

VORAGO VA416xx FreeRTOS Application Example

November 4, 2020, Version 1.0

VA4162x - VA4163x

Abstract

This document provides information on how to setup <u>FreeRTOS</u> on the PEB1-VA416xx development kit. This tutorial/project help to start using this small footprint but powerful operating system on the VA416xx with its many peripherals and advanced features. The project is a small generic Kiel MDK project. The project creates two tasks, each outputting its task name to the serial port, demonstrating the RTOS functionality.

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1 RTOS Basics

This section covers some of the terminology and structures used in RTOS based systems.

Threads are ongoing tasks implemented as an infinite loop and added to a queue. Thread and task are often used synonymously. A handle is necessary to reference a thread once it is created. Threads may be intended for static use or allowed to have dynamic creation/removal.

While traditional non-RTOS solutions typically have a system of prioritized interrupts that can take control from the main program or lower priority interrupts, an RTOS differs in that active threads of the same priority automatically share CPU control via arbitration.

There is a wide range of arbitration options. The simplest is time-sharing round-robin, where threads are switched back and forth on a regular period. It is preemptive in that a given thread does not yield control when it has completed, rather control is taken by the scheduler.





Figure 1-1 - Round-robin CPU time sharing diagram

Multiple tasks can access resources, yet it is often unsafe for a second thread to access a resource while it is already in use. Examples of shared resources could be a UART or a common variable being changed while math operations are being performed. A similar conflict can exist in a non-RTOS system when an interrupt needs to access a resource being used by the main code or a lower priority interrupt.

A straightforward solution to this is masking/disabling interrupts during a critical section to stop arbitration. Control cannot be handed to another thread in that time, but this blocks all other threads entirely, not just attempts to access that resource. A more elegant solution uses semaphores to lock off access to specific resources to prevent other threads from accessing them. Semaphores are software structures that signal the



availability of a resource. A mutex is a binary semaphore that can only be unlocked by the thread that locked it.

See <u>http://www.freertos.org.html</u> for more details

2 RTOS Kernel and Support Files

A standard file structure is used to allow FreeRTOS to be portable between different MCUs. This section reviews the structure which must be followed.

The FreeRTOS kernel itself is contained within 3 essential files:

tasks.c,
 queue.c, and
 list.c.

Four other support files are typically required:

- 1. Port.c is essential and contains the architecture-specific code. Since ARM Cortex M4 is a standardized architecture, a port.c made for any Cortex M4 based MCU should work.
- 2. Heap_1.c is the simplest of 5 memory management options for using a heap. A heap is a preserved area of memory that can be temporarily allocated to a task. For instance, a block of data from a serial bus may be temporarily stored in the heap area. When the data is processed, the allocated heap space is released. Memory management options are described in detail at http://www.freertos.org/a00111.html
- 3. FreeRTOSConfig.h is essential. It contains options specific to your application and should be located with your project.
- 4. Timers.c is only necessary if the application uses timers. This application note utilizes the tick counter, which is part of the Cortex M CPU but not peripheral timers.



3 Project Requirements

3.1 Hardware Requirements

Vorago PEB1-VA416X0 development kit (only CPU SBC required) USB to TTL Serial Cable

3.2 Vorago Evaluation Kit Setup

On the EVK CPU SBC:

- Connect a micro USB cable to the micro USB receptacle J17 on the EVK PEB-1 Core card. This connector provides power and a JLink OBD debug connection to the VA416xx.
- Connect USB to UART cable to J7 for the FreeRTOS example's output. Below is the connector pinout, which is also silkscreened on the PEB-1 Core card.

PG[0] (UART0_TX→cable RX) on pin J7-1 PG[1] (cable TX→UART0_RX) on pin J7-2 GND on pin J7-3

3.3 Software Requirements

Keil µVision MDK Development Software

After installing it like any other Windows application, there should be a shortcut placed on your desktop. Open it, and you should get a blank IDE workspace described further below. It is assumed that the user has gotten a previous project compiling loading and running in Keil MDK.

Tera Term (or Putty)

A serial terminal is required for viewing FreeRTOS output. Configure serial port to 230K 8N1.

4 Starting a New Keil MDK Project

Before getting started with µVision, ARMs <u>Getting started with MDK</u> is an excellent reference for using Keil MDK software. Once the Keil µVision application has been launched for the first time, a window opens with a blank project. On subsequent launches, the µVision IDE opens with the last closed project. A project can be returned



to a blank state by selecting the "Project →Close Project" in the pulldown menus. A blank project can be seen in Figure 4-1.

