## OPTIMIZE FreeRTOS WITH MCUXPRESSO SOFTWARE AND TOOLS

CLARK JARVIS MCUXPRESSO SOFTWARE AND TOOLS PRODUCT MARKETER AMF-DES-T2634 | JUNE 2017





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## AGENDA

- Overview MCUXpresso Software and Tools
  - MCUXpresso SDK
  - MCUXpresso Config Tools
  - MCUXpresso IDE
- Overview FreeRTOS
  - -FreeRTOS
  - Segger RTT and SystemView
  - Percepio Tracealizer
  - -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/mc@xpresso

CFG

IDE

SDI

### **MCUXpresso Software and Tools**

for Kinetis and LPC microcontrollers



SDK

#### **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

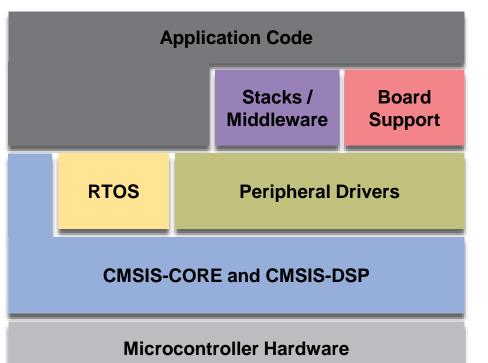
- Kinetis MCUs
- LPC Microcontrollers
- i.MX Application Processors



### **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
- IwIP, 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



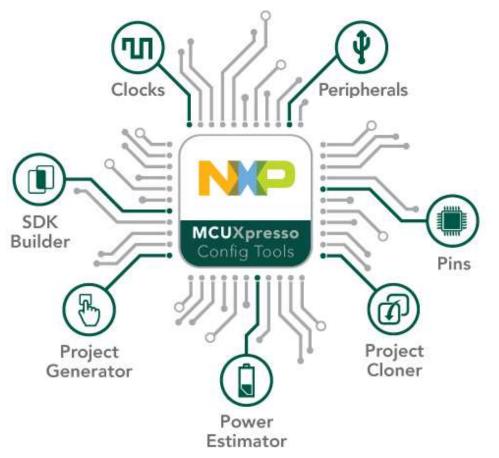
Open Source Initiative



## **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.

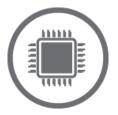


**Project Cloning** creates a standalone SDK project based on a example application available within SDK release.



**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

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#### **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**

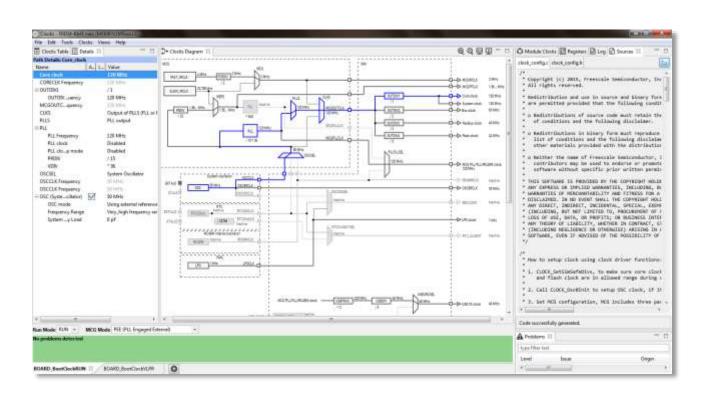
for Kinetis & LPC

Easy-to-use clock configuration



#### **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

		Create a new configuration	-	
	ment with the selected MCUXpresso SDKv2 Package (SDK can be obtained a	Clone an SDK example		
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		SDK v2 +		
		Name your configuration		
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#### **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

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l		Eclipse	Framework f	for C/C++, extensib	ble with many	plugins		
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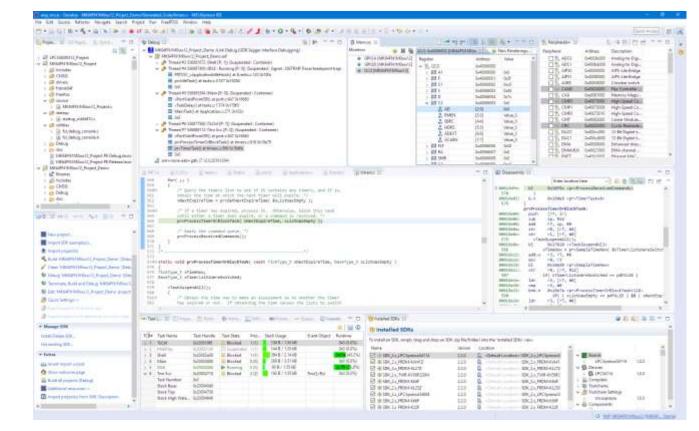
#### **Product Features**

