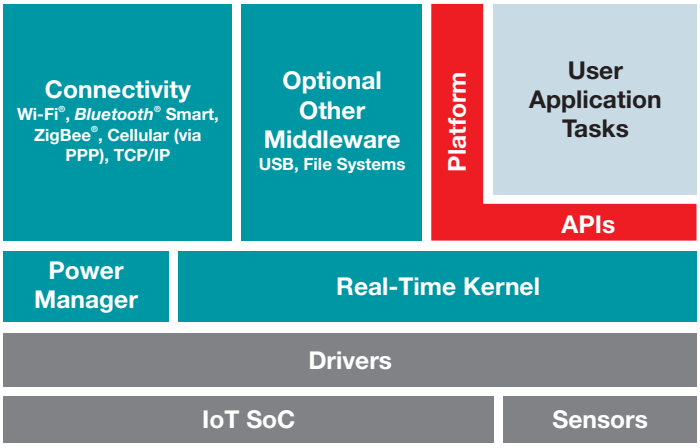
TI-RTOS: A real-time operating system for TI devices

Texas Instruments

TI-RTOS is a real-time operating system that enables faster development by eliminating the need for developers to write and maintain system software such as schedulers, protocol stacks, power management frameworks and drivers. It is provided with full C source code and requires no up-front or runtime license fees. TI-RTOS is supported directly by TI.

TI-RTOS scales from a low-footprint, real-time preemptive multitasking kernel to a complete RTOS with additional middleware components including a power manager, TCP/IP and USB stacks, a FAT file system and device drivers, allowing developers to focus on differentiating their application. It provides a consistent embedded software platform across TI's embedded processing portfolio, making it easy to port existing applications to the latest devices. TI-RTOS is available across TI's MCU and wireless MCU product families and can be downloaded directly from **www.ti.com/tool/ti-rtos** or using the Code Composer Studio™ Update Advisor. TI-RTOS is also available for TI's DSP and ARM® Cortex®-A-based processors, but must be obtained by downloading the specific software development kit (SDK) for these devices.



TI-RTOS scales from a real-time kernel to a complete OS with connectivity stacks, a file system, power management and drivers to provide a standard system software base for TI devices

To meet the needs of embedded developers who need to fit applications within the confines of on-chip memory, TI-RTOS is based on a modular architecture enabling easy removal of software functionality not required in the application. In addition, the components themselves are scalable, allowing for further reductions in both program and data memory requirements.

Deterministic, real-time kernel

The TI-RTOS Kernel (formerly called SYS/BIOS™) is optimized for use in performance and footprint-sensitive applications. TI-RTOS Kernel provides preemptive multitasking, communication and synchronization primitives and memory management. In addition, it provides standard interfaces for managing select hardware resources such as interrupts, timers, exceptions and power-saving modes. OS objects, such as tasks and semaphores, may be created either dynamically by the application or statically using a configuration tool.

To support hard real-time applications, such as motor control where failure to respond to an interrupt may result in a critical system failure, TI-RTOS Kernel supports "zero-latency interrupts" so that the most critical interrupts are never disabled.

TI-RTOS Kernel services	Description
Task	Independent, pre-emptible thread of execution that has its own stack and can yield the processor
SWI	Pre-emptible thread that uses program stack but cannot yield
Clock	Time-triggered periodic functions
Event	Wait on multiple events (semaphore, mailbox, I/O, user-defined, …)
Mailbox	Mailboxes for synchronized fixed-sized data exchange between tasks
Semaphore	Counting and binary semaphores
Gate	Protects against concurrent access to critical data structures
Heaps	Variable-sized heap, fixed-sized buffers, variable-sized allocation based on multiple fixed-sized buffer pools
HWI	Interrupt management
Timer	Interface to hardware timers, supporting one-shot or continuous callbacks
Diagnostics	Logs, timestamps, enable/disable diagnostics

Table 1. TI-RTOS Kernel offers a broad range of kernel services

Power management

TI-RTOS fully leverages the power management features of TI's ultra-low power microprocessors. TI-RTOS Kernel supports tickless operation, which greatly reduces the frequency of unnecessary wake-ups simply to serve the timer interrupt for the tick. When to suppress ticks is managed transparently by the TI-RTOS Kernel, freeing the user of the need to explicitly hardcode this into their application. For most ultra-low power MCUs, TI-RTOS also provides a power manager that controls peripheral clock gates and power domains and implements aggressive "standby" low-power modes that reduce power consumption to a tiny percentage

of normal execution. The power manager is integrated with power-aware drivers and stacks which enable the optimal power-down state to be selected automatically when the processor enters the idle thread.

Toolchain support

TI-RTOS applications may be developed using TI's Code Composer Studio (CCStudio) Integrated Development Environment (IDE), IAR's Embedded Workbench (EW) or GCC. The TI-RTOS examples are fully integrated into the CCStudio IDE and EW project managers. GCC support has both command line and CCStudio IDE project examples. The TI-RTOS RTOS Object Viewer (ROV) enables developers to examine the state of operating system objects, such as tasks and semaphores, and diagnose why a task is not executing when expected. ROV also provides data on stack usage and indicates whether stack overflow may have occurred. This information enables developers to optimize stack size to save memory and to easily detect stack overflow problems. ROV is integrated into both the CCStudio IDE and EW developments environments.