🔢 µVision			_		×
<u>F</u> ile <u>E</u> dit <u>V</u> iew <u>P</u> roject Fl <u>a</u> sh <u>D</u> ebug Peripherals <u>T</u> ools <u>S</u> VCS <u>W</u> indow <u>H</u> elp					
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EProject Books {} Functions 0, Templates					
Build Output					Д 🔀
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					\sim
					>
E Build Output					

Figure 4-1 Keil MDK Blank Project

5 µVision Software Pack File Installation

Before creating a new project, software pack files may need to be installed. Pack files are a method of adding device information and software drivers into MDK in a standard manner. A pack file is simply a .zip file renamed .pack. During MDK installation, the pact filetype is associated with the <u>Pack Installer</u> tool (🏟). Pack files are loaded into the MDK environment with the pack installer. Once installed pack files are then managed in individual projects with the <u>Manage Run-time Environment</u> tool (*).

Several software pack files are needed to configure FreeRTOS in MDK. Before creating a new project, click on the pack installer tool icon (\bigotimes) in the µVision menu bar and wait for the tool to load its main menu.



The left sidebar (Devices) is a list of all the available pack files for all MDK installed microcontrollers. Look for the for VA416xx. then select Vorago::VA416xx Series::VA416xx. If there is no Vorago::VA416xx Series shown, then the device support package has not been loaded. Visit Voragotech.com, download the VA416xx pack file, and double click on the .pack file to launch the pack installer. When this process completes the Vorago::VA416xx Series should be visible in the Pack Installer tool.

On the right-side panel are various ARM CMSIS, Keil pack files. All of the following pack files are part of the Keil MDK installation and must be shown and have a green pack icon next to them. See Figure 5-1. If any pack shown below is not available, please reload Keil MDK or contact Keil for assistance.