- 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



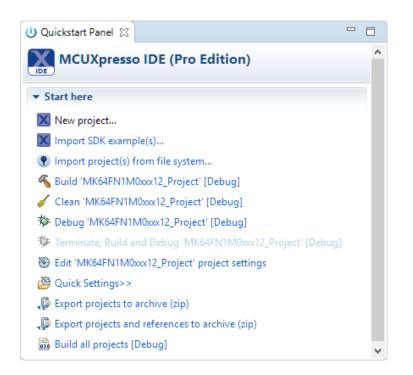
## **Eclipse Framework**

- 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



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### **New Project Wizard: Data Driven Device Support**

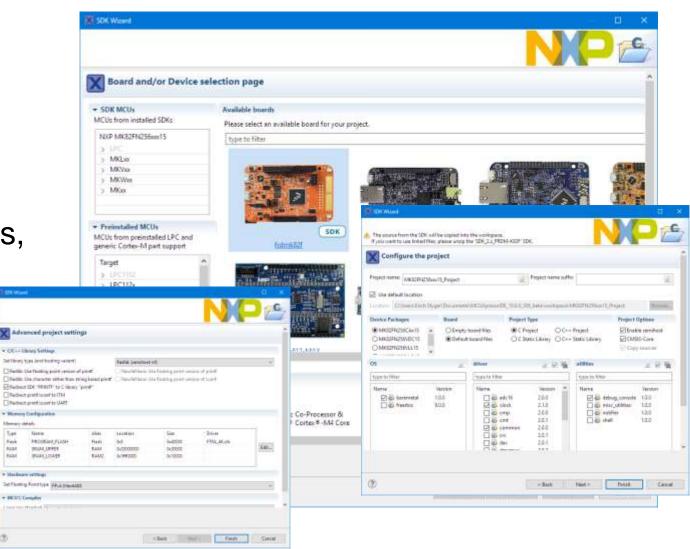
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- SDK MCUs (LPC and Kinetis)
- Preinstalled LPC and generic Cortex-M
- Installable device support through SDK packages (data driven)
- Selection of package, RTOS, drivers, utilities
- Standalone and linked projects
- Advanced project settings







#### **Device Support**

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

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🕅 Installed SDKs				
To install an SDK, simply drag a	and drop an SDK	zip file/folder) into the 'Installed SDKs' view.		
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## **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

<ul> <li>MCU C Compiler</li> <li>Dialect</li> <li>Preprocessor</li> </ul>	Manage linker script Enable automatic placer Link application to RAM	-	ration field in image	
🖄 Includes 🖄 Optimization	Stack offset	0		
Debugging	Library	NewlibNano (nohos	t)	~
Warnings Wiscellaneous Architecture	Enable printf float     Enable scanf float			
<ul> <li>MCU Assembler</li> </ul>	Linker script	MK64FN1M0xxx12_F	project_Demo_Debug	ld
(월 General (철 Architecture & Headers	Script path			
🖌 🛞 MCU Linker	Heap and Stack placement	MCUXpresso Style		~
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Architecture	libNano (nohost)		~	
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### **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

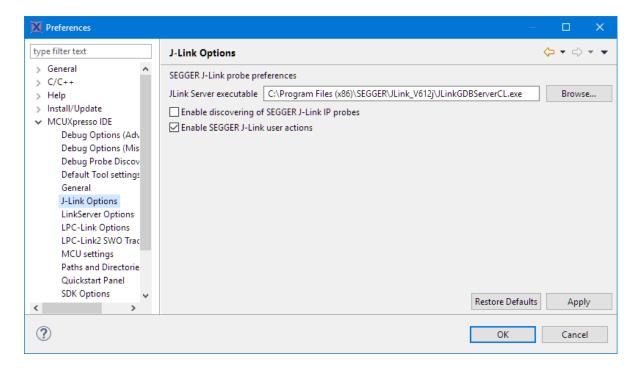






#### **Automatic Probe Discovery and Configuration**

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



X Probes discovered				- 🗆	×
Connect to target: MK64FN1N					
3 probes found. Select the probe	to use:				
Available attached prob	es				
Name	Serial number/ID	Туре	Manu	IDE Debug I	Mode
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🔒 J-Link OpenSDA	621000000	USB	SEGGER	All-Stop	
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### **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)

