IEEE Standard for a Real-Time Operating System (RTOS) for Small-Scale Embedded Systems

IEEE Consumer Electronics Society

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New York, NY 10016-5997
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IEEE Std 2050™-2018

IEEE Standard for a Real-Time Operating System (RTOS) for Small-Scale Embedded Systems

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Standards Committee
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IEEE Consumer Electronics Society

Approved 11 May 2018

IEEE-SA Standards Board

Abstract: A real-time operating system (RTOS) called *µT-Kernel* for small-scale embedded systems such as systems with a single chip microcomputer including 16-bit CPUs, systems with a small amount of ROM/RAM, and systems without a memory management unit (MMU) are specified in this standard.

Keywords: 16-bit CPU, alarm handler, API, Application Programming Interface, cyclic handler, device management, embedded, event flag, fast lock, fast multi-lock, IEEE 2050™, interrupt handler, kernel, IoT edgenode, mailbox, memory pool, message buffer, mutex, non-task portion, physical timer, power management, power saving, priority-based, quasi-task portion, real time, real-time operating system (RTOS), semaphore, service profile, single chip microcomputer, single chip microcontroller, small scale, system call, task, task dispatching, task portion, task-independent portion, task scheduling, TRON, µT-Kernel

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3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-1-5044-4858-1 STD23105
Print: ISBN 978-1-5044-4859-8 STDPD23105

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Introduction

This introduction is not part of IEEE Std 2050™-2018, IEEE Standard for a Real-Time Operating System (RTOS) for Small-Scale Embedded Systems.

This standard defines the specification of a real-time operating system (RTOS) called µT-Kernel. µT-Kernel is the latest result from the TRON project, which was started by Dr. Ken Sakamura, then at the University of Tokyo in 1984.[1]

The TRON Project envisioned that environments optimized to humans would be created by embedding small microprocessors, invented in the prior decade, in many objects in our surroundings and having them talk to each other. In the TRON Project, the computing paradigm to achive this goal was called a "Highly Functionally Distributed System (HFDS)" and an RTOS called ITRON was created to control such microprocessors efficiently. The specificaton of the first version of ITRON, namely ITRON1, was published in 1987. The project promoted the industry-academic cooperation and published the technical specification and other information so that anyone can make use of the technology for free under the philosophy of "Open Approach." As a result, ITRON specification OS was born and it ran on many types of processors. It became the de facto standard RTOS for embedded computer systems. Additionally, the development of "µITRON," which is an improved version of ITRON and has better adaptability, proceeded concurrently.[2] OSs based on ITRON and µITRON specifications have been used widely in many embedded computer systems: they are used in consumer products, such as home electronic appliances and AV equipment, and industrial applications, such as machine control on factory floors, engine control of automobiles, etc.

The concept of "HFDS," which the TRON Project proposed, started to be called "ubiquitous computing" before the turn of the century and is now widely recognized as the Internet of Things (IoT). Since its inception in 1984, the TRON Project has targeted the IoT in today's parlance as the main application field of microprocessors and carried out research and development of OS and computer architecture. The latest result of such research and development of OS is µT-Kernel, a resource-efficient RTOS suitable for IoT edge nodes. It is an improvement of µITRON, and has features for IoT.

µT-Kernel improves development efficiency of the software by standardizing basic OS functions and API specification. It is designed to deliver high performance even on a lower-end single-chip microcontroller unit (MCU), including 16-bit MCU, MCUs without a memory management unit (MMU), and small-scale embedded systems with a small amount ROM/RAM. Furthermore, µT-Kernel has functions such as device driver control and power saving, so it can build low-power systems in which various types of devices and communication methods are embedded for building an IoT network. Today, the TRON Forum, a non-profit organization chaired by Dr. Ken Sakamura, is the main proponent of TRON Project activity.

Based on the adoptions so far, it has been reported that more than half of embedded devices use the results of the TRON Project in the 2010s, 30 years after the inception of the project.[3] In the IoT age, the RTOS family developed by the TRON Project is the most suitable basic technology to build high-performance IoT edge node devices, which operate in an efficient manner with small resources and small power consumption. With this background, the TRON Project has decided to standardize the specification of µT-Kernel, its latest version of RTOS, as IEEE Std 2050™-2018, to further improve the development efficiency of IoT edge nodes by making the specification widely recognized as an IEEE standard.

[1] Information is available at http://www.tron.org/.
[2] See µITRON 3.0: An Open and Portable Real-Time Operating System for Embedded Systems : Concept and Specification, Ken Sakamura, IEEE Computer Society Press Los Alamitos, CA, USA ©1997, ISBN: 0818677953.
[3] Information is available at http://www.tron.org/blog/2017/07/press20170406/.

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IEEE Standard for a Real-Time Operating System (RTOS) for Small-Scale Embedded Systems

1. Overview

1.1 Scope

This standard is a real-time operating system (RTOS) specification for small-scale embedded systems such as systems with a single chip microcomputer (single chip microcontroller) including 16-bit CPUs, systems with a small amount of ROM/RAM, and systems without a memory management unit (MMU).

The RTOS defined in this document is called *µT-Kernel*. This RTOS specification includes *µT-Kernel/OS*, which provides the basic functions of RTOS such as scheduling, synchronization, and communication of tasks. The RTOS specification also includes *µT-Kernel/SM (System Manager)*, which provides the extension function for system management.

1.2 Positioning and basic design policy of µT-Kernel

The µT-Kernel specification defines an embedded RTOS with a small resource footprint meant for controlling IoT edge devices. Standardization OS functions and Application Programming Interface (API) improves the reusability and distribution of software and the development of applications. It is also designed so that it can perform well on resource poor systems such those with a single chip microcontroller unit (MCU), or MCUs without MMUs, and systems with a small amount of ROM/RAM. It also features device driver management functions, energy-saving functions, etc., to build resource-efficient systems that support various types of network protocols for the IoT and incorporate various devices.

The µT-Kernel specification defines a standard for an RTOS, and it can be implemented on many types of CPUs irrespective of CPU architectures. At the same time, the designers are aware that it makes sense to adapt the OS implementation or limit the OS functions in the case of very resource-poor systems in order to cope with a particular choice of CPU and hardware configuration as in the case of tiny IoT edge nodes. To cope with such situations, a concept and description of "service profile" has been introduced in µT-Kernel to leave room for the flexible implementation of the OS, at the same time retaining the compatibility of software and portability. Service profile makes it possible to formally describe the omission and/or difference of functions available in a particular implementation of the OS. This makes it easy for middleware and applications that run under the OS to learn and cope with the implementation-dependent differences.