Open Architecture for Real-Time Embedded Systems
TRON Project

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Today’s Talk

Presentation of TRON Project: “Open Architecture” Project for Real-Time Embedded Systems
Overview of the Platform
Self-Introduction

- Main Interest in Real-Time Embedded Computer Systems
- Involved in TRON Project
  - A computer architecture project, for close to 30 years (since 1984)
- Current Interest: Ubiquitous Computing or the IoT
  - An important application of embedded technology
    - The application of the 21st century

TRON Project Since 1984
The Real-time Operating System Nucleus

1986: ITRON Specification OS
  - Industrial TRON
  - 2002: T-Kernel
  - 2011: T-Kernel 2.0
Where Is TRON RTOS Family Used?

HAYABUSA (Falcon) JAXA
Communication Unit (DHU) used μTRON2.0 specification OS.

BepiColombo (Exploration of the planet, Mercury) JAXA/ESA (European Space Agency)
Data Communication I/F for the vehicle, SpaceWire node, uses T-Kernel/SE.
Products That Deploy TRON OS

AQUOS
SHARP

Colorio
Printer
EPSON

DVD
Recorder
HITACHI

EXLIM
CASIO

Electronic
Piano
YAMAHA

Car Navigation System
DENSO

Lexus
TOYOTA
BOSCH Has Adopted T-Kernel for Its Car Navigation Systems

- Used in cars from OPEL and other automobile makers (outside Japan as well).

OS Family from TRON Project

- CPU Agnostics
  - CPUs from all the major CPU manufacturers: ARM, Freescale, Fujitsu, Intel, NXP, Renesas, Samsung, STMicro, Texas Instrument, Toshiba
    - ARM architecture, MIPS architecture, and others

- CPU
  - 8-bit: µlTRON
  - 16-bit: µlTRON, µT-Kernel
  - 32-bit without MMU: µlTRON, µT-Kernel
  - 32-bit with MMU: T-Kernel
  - Multi-CPU: AMP T-Kernel and SMP T-Kernel
TRON Holds 60% Share

50% or more of the share has been held by TRON for 13 years since 1999.

TRON Project: Approach

RTOS
Bottom-up Approach
Application for Today and Future
Top-down Approach
Features of T-Kernel

- Open & Free
- Strong real-time performance thanks to priority-based preemptive scheduling
- Scalability
  - From 1-chip microcomputer to multi-core high-end processor
- Small Memory Footprint
- One Stop Service
For a 3rd Party Technical Evaluation of TRON and T-Kernel

- An Article in IEEE MICRO

- Overall Evaluation
  - Practical system with TRON/T-Kernel
  - Good balance between rich and practical API and small memory footprint

- System Size
  - ROM size is large, but the required amount of RAM is small.

- Absolute Time Specification
  - Hardware independence of real-time code

International Development

User Examples
USA: RTEMS User Base

- RTEMS: A real-time OS that includes μITRON API support
  - http://www.rtems.com/
- Many users including Argonne National Laboratories use RTEMS.
  - Research institute for peaceful use of atomic energy
  - Managed by US DOE
  - Today’s research areas include photonics, battery, high-performance computing, physical chemistry, etc.

Argonne Lab’s slides that explain RTEMS

NoTA Project
VTT Finland

EIoTA

JOIN US!
Singapore NTU

Textbooks in Chinese and Vietnamese
TEDN: T-Engine Developer Network
http://www.t-engine.info/

- English Site for Developers
  - Hyperlinked specification, BBS/FORUM, tutorials
- Managed in Singapore

Why Is TRON So Popular?

The foremost reason is …
Open & Free

All the technical information is publicly available.
Source program is provided.
Anyone can use TRON for free.

All the source programs are provided by T-Engine Forum for free.
They can be commercially sold with some added value.
T-Engine Forum

An international NPO to promote the result of TRON Project

Publishes Specification
Releases Source Code
Holds Annual TRONSHOW
All Information Is Freely Available from the TEF Web Site

- All the relevant information is publicly available.
- Commercial usage is allowed without any royalty payment.
- License (T-License 2.0) is friendly to the needs of the embedded systems industry.

License Suited for Embedded Systems

- **T-License 2.0**
  - The downloaded T-Kernel source code can be changed and the operating system can be embedded in a system for free.
  - **Unlike GPL**, no obligation of disclosing the modified source code
    - No obligation of disclosing the source code when a source code developed in the user’s company is combined, which is a thorny point of GNU Copyleft, etc. in the embedded systems industry.
  - Redistribution of the changed and improved source code is possible.
  - License with traceability
Why Is TRON So Popular?