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Name	Value	Description 🔶		Thread [1] < main> (Suspended : Step)
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1010 r <b>1</b>	0x0000004			m0slave Debug [C/C++ (NXP Semiconductors) MCU 4 m0slave.axf
1010 r2	0x02010000		1	
1010 r3	0xE000ED08			Thread [1] < main> (Suspended : Breakpoint) main() at m0slave.c:35 0x201016c
1010 0101 <b>r4</b>	0x020100D4			
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1919 Registers <1> 🔀	🏝 📲 🗖 🚺	3 🛃 🔻 🗖 🖬	25 26	<pre>defined (MULTICORE_MASTER_SLAVE_M4SL boot_multicore_slave();</pre>
m4master.axf: Thread [1]			27	#endif
Name	Value	Description	28	// TODO: insert code here
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1919 rO	0x02010119		31	<pre>// Force the counter to be placed into</pre>
1010 r <b>1</b>	0x0000004D		32 33	<pre>volatile static int i = 0 ; // Enter an infinite loop, just increm</pre>
1010 r2	0xC0C4004D		34	while(1) {
1910 r3	0x40000300		⇒ 35	i++ ;
		•	36	}
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## 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

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Cor	Connect to target: MK64FN1M0xxx12										
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Av	Available attached probes										
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(×)= sensorValue	long	1048	
			0
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🖳 Real Time Expressions 🛛	🏝 📲 📄 🕷	: ×	S 🚱 🗸	
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(x)= nofSamples	int		7290	
🖶 Add new expression				
<				3
				1
<				>

#### **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)

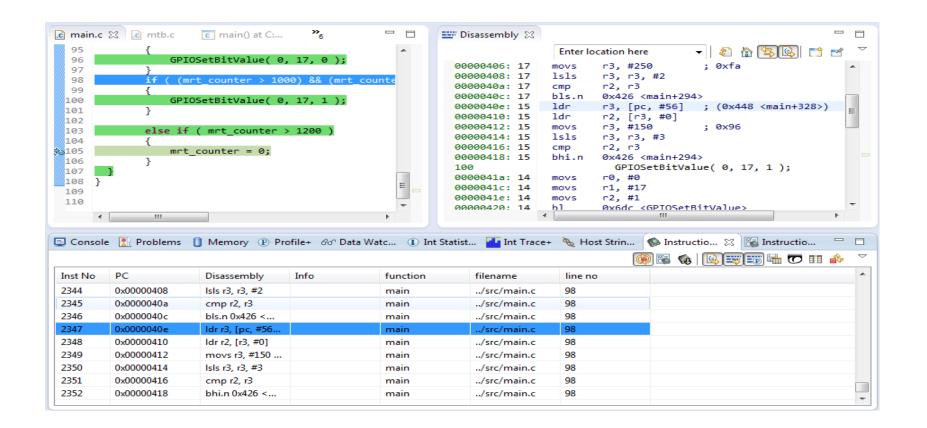
	🛃 Peripherals+ 🛛	1. st			1919 Regis	ters 🛛	🏝 📲 🗖 🗖	i 🛃 🔍 🗖 🖬
	Peripheral	Address	Description	^	Name		Value	Description ^
	🗌 🛃 FTM0	0x40038000	FlexTimer Module		🗸 👬 N	/K64FN1M0xxx12		MK64FN1M0x
	□ 🗖 FTM1	0x40039000	FlexTimer Module		10	10 rO	0x0000007	
	E RTM2	0x4003a000	FlexTimer Module		10	10 r1	0x0000000	
	🗌 🛃 FTM3	0x400b9000	FlexTimer Module		10	19 r2	0x0000EA60	
	🗌 🛃 GPIOA	0x400ff000	General Purpose In	pu	10	11 r3	0x00004DBC	
	🗌 🛃 GPIOB	0x400ff040	General Purpose In		10	<sup>10</sup> r4	0xA5A5A5A5	
	🖂 🛃 GPIOC	0x400ff080	General Purpose In			11 r5	0xA5A5A5A5	
	🗌 🛃 GPIOD	0x400ff0c0	General Purpose In		10	11 r6	0xA5A5A5A5	
	🗌 🛃 GPIOE	0x400ff100	General Purpose In		10	10 r7	0x20002AB8	
	🗌 🛃 I2C0	0x40066000	Inter-Integrated Cir			11 r8	0xA5A5A5A5	
	□ <mark></mark>	0x40067000	Inter-Integrated Cir			11 r9	0xA5A5A5A5	
	□ <mark> </mark>	0x400e6000	Inter-Integrated Cir			19 r10	0xA5A5A5A5	
	□ <sup>1</sup> / <sub>2</sub> 12S0	0x4002f000	Inter-IC Sound / Sy			li r11	0xA5A5A5A5	
		0x4007c000	Low leakage wakeu	p		11 r12	0xA5A5A5A5	
		0x40040000	Low Power Timer			10 sp	0x20002AB4	
	□ 🚡 MCG	0x40064000	Multipurpose Clock			19 Ir	0x000129C1	
		0xe0080000 0xe000e100	Core Platform Misc			10 pc	0x00012990	
			Intested vectored int	rer		li psr	0x81000000	
	MK64FN1M0xxx12 Per GPIOC [0x400ff080]	ipheral:				19 flags	Nzcvg	
	General Purpose Input	/Output				11 epsr	none	
<b>.</b>						19 ipsr	0 (Base)	
📋 Memory 🔀		👕 🛃 101 <u>9</u> 1010 📑	🛛 🕄 🖏 🖷 ·	• ~ •		lî msp	0x2002FFE0	
Monitors	🕂 🗶 💥 GPIO	D: 0x400ff0c0 [MK64F	🕄 🕂 New	Renderin		11 control	0x0000002	
		_	_		3	19 cycle	0x07613A23	
-	/K64FN1M0xxx Regi	ster	Address	Value		11 cycledelta	0x00E76F7B	
GPIOD [N	NK64FN1M0xxx 🗸 🚽	GPIOD	0x400ff0c0			10 vectpc	n/a	
I2C0 [MK		iiii PDOR	0x400ff0c0	0x6	0	11 faults	n/a	
		lili PSOR	0x400ff0c4	<write< td=""><td>onho i</td><td>10 basepri</td><td>0x0000000</td><td></td></write<>	onho i	10 basepri	0x0000000	
		All PSOR All PCOR	0x400ff0c8		office of the second se	11 primask	0x0000000	
				<write< td=""><td></td><td>1) faultmask</td><td>0v0000000</td><td>¥</td></write<>		1) faultmask	0v0000000	¥
		😁 PTCO	[31:0]	<write< td=""><td></td><td></td><td></td><td>&gt;</td></write<>				>
		Bill PTOR	0x400ff0cc	<write< td=""><td>-</td><td>cycle</td><td></td><td>^</td></write<>	-	cycle		^
		Bill PDIR	0x400ff0d0	0хб		:0x07613a23		
		Sill PDDR	0x400ff0d4	0xf		imal:1238123: al:007302350		~
						ALCONCOMPTON	+ 1	>
<	>							