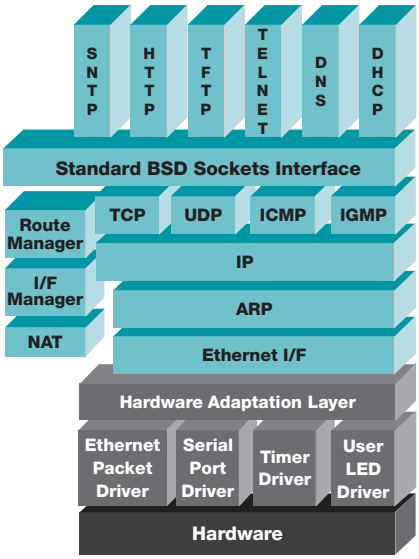
Developers using CCStudio IDE may also view run-time application behavior using the System Analyzer tools. These include a graphical view of the sequence of thread execution in an application and a CPU load graph, which illustrates the level of processor loading against program execution, as well as the % consumed by each task. This enables developers to determine areas where CPU resources are being stretched or where there is headroom to add more functions.

Developers have full control over which TI-RTOS instrumentation is included in their builds, enabling them to tailor the debug capability to the memory constraints of their system. Instrumentation buffers may be viewed using a JTAG emulator or streamed off in real-time via a UART, USB or Ethernet port.

The TI-RTOS configuration tool enables developers to configure OS functionality either graphically or via scripts and exclude OS components not required by the application. If desired, OS object instances, such as threads and semaphores, can be created statically through the configuration tool, reducing memory footprint by eliminating the code required for dynamic create and delete operations.

TCP/IP stack and wireless connectivity

TI-RTOS Networking includes a dual-mode IPv4/IPv6 stack. The stack is complemented by additional network applications commonly required in embedded applications such as HTTP server, DNS, DHCP Client and Server, TFTP, SNTP and Telnet. A standard BSD-sockets interface is provided to simplify porting of other network-based applications. In addition, zero-copy and raw Ethernet interfaces are available when greater efficiency is required. PPP is provided for applications that need to interface to cellular modems.



▲ *TI-RTOS includes an IPv4/IPv6 networking stack along with associated networking applications such as HTTP*

For the TM4Cx, MSP430™ and MSP432™ microcontrollers, TI-RTOS includes an SPI-driver-based interface to the SimpleLink™ C3100 for developers who need to add wireless networking to their applications, but cannot accommodate the footprint of a full 802.11 wireless stack in on-chip memory. TI-RTOS fully supports the on-chip Wi-Fi® present in the SimpleLink CC3200 and the integrated *Bluetooth*® and ZigBee® communications available in the SimpleLink CC26xx series.

FAT-compatible file system

Many embedded applications may find it useful to be able to read/write data to/from USB Flash drives or SD cards. To facilitate data exchange with the embedded application, the TI-RTOS File System provides a FAT-compatible file system. Applications can access the file system services through standard C I/O APIs or lower overhead native APIs.

	C28xx	C28FM3x	TM4Cx	MSP430™	MSP432™	CC3200	CC26xx
Kernel	●	●	●	●	●	●	●
Wired networking		●	●				
Wireless connectivity			Wi-Fi®	Wi-Fi®	Wi-Fi®	Wi-Fi®	BLE, ZigBee®
Power management					●	●	●
USB		●	●	●			
File system	●	●	●	●	●	●	●
Drivers		●	●	●		●	●
Instrumentation	●	●	●	●		●	●

Table 2. TI-RTOS is available for many TI device families, but not all components are available for all families

USB host and device support

TI-RTOS USB includes both host and device stacks as well as the associated USB controller driver. In addition, MSC Host, CDC Device and HID Host and Device class drivers are provided. The MSC Host Class driver is provided as part of a pre-tested solution with the FAT file system for reading and writing to USB Flash drives. The CDC Device and HID Host and Device class drivers are reference implementations that can also serve as templates for developers to customize for their own specific HID or CDC device. Reference implementations are provided for both HID keyboard and mouse.

Device drivers and board initialization

For most devices, TI-RTOS includes a set of device drivers and board initialization files for evaluation boards. TI-RTOS device drivers provide a consistent API across all device families by abstracting away differences in hardware peripheral implementation. This makes customer applications easy to port between different devices. An extensive set of examples demonstrates how to use both the drivers and any associated middleware. TI-RTOS drivers include UART, I^2C, SPI, SD card (via SPI), Ethernet, Watchdog, GPIO and various USB-based offerings.

TI-RTOS device drivers are designed to be thread-safe and blocking (i.e., not polling), enabling them to work efficiently in a multitasking environment. They are also board-independent, enabling developers to port them to their custom boards without modification. All board-specific code, such which peripheral interrupts are used or how many UARTs are needed, is isolated in a separate “board_name.c” file. A developer simply needs to modify this for their own board to port over TI-RTOS.

Download TI-RTOS from **www.ti.com/tool/ti-rtos** or through the Code Composer Studio IDE Applications Center.

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