ARM::CMSIS ARM::CMSIS-Driver ARM::CMSIS-FreeRTOS Keil::ARM_Compiler

Devices Boards		Þ	d Packs Examples		
earch: +	×E		Pack	Action	Description
vice	/ Summary		Device Specific	1 Pack	VA416xx selected
Ambia Micro	10 Devices		Vorago::VA416xx	🔶 Up to date	VA416xx ARM Cortex-M4 Device Family Pack
Amiccom	5 Devices		- Generic	48 Packs	
Analog Devices	15 Devices		Alibaba::AliOSThings	🚸 Install	AliOS Things software pack
- APEXMIC	16 Devices		-Arm-Packs:PKCS11	🗇 Install	OASIS PKCS #11 Cryptographic Token Interface
+ ARM	57 Devices		Arm-Packs::Unity	🗇 Install	Unit Testing for C (especially Embedded Software)
+ AutoChips	46 Devices		- ARM: AMP	🔶 Up to date	Software components for inter processor communication (Asymm
Cmsemicon	22 Devices		- ARM::CMSIS	🔶 Up to date	CMSIS (Cortex Microcontroller Software Interface Standard)
Cvpress	889 Devices		5.7.0 (2020-04-09)	K Remove	CMSIS (Cortex Microcontroller Software Interface Standard)
Pialog Semiconductor	15 Devices		5.6.0 (2019-07-10)	K Remove	CMSIS (Cortex Microcontroller Software Interface Standard)
E PELAN	1 Device		Previous		ARM::CMSIS - Previous Pack Versions
	3 Devices		-ARM::CMSIS-Driver	🔶 Up to date	CMSIS Drivers for external devices
+ 9 GigaDevice	293 Devices		2.6.1 (2020-07-13)	🗱 Remove	CMSIS Drivers for external devices
- Goodix	18 Devices		-2.5.0 (2019-12-02)	🗱 Remove	CMSIS Drivers for external devices
HDSC	75 Devices		-2.4.1 (2019-07-11)	K Remove	CMSIS Drivers for external devices
Holtek	215 Devices		Previous		ARM::CMSIS-Driver - Previous Pack Versions
- Infineon	183 Devices		+ ARM::CMSIS-Driver_Va	🐵 Install	CMSIS-Driver Validation
+ V Lapis Semiconductor	2 Devices		ARM::CMSIS-FreeRTOS	🔶 Up to date	Bundle of FreeRTOS for Cortex-M and Cortex-A
- 2 Maxim	16 Devices		-10.3.1 (2020-04-30)	X Remove	Bundle of FreeRTOS for Cortex-M and Cortex-A
- Ø MediaTek	2 Devices		Previous		ARM::CMSIS-FreeRTOS - Previous Pack Versions
R . Microchin	404 Devices		ARM::CMSIS-RTOS_Vali	🗇 Install	CMSIS-RTOS Validation
A Microsomi	6 Devices		ARM:mbedClient	🕸 Install	ARM mbed Client for Cortex-M devices
A MindMotion	123 Devices		ARM::mbedCrypto	🐵 Install	ARM mbed Cryptographic library
Nordic Semiconductor	19 Devices		ARM::mbedTLS	🐵 Install	ARM mbed Cryptographic and SSL/TLS library
	744 Devices		ARM::minar	🗇 Install	mbed OS Scheduler for Cortex-M devices
+ V NXP	1261 Devices		- ARM::TFM	Install+	Trusted Firmware-M (TF-M) reference implementation of Arm's PL
Rednine Signals	4 Devices		ASN::Filter_Designer	🐵 Install	Intuitive graphical FIR/IIR digital filter designer
- RelChip	1 Device		EmbeddedOffice:Flexi	🗇 Install	Flexible Safety RTOS
Renecas	36 Devices		E Keil::ARM_Compiler	🔶 Up to date	Keil ARM Compiler extensions for ARM Compiler 5 and ARM Com
E Silicon Labs	960 Devices		-1.6.3 (2020-04-22)	Remove	Keil ARM Compiler extensions for ARM Compiler 5 and ARM Com
+ 9 Sinowealth	1 Device		-1.6.2 (2019-11-12)	K Remove	Keil ARM Compiler extensions for ARM Compiler 5 and ARM Com
SONEY	60 Devices		Previous		Keil::ARM_Compiler - Previous Pack Versions
STMicroelectronics	1616 Devices		Keil::iMXRT105x_MWP	Install+	NXP i.MX RT 1051/1052 MDK-Middleware examples and CMSIS-Dr
Texas Instruments	350 Devices		E Keil::MXRT1060_MWP	🐵 Install+	NXP i.MX RT 1061/1062 MDK-Middleware examples and CMSIS-Dr
Toshiha	232 Devices		E Keil::iMXRT1054_MWP	Install+	NXP i.MX RT 1064 MDK-Middleware examples and CMSIS-Drivers
- Q Unisoc	1 Device		Keil:Jansson	🗇 Install	Jansson is a C library for encoding, decoding and manipulating JSG
- Vorago	1 Device		-Keil::LPC5556x_TFM-PF	🐵 Install+	NXP LPC5556x MCU Family TF-M Platform Support
A VA416xx Series	1 Device		Keil::LPCXpresso55569	🐵 Install+	NXP LPC55569 Series LPCXpresso55569 Board Support Pack
C VM16m	ARM Contex-M4_20 MHz 64 kB RAM_256 kB ROM		Keil:MDK-Middleware	Up to date	Middleware for Keil MDK-Professional and MDK-Plus
© ₽ XMC	2 Devices		€ Keil::STM32L5xx_TFM	🐵 Install+	STMicroelectronics STM32L5 Series TF-M Platform Support
Tilon	7 Devices		IwiP::IwiP	🔶 Up to date	IwIP is a light-weight implementation of the TCP/IP protocol suite
the standy	1.11011001		+ MDK-Packs::AWS_loT	🐵 Install	SDK for connecting to AWS IoT from a device using embedded C
		-1			
	- /		Leader		
ut					
In Pack descriptions	D Endallade 1.2.0 Available: 1.2.0				

Figure 5-1 Keil MDK Pack Installer Setup



Once the required pack files are visible into the KEIL MDK environment, a new project can be started.

6 μVision Project Setup

To create a new project, click on the "Project tab→New µVision Project." Before creating your project, the µVision IDE doesn't automatically create a subdirectory. Since it is best to have all source files in one place, create a directory got the project first. For this example, name the folder "Vorago VA416xx FreeRTOS "and the project "Vorago VA416xx FreeRTOS." Reference Figure 6-1.