### Instruction Trace (NXP LinkServer)

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



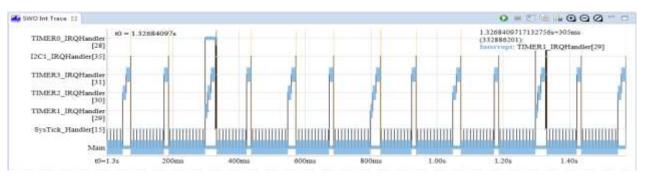
#### SWO Trace (NXP LinkServer)

#### IND SWO ITM Console 🔀

O = E + - -

Enable Trace	Value							100 C	E + + = = =
	value	Format	Type	Access	Item	Value	Time	Access	Repeats
V count_ct0	0x00000130	0x%08x	Value	Read	count_ct0	0x00000130	1.241m	W	0
Count_ctl	0x0000025d	0x%08x	Value	Read	count_ct0	0x0000012f	1.241m	R	0
count_stick	0x000076cb	0x%08x	Value	Read	count_ct1	0x0000025d	1.240m	W	0
CONTRACTOR COMPACT					count_ct1	0x0000025c	1.240m	R	0
					count_ct1	0x0000025c	1.232m	W	0
					count_ct1	0x000025b	1.232m	R	0
					count_ct0	0x0000012f	1.224m	W	0
a subscription of the participation of the particip	and the second second second	dial second			count ct0	0x0000012e	1.224m	R	0
	v count_ct1	Image: count_ct1         0x0000025d           Image: count_stick         0x000076cb	W count_ct1 0x0000025d 0x%08x	Image: Count_ctl         0x0000025d         0x%08x         Value           Image: Count_stick         0x000076cb         0x%08x         Value	Image: count_ctl     0x0000025d     0x%08x     Value     Read       Image: count_stick     0x000076cb     0x%08x     Value     Read	Image: Count_ct1       0x0000025d       0x%08x       Value       Read       count_ct0         Image: Count_ttick       0x000076cb       0x%08x       Value       Read       count_ct1         Image: Count_ttick       0x000076cb       0x%08x       Value       Read       count_ct1         Image: Count_ttick       0x000076cb       0x%08x       Value       Read       count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1       Image: Count_ct1         Image: Count_ttick       Image: Count_ct1       Image	Count_ct1         0x0000025d         0x%08x         Value         Read         count_ct0         0x0000025d           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x0000025d           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x0000025c           count_ct1         0x0000025c         count_ct1         0x0000025c         count_ct1         0x0000025c           count_ct0         0x00000126         count_ct0         0x00000126         count_ct0         0x00000126	Count_ct1         0x0000025d         0x%08x         Value         Read         count_ct0         0x000012f         1.241m           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x000025c         1.240m           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x000025c         1.240m           count_ct1         0x000025c         1.232m         count_ct1         0x000025c         1.232m           count_ct0         0x000002f         1.224m         count_ct0         0x0000012f         1.224m	Count_ct1         0x0000025d         0x%08x         Value         Read         count_ct0         0x000012f         1.241m         R           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x000025c         1.240m         W           count_stick         0x000076cb         0x%08x         Value         Read         count_ct1         0x000025c         1.240m         R           count_stick         0x0000076cb         1.241m         R         R         count_ct1         0x0000025c         1.240m         R           count_stick         0x0000076cb         1.241m         R         R         count_still         0x0000025c         1.232m         R           count_still         0x0000025f         1.224m         R         count_still         0x0000026c         1.224m         R

