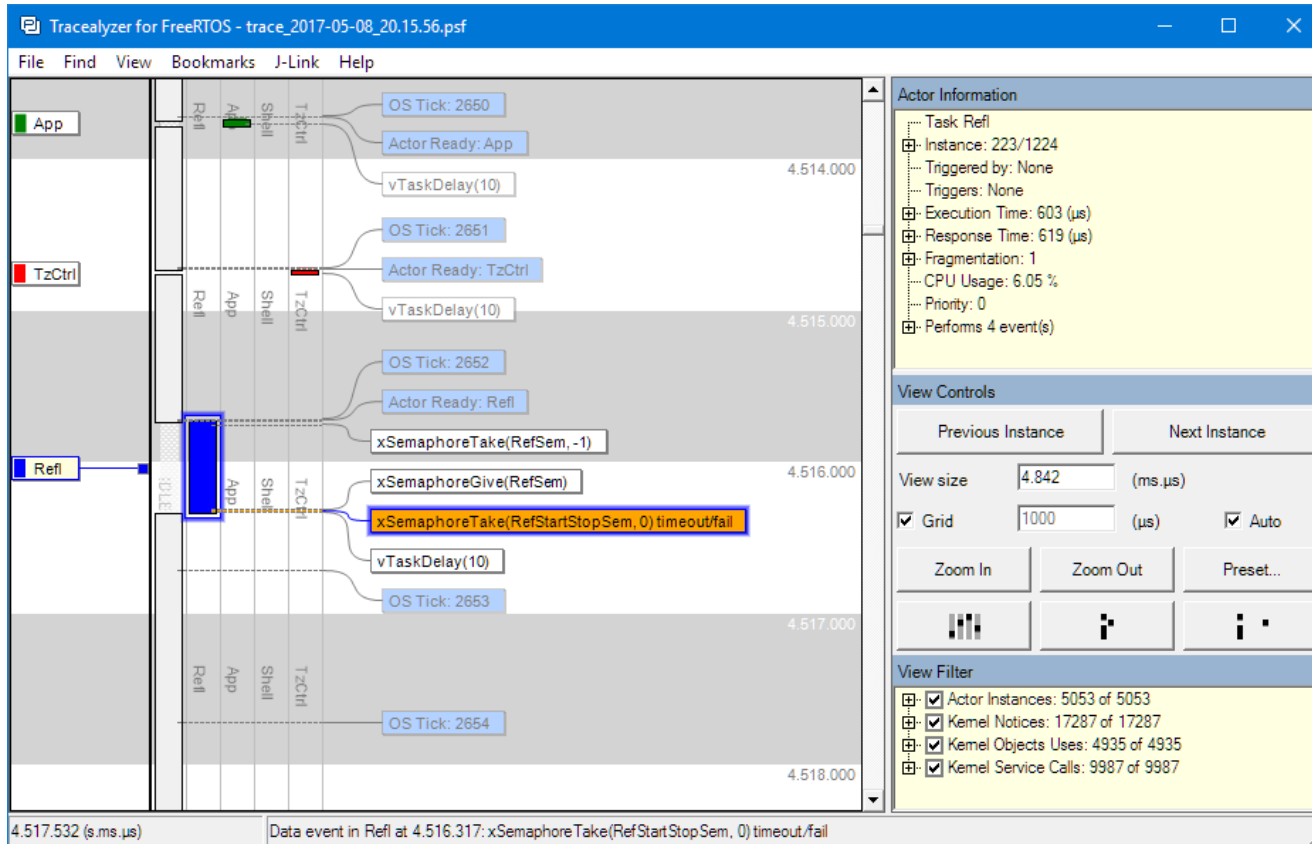
Download Tracealyzer and get started within a minute!

Tracealyzer is provided in a single installer for demo, evaluation and commercial use. The evaluation mode is enabled by registering in the application and allows for **10 days evaluation** usage. If you need more time, you may [request an extension](#). There is also a **demo** mode that allows you to start exploring the visualization right away, using an example trace. If using Linux, download the .tgz archive, extract and run the application using [Mono](#).

	Windows installer (.exe)	Other OS (.tgz)
Tracealyzer for FreeRTOS	Download	Download

Tracalyzer Views

- Memory Heap Utilization (memory leaks)
- Communication Flow (usage of queues)
- Timeouts





Summary

Summary

- NXP FreeRTOS Enablement
 - MCUXpresso IDE
 - MCUXpresso SDK
 - MCUXpresso Config Tools
- Optimizing FreeRTOS
 - FreeRTOS Configuration
 - Segger RTT and SystemView
 - Percepio Tracealyzer
 - NXP Kernel and Thread Awareness





MCUXpresso
Software and Tools

COMMON TOOLKIT
FOR THOUSANDS
OF KINETIS® & LPC
MICROCONTROLLERS



www.nxp.com/mcuxpresso

Additional Resources

- Web pages
 - MCUXpresso Software and Tools – www.nxp.com/mcuxpresso
 - MCUXpresso SDK – www.nxp.com/mcuxpresso/sdk
 - MCUXpresso IDE – www.nxp.com/mcuxpresso/ide
 - MCUXpresso Config Tools – www.nxp.com/mcuxpresso/config
 - [Supported Devices Table \(Community Doc\)](#)
- Communities
 - MCUXpresso Software and Tools - <https://community.nxp.com/community/mcuxpresso>
 - MCUXpresso SDK – <https://community.nxp.com/community/mcuxpresso/mcuxpresso-sdk>
 - MCUXpresso IDE – <http://www.nxp.com/mcuxpresso/ide/forum>
 - MCUXpresso Config Tools – <https://community.nxp.com/community/mcuxpresso/mcuxpresso-config>



SECURE CONNECTIONS
FOR A SMARTER WORLD