Corganize New folder MDK-ARM Name New folder Spec & Manuals This PC 3D Objects Desktop Documents Downloads Music Pictures Videos Solos OS (C:) DATA (D:)	Kreate New Project	t	×
Organize New folder MDK-ARM Name New folder Type Spec & Manuals No items match your search. This PC 3D Objects Desktop Documents Downloads Music Pictures Videos G OS (C:) DATA (D:)	\leftrightarrow \rightarrow \sim \uparrow	« VORAGO > Software > Vorago VA416xx FreeRTOS 🗸 💆 🔎 Se	arch Vorago VA416xx Free
MDK-ARM New folder Spec & Manuals This PC 3D Objects Desktop Documents Downloads Music Pictures Videos G S (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) Cancel	Organize 👻 Ne	ew folder	8== ▼ (?)
New folder No items match your search. Spec & Manuals No items match your search. This PC 3D Objects Desktop Documents Downloads Music Pictures Videos Videos Save as type: File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx)	MDK-ARM	Name Date modified Type	Size
 This PC 3D Objects Desktop Documents Downloads Music Pictures Videos OS (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvprojx *.uvprojx) A Hide Folders Save Cancel	New folder	No items match your search.	
 Dobjects Desktop Documents Downloads Music Pictures Videos OS (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) A Hide Folders Save Cancel	This PC		
 □ Desktop □ Documents □ Downloads □ Music □ Pictures □ Videos □ OS (C:) □ DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx)	3D Objects		
Documents Downloads Music Pictures Videos So (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) A Hide Folders Save Cancel	📃 Desktop	1	
Downloads Music Pictures Videos So (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) A Hide Folders Save Cancel	🔮 Documents		
Music Pictures Videos So (C:) DATA (D:) File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) A Hide Folders Save Cancel	👆 Downloads		
	👌 Music		
Image: Save as type: Vorago VA416xx FreeRTOS A Hide Folders Save	Pictures		
Image: Save as type: Project Files (*.uvproj; *.uvprojx) Image: Hide Folders Save	📔 Videos		
DATA (D:) File <u>n</u> ame: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) Hide Folders <u>Save</u> Cancel	🏪 OS (C:)		
File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) Hide Folders Save	DATA (D:)		
File name: Vorago VA416xx FreeRTOS Save as type: Project Files (*.uvproj; *.uvprojx) Hide Folders Save Cancel 	-	•	
Save as type: Project Files (*.uvproj; *.uvprojx) A Hide Folders Cancel	File <u>n</u> ame:	Vorago VA416xx FreeRTOS	~
∧ Hide Folders Cancel	Save as <u>t</u> ype:	Project Files (*.uvproj; *.uvprojx)	~
∧ Hide Folders Save Cancel			
A Hide Folders Cancel			
	A Hide Folders	Sa	ve Cancel

Figure 6-1 Setting the Project Directory and Name

Once the project directory and name are created, the "Save" button opens the target selection dialog box to define the project's target microcontroller selection. Select the Vorago::VA416xx Series::VA416xx device, as shown in Figure 6-2.



Select Device for Target 'Target 1'		×
Device		
Software Packs	•	
Vendor: Vorago Device: VA416xx Toolset: ARM Search:		
	Description:	
 ARM ✓ Vorago ✓ VA416xx Series ✓ VA416xx 	The VA416xx series contains an ARM Cortex-M4 processor running up to 100 MHz with a peripheral set including I2C, SPI, UART, Ethemet, CAN, Spacewire, DMA, ADC, and DAC	
	OK Cancel Help	

Figure 6-2 Setting Project Microcontroller Target

After these steps, we have to select what pack files are to be used in the project. The pack file selection is accomplished with the Manage Run-time Environment (*). The blank dialog box is shown in Figure 6-3

ftware Component	Sel.	Variant		Version	Description	
🚸 CMSIS					Cortex Microcontroller Software Interface Components	
CMSIS Driver					Unified Device Drivers compliant to CMSIS-Driver Specifications	
🚸 Compiler		ARM Compiler		1.6.0	Compiler Extensions for ARM Compiler 5 and ARM Compiler 6	
🔶 Device					Startup, System Setup	
🚸 File System		MDK-Plus	\sim	6.13.8	File Access on various storage devices	
🔶 Graphics		MDK-Plus	\sim	6.10.8	User Interface on graphical LCD displays	
🚸 Network		MDK-Plus	\sim	7.14.0	IPv4 Networking using Ethernet or Serial protocols	
🚸 RTOS		FreeRTOS		10.3.1	FreeRTOS Real Time Kernel	
		MDK-Plus	\sim	6.14.1	USB Communication with various device classes	
						_
lidation Output		Descriptio	on			