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	-



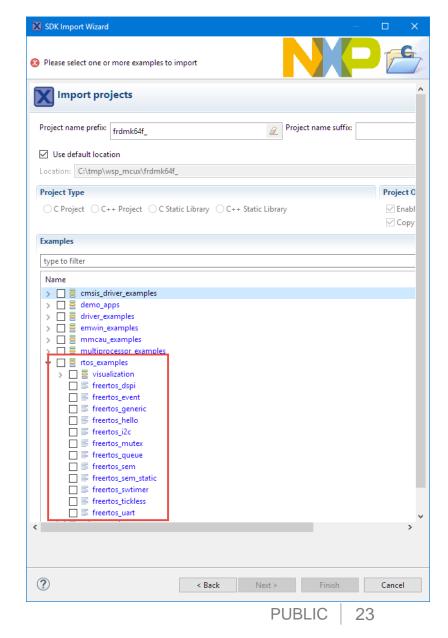
🗜 SWO Profile 🔀									🜔 🔳 🔚 陆 🕓 🛙	<b>k</b> – –
Function	Cumulative samples	Cumulative samples %	Current samples %	Coverage %	First	Last	Since	Avg Between	Coverage bitmap	
Board_LED_Toggle	82	0.0%	0.0%	22.7%	210	25	8.125s	303.719ms	0000000011110	
Chip_GPIO_SetPinToggle	25	0.0%	0.0%	12.5%	12	16	147	154.913ms	0010000000000	
Chip_TIMER_ClearMatch	4	0.0%	0.0%	10.0%	1.5	32	529	7.791s	000000000000	
CT32B0_IRQHandler	2	0.0%	0.0%	<b>1</b> 1.5%	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. <mark>6</mark> %	280	33	158	328.010ms	00000101101000	l
updateB	996882	61.4%	61.4%	90.0%	184	33	0.00	33.344us	11111111111111	



### FreeRTOS with MCUXPresso Software and Tools

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

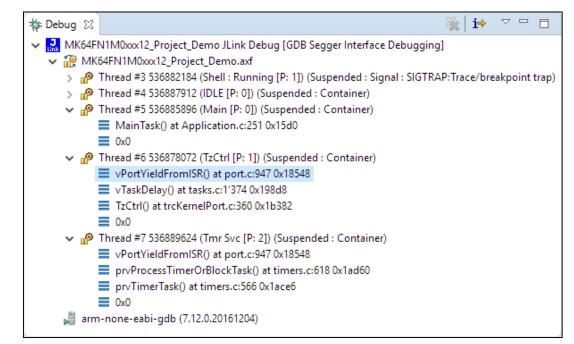
(U) Q ☆ (x)= G [] M • B (x)= V □	1	
MCUXpresso IDE (Pro Edition)		^
IDE		
▼ Start here		
🔀 New project		
Minport SDK example(s)		
Import project(s) from file system		~
<	>	





### **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

	Window Help		NP Hea	p Usage (Fre	eeRTOS) 🛛						89	🔒 🛈 🗖 🗖	
Task Li	ist												1
Queue	e List		Туре	Heap E		Heap End		Heap Usage		Free Space	Heap Usage Gr		
Timer	List	1	2	0x2000	15a0	0x200063c0		12.96 kB / 19.53 l	kB 3	3.64% (6.57 kB)	66.36	i% Used	
Heap U	Usage	E	# ^	Details				Block Start		Block End	Size	^	
NXP C	ommunity	-	-										
·	-			Allocate				0x200015a0		0x200015af	0x10 (16 E		
About	FreeRTOS TAD		2		ask Stack)			0x200015b0		0x20001be7	0x638 (1.5		
		_	3	Allocate				0x20001be8		0x20001bf7	0x10 (16 E		
Task List	: (FreeRTOS) 🔀		4	TzCtrl (T	-			0x20001bf8		0x20001c57	0x60 (96 E		
CB# ⊤as	sk Name	Task Handle	Task Score	Allocate				0x20001c58		0x20001cb7	0x60 (96 E	8) 🗸	ļ
					JUNCK USBYE		nt Object	Kuntin					
1 TzC		0x20001bf8	Blocked	1 (1)	120 B / 1.5				0.0%)				
	diPlay	0x20002300	Blocked	1 (1)	128 B / 1.5				0.0%)				
3 She		0x20002c08	Running	1 (1)	368 B / 2.1				100.0%)	_			
4 Ma	iin	0x20003a88	😣 Ready	0 (0)	36 B / 3.5	1 kB		0x0 (	0.0%)				
5 NP	Queue List (FreeRTO	S) 🛙						00	🗄 🛈				
#	Queue Name	2	Address	Length	Item Size	# Tx	. # Rx	Queue Type		^			
$\sim$	1 TmrQ		0x20003b28	0/10	0x10 (16 B)	0	1	Oueue					
	Head:		0x20003b78		NP Timer List	t (FreeRTOS) 🛛	3					00	🔚 🛈 🖻
	Tail:		0x20003c18		ID ^	Timer Name		Period [ti	Auto re	elo Timer Num	har Ci	allback function	
	Read from:		0x20003b78					-					
		2			0x0	timer0		10	Yes	0x0	Tv	imerCallback (0x00	000f6d)
#	Address	Queue	Data [DEC] Q	ueue Data [									