The second reason is …

Support Infrastructure
Hardware, Software, Service, etc. from Many Sources

- Hardware (CPU board), etc.
- Development environment
- Middleware
  - Open $\times$ Open = $\infty$, i.e. infinity

These are available from many sources thanks to the open architecture approach.
T-Engine Reference Board

Development Environment

- Offered for free from the TEF web site
  - Eclipse development environment
    - Runs on Windows computers
    - Compile and build
    - Transfer of programs to the target machine and execution
    - Debugging function
  - Compiler, Cygwin
    - gcc
    - Cygwin
  - Emulation using QEMU
    - Runs on Windows computers

- Many others from commercial sources
Open $\times$ Open $= \infty$
T2EX: T2 Extension

- An extension (add-on) to T2 (T-Kernel 2.0)
- Offers added functions for the network age
  - File system support
  - TCP/IP stack support
  - Portability: POSIX-like APIs and standard C libraries
  - Others
- Can be used to port other middleware and application easily
- Source code available for free from T-Engine Forum
  - Availability: 4Q 2012

T2EX: Design Considerations

- Maintain real-time response of T2
- TCP/IP stack: socket programming for familiarity and portability
- File System Support (FAT as sample)
- Safety Programming
- Portability
  - POSIX
  - C standard libraries
Support for Wide Range of CPUs and Scalability

- Supports the latest CPUs
  - 5 to 6 times the speed of old CPUs compared to 8 years ago (beyond 1 GHz clock) when T-Kernel version 1.0 was released.
  - Supports SoC (System on Chip)
    - SoC: System on Chip with which most of computer functions as well as CPU can be equipped in one chip
  - Supports multi-core CPUs
  - Chip-agnostic

Support by Semiconductor Companies

- TRON RTOS OS family has been well received by semiconductor companies who produce MCUs.
- TRON RTOS is sometimes bundled in a developer kit.
From ARM to Intel

- UCT μT-Kernel DevKit Tuned for Kinetis
  - μT-Kernel optimized for Freescale Kinetis K60 family (ARM Cortex M4)
  - License for the mass production
    - It can be copied within a project for free.
  - Small memory footprint
PMC T-Kernel / x86 SDK and Evaluation Kit

PERSONAL MEDIA CORP.
www.personal-media.co.jp

System function
USB II manager
MMC storage class
CF/SD I/O
HDD

MicroScript

File manager
Font manager

UHCI II/III manager

PMC T-Kernel
Real-time OS
Supports MMU

PMC T Monitor
System function (boot function)

PC/AT compatible hardware

PC/AT compatible hardware

Basic Configuration
LAN option
USB option
GUI option

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MP T-Kernel: RTOS for Multi-core Processors

- AMP (Asymmetric MP)
  AMP T-Kernel

- SMP (Symmetric MP)
  SMP T-Kernel

NaviEngine
Renesas Electronics
ARM11 × 4 core

SH7786
Renesas Electronics
SH-4A × 2 core

T-Kernel & ITRON Road Map
Future Computing Paradigm

Cloud + Embedded Systems

Suited for the Future IoT Applications

The IoT (Internet of Things), or ubiquitous computing will require many small nodes connected to the Cloud.
Future Applications and Trends

The approach of the open and free architecture should prove useful to support the new applications by offering the new features.

- Sensor nodes in ubiquitous sensor network
- Machines such as home electronic appliances in M2M (Machine to Machine) applications
- Additional Features
  - Interoperability: A single organization can not check alone.
  - Reliability: A single organization can not test alone.

The Internet of Things (IoT)

- Smart Healthcare
- Smart House / Smart City
- Food Traceability Systems
- Sensor Networks
Smart Healthcare Monitoring Device

Smart House / Smart City
Smart Grid / Smart Metering for Energy-saving

- Electric energy of the circuit of distribution board
- Amount of water used
- Amount of gas used
- Electricity produced by wind power
- Electricity produced by solar power

Measures the temperature, humidity and illuminance
Detects when there is a person nearby

Measures the electric energy of the device connected to the socket
Concluding Remarks

T-Kernel Is Open and Free.
Please download and use it to build future smart systems.

Thank you
http://www.t-engine.org/