Figure 6-3 Default Manage Run-time Environment



Some pack files are dependent on others. During selection, if any checkboxes turn orange or warnings are shown in the validation output dialog box, click on the "Resolve" button, and the required packages are added to the µVision project. Note the two additional pulldown selections required. Figure 6.4 shows all the required pack files for the FreeRTOS example.

oftware Component	Sel.	Variant	V	/ersion	Description
			- i		Cortex Microcontroller Software Interface Components
CORE	~		5.	.4.0	CMSIS-CORE for Cortex-M, SC000, SC300, ARMv8-M, ARMv8.1-M
DSP		Source	~ 1.	.8.0	CMSIS-DSP Library for Cortex-M, SC000, and SC300
🔷 NN Lib	Ē		1.	.3.0	CMSIS-NN Neural Network Library
🗉 🚸 RTOS (API)			1.	.0.0	CMSIS-RTOS API for Cortex-M. SC000. and SC300
RTOS2 (API)			2	.1.3	CMSIS-RTOS API for Cortex-M. SC000, and SC300
			-		Unified Device Drivers compliant to CMSIS-Driver Specifications
			1	3.0	CAN Driver API for Cortex-M
Ethernet (ADI)			2	2.0	Ethernet MAC and PHV Driver API for Cortex-M
Ethernet MAC (ADI)			2	2.0	Ethernet MAC Driver API for Cortex-M
Ethernet DHV (ADI)			2	2.0	Ethernet PHV Driver API for Cortex-M
			2.	2.0	Electronic ADI for Context M
			2.	.3.0	Flash Driver API for Cortex-M
			2.	.4.0	IZC Driver API for Cortex-IM
I MCI (API)			2.	.4.0	MCI Driver API for Cortex-M
🕀 💠 NAND (API)			2.	.4.0	NAND Flash Driver API for Cortex-M
🗈 💠 SAI (API)			1.	.2.0	SAI Driver API for Cortex-M
🕀 💠 SPI (API)			2.	.3.0	SPI Driver API for Cortex-M
🖃 💠 USART (API)			2.	.4.0	USART Driver API for Cortex-M
Custom	~		1.	.0.0	Access to #include Driver_USART.h file and code template for custom im
CDC			1.	.10.0	Usb Host CDC ACM Compliant Device
PL2303			1.	.10.0	Prolific PL2303 USB to serial RS232 adapter (requires USB Host Prolific PL
🗉 💠 USB Device (API)			2.	.3.0	USB Device Driver API for Cortex-M
🕖 🚸 USB Host (API)			2.	.3.0	USB Host Driver API for Cortex-M
			0.	.1.0	Virtual I/O
WiFi (API)			1.	.1.0	WiEi driver
Compiler		ARM Compiler	1	60	Compiler Extensions for ARM Compiler 5 and ARM Compiler 6
Event Recorder		DAR	1	4.0	Event Recording and Component Viewer via Debug Access Port (DAD)
	1	DAP		.4.0	Event Recording and Component viewer via Debug Access Polit (DAP)
	_	Ella Contorra	- 1	2.0	Ketarget input/Output
		File System	1.	.2.0	Use retargeting together with the File System component
SIDERK		Breakpoint	× 1.	.2.0	Stop program execution at a breakpoint when using STDERK
SIDIN		Breakpoint	~ 1.	.2.0	Stop program execution at a breakpoint when using STDIN
STDOUT	✓	User	 ✓ 1. 	.2.0	Redirect STDOUT to a user defined output target (USART, Graphics Displa
		Breakpoint	~ 1.	.2.0	Stop program execution at a breakpoint when using TTY
Device					Startup, System Setup
Startup	~		1.	.0.0	Vorago VA416xx devices
💠 File System		MDK-Plus	~ 6.	.13.8	File Access on various storage devices
💠 Graphics		MDK-Plus	~ 6.	.10.8	User Interface on graphical LCD displays
🚸 Network		MDK-Plus	~ 7.	.14.0	IPv4 Networking using Ethernet or Serial protocols
🚸 RTOS		FreeRTOS	1(0.3.1	FreeRTOS Real Time Kernel
Config	v	FreeRTOS	~ 10	0.3.1	FreeRTOS API configuration file
Core	~	Cortex-M	~ 10	0.3.1	Core API (Kernel, Tasks, Semaphores, Mutexes, Queues) for Cortex-M
Coroutines			10	0.3.1	Co-routine API
Event Groups			1/	0.3.1	Event Group API
		Hean 4	10	0.2.1	Coolescences adjacent free memory blocks to avoid fragmentation. Inclu
	V	rieap_4	V 10	0.3.1	Coalescences adjacent free memory blocks to avoid fragmentation. Inclu
Wiessage Buffer			1	0.3.1	Message Buffer API
Stream Buffer			10	0.3.1	Stream Buffer API
Timers			10	0.3.1	Timer API
SB USB		MDK-Plus	~ 6.	.14.1	USB Communication with various device classes
lideline Output		Description			
induced output		Description			