### 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**

- <u>http://www.freertos.org</u>
- 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**

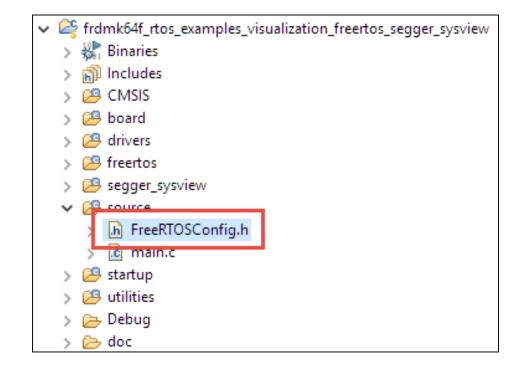
- Static
  - FreeRTOS Configuration
    - Only enable what is necessary
  - Compiler/Linker
    - Enable higher level of optimizations (-O3, -flto)
    - Use optimized libraries (no semihosting/no-host, RedLib, newlib-nano)
- Dynamic
  - FreeRTOS Runtime Statistics
  - Segger SystemViewer
  - Percepio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

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



#### **Application Hooks**

<pre>#define configUSE_IDLE_HOOK</pre>	1
<pre>#define configUSE_TICK_HOOK</pre>	1
<pre>#define configUSE_DAEMON_TASK_STARTUP_HOOK</pre>	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 #define configUSE\_MALLOC\_FAILED\_HOOK

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

📭 Task	List (FreeRTOS)	23			
TCÊ#	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	③ Ready	2 (2)	💧 0 B / 644 B
> 4	second_task	0x20001440	Running	3 (3)	\land 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

- 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

NP Task	List (FreeRTOS)	22					••• 🗄 🛈 🗖 🗖
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		<u>A</u>
> 4	second_task	0x20001440	Running	3 (3)	🔒 36 B / 260 B		<u>A</u>
> 1	first_task	0x20000c10	Blocked	4 (4)	🚯 220 B / 228 B		<u>A</u>







## **Task Name Length**

## #define configMAX\_TASK\_NAME\_LEN

- 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

CB#	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		<u>A</u>
> 1	Unknown	0x20000c10	Blocked	4 (4)	🗥 220 B / 228 B		<u>A</u>
> 4	Unknown	0x20001410	Running	3 (3)	🕭 24 B / 260 B		<u>A</u>



## **Queue Registry**

### #define configQUEUE\_REGISTRY\_SIZE

- 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

NP Que	ue List (FreeRTOS) 🔀										III 📔 🛈 🗖 🗖
# ^	Queue Name		Address		Length	lte	m Size	# Tx	# Rx	Queue	Туре
1	GI2C1_Mutex		0x200114f8		0/1	Em	pty	0	0	Recurs	ive Mutex
> 2	AppMsgQueue		0x200119a8		0/10	0xc	: (12 B)	0	0	Queue	
#	Address	Oueue [	)ata [DEC]	Oueue	Data [HE]	x1	Queue Data	BIN1			Queue Data [ASCII]
								,			

## **RTOS Timers**

#define configUSE_TIMERS	1
<pre>#define configTIMER_TASK_PRIORITY</pre>	2
<pre>#define configTIMER_QUEUE_LENGTH</pre>	10
<pre>#define configTIMER_TASK_STACK_DEPTH</pre>	<pre>(configMINIMAL_STACK_SIZE * 2)</pre>