Figure 6-4 Full FreeRTOS Pack File List



Exiting the Manage Run-time Environment and returning to the μ Vision project, many files have been added to the project (see Figure 6-5). These files are the Vorago device-specific files and files needed for the RTOS. If any selections are not available, return to Section 5 μ Vision Software Pack File Installation and ensure all proper packs are installed.



Figure 6-5 Example Project Imported Pack Files



For character output, STDOUT needs to be redirected. For printf() to use the device UART, MDK provides a file named retarget_io.c. Device-specific user functions that connect putchar() of the STDOUT to the USART driver is required.

Figure 6-6 shows how to create a user code template (stdout_USART.c) with information from the pack files and MDK to perform the redirection.

Add New Item	to Group 'Source Gro	oup 1'		×
C C File (c)	Add template file(s) to the pro-	oject.	
C++ File	(.cpp)	Component • CMSIS Driver	Name USART Driver	
h Header F	(.s) File (.h)	Compiler	STDOUT User Template	
Text File	(.txt)	I/O:STDOUT STDOUT via Display I/O:STDOUT STDOUT via USART		
Image Fil	le (.*)			
User Coo	le Template			
Type:	User Code Templa	te		
Name:	stdout_USART.c			
Location:	D:\VORAGO\Softv	vare\Vorago VA416xx FreeRTO	s	
		Add	Close	Help

Figure 6-6 Creating stdout File

Using the User Code Template function in MDK pulls in header support files like Driver_USART.h, Driver_Common.h, and any other header files as required. Using the Add New Item function also adds the stdout_USART.c and headers to the project file.

Returning to the μ Vision project, open stdout_USART.c and delete the file's entire text. Replace the deleted code with the code from Appendix A.



Add New Item to G	Add New Item to Group 'Source Group 1'				
C File (.c)		Create a new C source file and add it to the project.			
C++ File (.cpp)				
A Asm File (.s)					
h Header File (J	h)				
Text File (.txt)					
Image File (.*))				
User Code Te	emplate				
Type:	C File (.c)				
Name:	main				
Location:	re\Vorago VA416xx FreeRTOS				
		Add Close Hel	p		

Figure 6-7 Main.c Creation

Figure 6-7 shows the creation of the main.c file, it is created similar to the creation of the stdout_USART file. Since it is created with the C File selection and not the User Code Template, no additional files are created or included but, the file main.c is added to the project.

Open the empty main.c file and insert the code from Appendix B.



7 Running the Project

Compile the project (F7) and download flash (F8) to load and run the project.

In main.c, the following happens:

- VA416xx is initialized using SystemInit() call
- Peripherals are enabled by writing to VOR_SYSCONFIG
- The system clock is set by writing to VOR_CLKGEN
- UARTO is configured by the stdout_init() call.
- Two tasks are created, each using the xTaskCreate() FreeRTOS call
- A binary semaphore is created with the xSemaphoreCreateBinary() FreeRTOS call
- The FreeRTOS task scheduler is started with the vTaskStartScheduler() FreeRTOS call

Each task will:

- Check for the printf semaphore
- Use printf functions
- Release the printf semaphore
- Delay

Once the FreeRTOS scheduler is running:

- The two tasks run with the same priority, so they have equal execution time.
- The binary semaphore is used to prevent the two tasks from competing for the UART resource.