- 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

NP Queu	ue List (FreeRTOS) 🔀										III 🗄 🛈 🗖 🗖	
# ^	Queue Name		Address		Length	lter	m Size	# Tx	# Rx	Queue	Туре	
> 1	TmrQ		0x20000e60		0/10	0x1	0 (16 B)	0	0	Queue		
												-
#	Address	Queue D	ata [DEC]	Queue	Data [HE)	g	Queue Data [B	N]			Queue Data [ASCII]	
												1,



## **Heap Scheme**

## #define configFRTOS\_MEMORY\_SCHEME

- 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

NP Heap	Usage (FreeRTOS) 🛛				••   🔡 🛈	)
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	
# ^	Details	1	Block Start	Block End	Size	^
1	Allocated		0x20000a98	0x20000a9f	0x8 (8 B)	
2	first_task (Task Stac	k)	0x20000aa0	0x20000b83	0xe4 (228 B)	
			0.000001.01	0.00000.07	0.0.7440.00	



## **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

NP Heap	Usage (FreeRTOS) 🔀				••   🔛 🛈	
Туре	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	
# ^	Details		Block Start	Block End	Size	^
1	Allocated		0x20000a98	0x20000a9f	0x8 (8 B)	
2	first_task (Task Stack)		0x20000aa0	0x20000b83	0xe4 (228 B)	~
-			0.000001.01	0.00000.07	0.0.0000	· · ·



## **Runtime Statistics**

<pre>#define configGENERATE_RUN_TIME_STATS</pre>	0
<pre>#define configUSE_TRACE_FACILITY</pre>	1
<pre>#define configUSE_STATS_FORMATTING_FUNCTIONS</pre>	0

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

CB#	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	Арр	0x200139c0	Running	1 (1)	1.79 kB / 7.8 kB		0x1190 (100.09
2	Accel	0x20011940	Ready	1 (1)	37 <mark>2</mark> B / 992 B		0x0 (0.0%)
4	IDLE	0x20013bc0	Ready	0 (0)	36 B / 392 B		0x0 (0.0%)



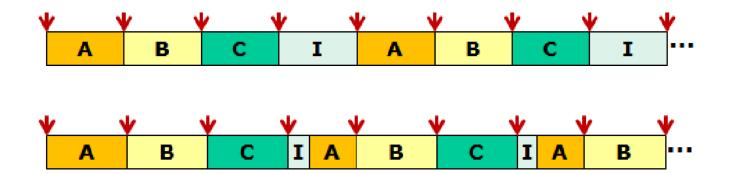


## **Idle Yielding**

### #define configIDLE\_SHOULD\_YIELD

In preemptive mode allows IDLE task to give back time to tasks

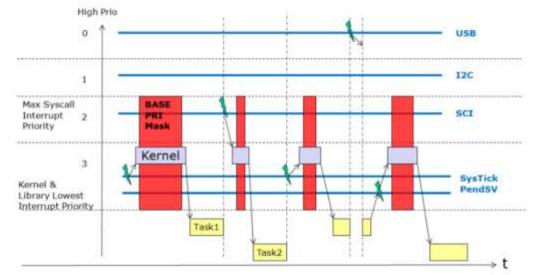
- Recommendation
  - Enable IDLE yielding
  - Impact: improved application performance



## **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+
- <u>http://mcuoneclipse.com/2015/11/16/segger-systemview</u>

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## **Segger SystemView**

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



**RTOS and Middleware** 

J-Link Debug Probes

J-Link Configurator

J-Link GDB Server

J-Link Commander

J-Link SWO Viewer

Continuous Recording

Single-Shot Recording

Post-Mortem Mode

J-Link Remote Server

Ozone - The J-Link Debugge

Home

🗄 General Info

J-Mem

J-Scope

1 J-Flash

SystemView

J-Flash SPI

🗄 Software

### The Embedded Experts



emWin upgrade for users of emWin libraries Search 🛟 Trade-In 🛛 🐺 Web Program 🛛 🐺 Shop

#### J-Link Debug Probes Software SystemView



Maximum system insight

Cycle-accurate profiling

V 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!

Contexts														
Name	Туре	Stack Information	Run Count	Frequency	Last Run Time	Min Run Time	Max Run Time	Total Run Time	Run Time/s		Min Run Time/	;	Max Run Time/s	
SysTick	🐓 #15		6688	1001 Hz	0.0116 ms	0.0105 ms (#260)	0.0665 ms (#19285)	94.5570 ms	13.9906 ms	1.40%	13.9633 m	s 1.40%	14.5148 ms	1.45%
Scheduler	\$		4624	688 Hz	0.0165 ms	0.0064 ms (#390	0.1662 ms (#13358)	64.5438 ms	9.4306 ms	0.94%	0.0 m	s 0.00%	10.1581 ms	1.02%
🔲 Арр	- @1	71 @ 0x1fff9cd8	669	100 Hz	0.0377 ms	0.0306 ms (#781	0.1952 ms (#17751)	24.8410 ms	3.6672 ms	0.37%	3.6205 m	s 0.36%	3.8436 ms	
Shell	- @1	103 @ 0x1fff9f40	683	103 Hz	0.0404 ms	0.0057 ms (#277	0.3438 ms (#13395)	28.1264 ms	4.0968 ms	0.41%	4.0166 m	s 0.40%	4.5802 ms	0.46%
Refl	∞ @0	74 @ 0x1fffa458	1349	199 Hz	1.870 ms	0.006 ms (#1319	1.880 ms (#13417)	1141.2270 ms	170.9532	17.10%	169.0978 m	s 16.91%	171.0401 ms	17.10%
🗌 Idle	Ċ		6352	956 Hz	0.9885 ms	0.0052 ms (#136	0.9925 ms (#13408)	5333.2962 ms	798.8894	79.89%	0.0 m	s 0.00%	798.8894 ms	79.89%
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## **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