As each task is placed in the run mode, it waits for the semaphore, uses printf(), and then releases the semaphore back to be used by another task. If a task does not have



the semaphore, it becomes blocked and waits for the semaphore to be released, and ownership is taken to execute its printf().

There is a short delay in each task to ease reading the serial output. Without delay, serial output is rapid and continuous.

Figure 7-1 Project Sample OutputShows the terminal output of the running project.



Figure 7-1 Project Sample Output

8 Next Steps

The FreeRTOS application, along with the Vorago VA416xx, creates a powerful system. An abundance of peripheral and peripheral modes in the VA416xx can be integrated into the many functions within FreeRTOS. Explore and expand your knowledge of both hardware and software by building on this simple example. Additional projects and idea can be found on the FreeRTOS website: <u>https://www.freertos.org/</u>



Appendix A Driver_USART.c code:

```
_____
          stdout_USART.c
* Name:
* Purpose: STDOUT USART Template
* Rev.: 1.0.0
*-----*/
/* Copyright (c) 2013 - 2015 ARM LIMITED
  All rights reserved.
  Redistribution and use in source and binary forms, with or without
  modification, are permitted provided that the following conditions are met:
  - Redistributions of source code must retain the above copyright
    notice this list of conditions and the following disclaimer.
  - Redistributions in binary form must reproduce the above copyright
    notice, this list of conditions and the following disclaimer in the
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  -----*/
* @file
          stdout USART.c
* @version V0.1
        12 October 2020
* @date
* @note
* VORAGO Technologies
* @note
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```



```
#include "Driver_USART.h"
#include "va416xx.h"
#define UART_CALC_CLOCKSCALE(_scc,_baud) ((_scc / (_baud * 16)) << \</pre>
UART_CLKSCALE_INT_Pos) | \
                              (((((_scc % (_baud * 16)) * \setminus
                       (_baud * 8)) / \
                       (_baud * 16))) << \
                       UART_CLKSCALE_FRAC_Pos)
//----- <<< Use Configuration Wizard in Context Menu >>> -----
// <h>STDOUT USART Interface
// <o>Connect to hardware via Driver_USART# <0-255>
// <i>Select driver control block for USART interface
#define USART_DRV_NUM
                            0
// <o>Baudrate
#define USART BAUDRATE
                           230400
// </h>
#define _USART_Driver_(n) Driver_USART##n
#define USART_Driver_(n) _USART_Driver_(n)
extern ARM_DRIVER_USART USART_Driver_(USART_DRV_NUM);
#define ptrUSART
                  (&USART_Driver_(USART_DRV_NUM))
** Start of Serial IO function.
 ** @brief
 int stdout_init(void)
{
 VOR_SYSCONFIG->PERIPHERAL_CLK_ENABLE |= CLK_ENABLE_UART0 | CLK_ENABLE_IOCONFIG | CLK_ENABLE_PORTG;
 VOR_SYSCONFIG->PERIPHERAL_RESET &= ~SYSCONFIG_PERIPHERAL_RESET_UART0_Msk;
 __NOP();
   NOP();
 VOR_SYSCONFIG->PERIPHERAL_RESET |= SYSCONFIG_PERIPHERAL_RESET_UART0_Msk;
// initialize port G for UARTO
 VOR_IOCONFIG->PORTG[0] |= 0x00002000; // PORTG.0 is UART0 Tx.
 VOR_IOCONFIG->PORTG[1] |= 0x00002000; // PORTG.1 is UARTO Rx.
// initialize UART0
 VOR_UARTO->IRQ_ENB = 0x00000001;
 VOR_UARTO->CLKSCALE = 0x000001B2;
 VOR_UART0->CLKSCALE = UART_CALC_CLOCKSCALE (SystemCoreClock/4, 230400); // APB2 divide by 4
 VOR_UARTO->ENABLE = 0x0000003;
return (0);
ł
/**
 Put a character to the stdout
 \param[in] ch Character to output
 \return
                The character written, or -1 on write error.
*/
int stdout_putchar (int ch) {
 uint32_t timeout = 100000;
 uint8_t buf[1];
 buf[0] = ch;
```



```
// Block until there is room on the FIFO to transmit a byte
while (( VOR_UART0->TXSTATUS & UART_TXSTATUS_WRRDY_Msk) == 0) { // wait for Tx ready
timeout--;
if(timeout == 0)
{
return(0xffffffff); // return -1, compiler won't complain
}
VOR_UART0->DATA = *buf;
return (ch);
}
```



Appendix B main.c code:

```
_____
/*-----
 * Name: main.c
 * Purpose: main Template
 * Rev.: 1.0.0
                                   -----*/
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   POSSIBILITY OF SUCH DAMAGE.
                             ----*/
/* Include files */
#include "va416xx.h"
#include <stdio.h>
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "semphr.h"
/* The task functions prototype*/
void vTask1( void *pvParameters );
void vTask2( void *pvParameters );
/* Task parameter to be sent to the task function */
const char *pvTask1 = "Task1 is running.";
const char *pvTask2 = "Task2 is running.";
/* Extern functions */
extern void SystemInit(void);
extern void SystemCoreClockUpdate(void);
extern int stdout_init (void);
                                    -----*/
/*---
/* Global semaphore variable */
SemaphoreHandle_t xSemaphore = NULL;
int main( void )
/* Board initializations */
        SystemInit();
/* Initializes the MCU clock, PLL will be used to generate main MCU clock */
         VOR_SYSCONFIG->PERIPHERAL_CLK_ENABLE |= CLK_ENABLE_UART0 | CLK_ENABLE_IOCONFIG | CLK_ENABLE_PORTG;
         VOR_SYSCONFIG->PERIPHERAL_CLK_ENABLE |= CLK_ENABLE_CLKGEN | CLK_ENABLE_UART0 | CLK_ENABLE_IOCONFIG |
CLK ENABLE PORTG;
         // initialize clock to maximum (100MHz)
         VOR_CLKGEN->CTRL0 = 0x87ECBB1A;
         VOR CLKGEN->CTRL1 = 0X00000010;
         SystemCoreClockUpdate();
/* Initialize the serial I/O(console ), making standard output to be send to USART1 */
         stdout_init();
         printf("\033[0H\033[2JInitialization is done.\r\n\n");
         /* Create one of the two tasks. */
         xTaskCreate(vTask1,
                                               /* Pointer to the function that implements the task. \star/
                     "Task 1",
                                               /* Text name for the task. This is to facilitate debugging only. */
                    configMINIMAL_STACK_SIZE, /* Stack depth in words. */
(void*)pvTask1, /* We are not using the task parameter. */
                     1,
                                               /* This task will run at priority 1. */
                    NULL );
                                               /* We are not using the task handle. */
```



```
/* Create the other task in exactly the same way. */
        xTaskCreate( vTask2, "Task 2", configMINIMAL_STACK_SIZE, (void*)pvTask2, 1, NULL );
/* Create a binary semaphore */
        xSemaphore = xSemaphoreCreateBinary();
        /* make the semaphore token available for the first time */
        xSemaphoreGive( xSemaphore);
        /* Start the scheduler so our tasks start executing. */
        vTaskStartScheduler();
        /* If all is well, we never reach here as the scheduler is be
        running. If we reach here, then it is likely that there was insufficient
        heap available for the idle task to be created. */
        for( ;; );
/*-----*/
void vTask1( void *pvParameters )
char *pcTaskName = (char *) pvParameters;
        /* Task is implemented in an infinite loop. */
        for( ;; )
        {
                /* Take semaphore */
                xSemaphoreTake(xSemaphore,(TickType_t) portMAX_DELAY);
                /* Print out the name of this task. */
                printf( "%s\r\n",pcTaskName );
                /* Give semaphore */
                xSemaphoreGive (xSemaphore);
                /* Delay for a period. */
                vTaskDelay( 2000 / portTICK_PERIOD_MS );
        }
}
/*-----*/
void vTask2( void *pvParameters )
ł
char *pcTaskName = (char *) pvParameters;
        /* Task is implemented in an infinite loop. */
        for( ;; )
        {
                /* Take semaphore */
                xSemaphoreTake(xSemaphore,(TickType_t) portMAX_DELAY);
                /* Print out the name of this task. */
                printf( "%s\r\n",pcTaskName );
                /* Give semaphore */
                xSemaphoreGive (xSemaphore);
                /* Delay for a period. */
                vTaskDelay( 2000 / portTICK_PERIOD_MS );
        }
}
```



9 Revision History

Date	Version	Sections	Description
11/04/2020	1.00	All	Initial draft

The use of this product is subject to the manufacturer's standard terms and conditions available on the manufacturer's website <u>here</u>.

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