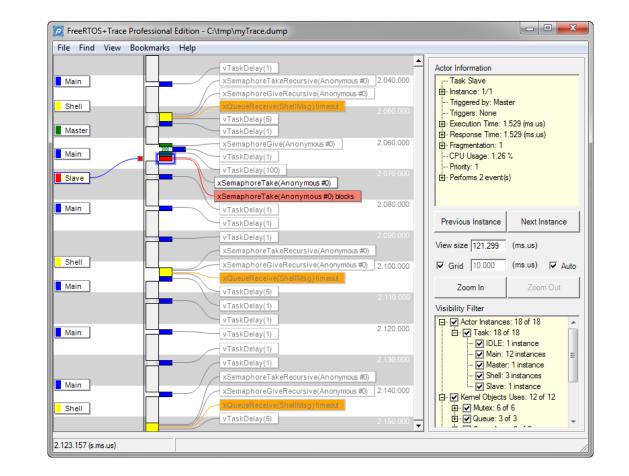
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20.369 032	App	🚺 KEYDBI
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## **Percepio Tracealizer**

- Percepio (<u>http://www.percepio.com</u>)
- 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 Tracealizer from Percepio**

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



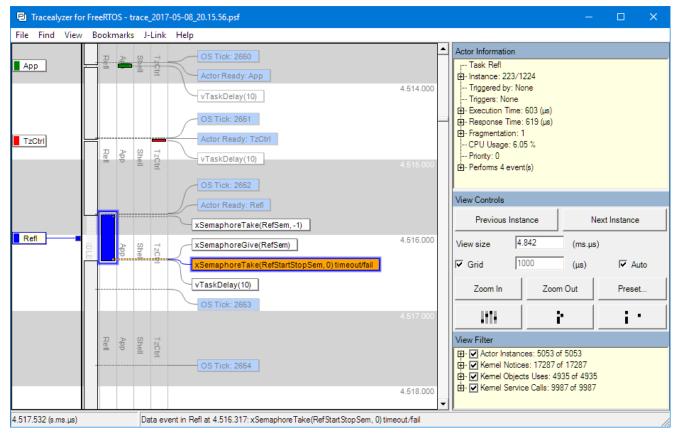
### Download Tracealyzer and get started within a minute!

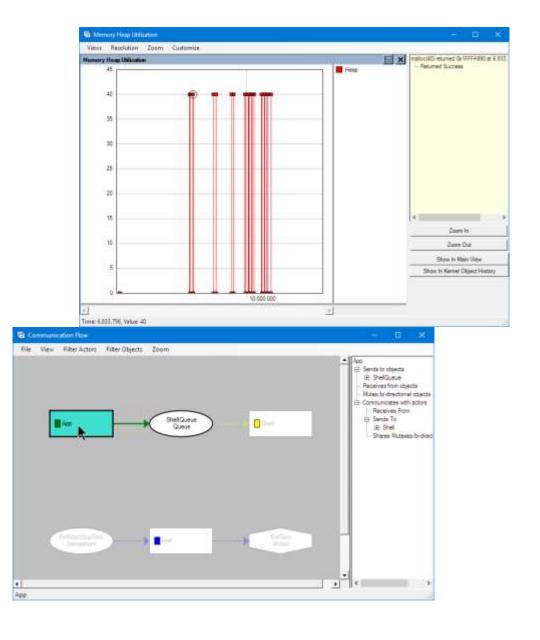
Tracealyzer is provided in a single installer for demo, evaluation and commercial use. The evaluation mode is enabled by registering in the application and allows for **10 days evaluation** usage. If you need more time, you may request an extension. There is also a **demo** mode that allows you to start 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 Tracealizer
  - NXP Kernel and Thread Awareness













MCUX presso Software and Tools

COMMON TOOLKIT FOR THOUSANDS OF KINETIS® & LPC MICROCONTROLLERS



## **Additional Resources**

Web pages

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



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