

Special Report: Choosing an RTOS

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Dec 12, 2002 (9:56 AM)

In the market for a commercial RTOS? This article provides an overview of RTOSes and how you can select the one for your project. You'll also find a list of vendors and their products and tips on comparing the products in the Embedded.com Buyer's Guide.

Engineers often use the term real-time to describe computing problems for which a late answer is as bad as a wrong one. These problems are said to have deadlines, and embedded systems frequently operate under such constraints. For example, if the embedded software that controls your anti-lock brakes misses one of its deadlines you might find yourself in an accident. So it's extremely important that the designers of real-time embedded systems know everything they can about the behavior and performance of their hardware and software.

The designers of real-time systems spend a large portion of their time worrying about worst-case performance. They must constantly ask themselves questions like: what is the worst-case time between the human operator pressing the brake pedal and an interrupt signal arriving at the processor? What is the worst-case interrupt latency? And what is the worst-case time for the software to respond by triggering the braking mechanism? Average or expected-case analysis simply will not suffice.

Most of the commercial embedded operating systems available today are designed for possible inclusion in real-time systems. In the ideal case, their worst-case performance is well understood and documented. To earn the distinctive title "Real-Time Operating System" (RTOS), an operating system should be deterministic and have guaranteed worst-case interrupt latency and context-switch times. Given these characteristics and the relative priorities of the tasks and interrupts in your system, it is possible to analyze the worst-case performance of the software using a technique such as rate monotonic analysis (see "Rate Monotonic Scheduling" by David Stewart and Michael Barr, March 2002, p.79).

An operating system is said to be deterministic if the worst-case execution time of each of its system calls is calculable. An operating system vendor that takes the real-time behavior of its product seriously will usually publish a datasheet providing the minimum, average, and maximum number of clock cycles required by each system call. These numbers may be different for different processors, but it is reasonable to expect that if the algorithm is deterministic on one processor it will be so on any other. (The actual times may differ, however.)

Interrupt latency is the total length of time from an interrupt signal arriving at the processor to the start of the associated interrupt service routine (ISR). When an interrupt occurs, the processor must take several steps before executing the ISR. First, the processor must finish executing the current instruction. Next, the interrupt type must be recognized. This is done by the hardware and does not slow or suspend the running task. Finally, and only if interrupts are enabled, the CPU's context is saved and the ISR associated with the interrupt is started.

Of course, if interrupts are ever disabled (say within a system call), the worst-case interrupt latency increases by the maximum amount of time that they are turned off. Each operating

system will internally disable interrupts in several places and for different lengths of time, so it is important that you know what your system's requirements are. One real-time project might require a guaranteed interrupt response time as short as 1 μ s, while another may require only 100 μ s.

The third real-time characteristic of an operating system is the amount of time required to perform a context switch. This is important because it represents overhead across your entire system. For example, imagine if the average execution time of any task before it blocks is 100ms but that the context-switch time is also 100ms. In that case, fully one half of the processor's time is spent within the context-switch routine!

Again, there is no magic number and the actual times are usually processor-specific, since they are dependent on the number of registers that must be saved and where. Be sure to get these numbers from any operating system vendor you are thinking of using. That way, there won't be any last minute surprises.

Selection process

Considering the cost of engineering time these days, a few thousand dollars is a bargain for a commercial RTOS. A wide variety of operating systems are available to suit most projects and pocketbooks. See the vendor listings following this article or go to www.embedded.com/bg for more detailed product information.

Commercial operating systems form a continuum of functionality, performance, and price. Those at the lower end of the spectrum offer just a basic preemptive scheduler and a few other key system calls. These operating systems are usually inexpensive, come with source code that you can modify, and do not require payment of any royalties.

Operating systems at the other end of the spectrum typically include a lot of functionality beyond the basic scheduler. These operating systems can be quite expensive, though, with startup costs ranging from \$10,000 to \$50,000 and royalties due on every copy shipped in ROM. However, this price often includes free technical support and training and a set of integrated development tools.

Between these two extremes are the operating systems that have modest up-front costs and/or royalties, but do not include source code; technical support may cost extra. Most commercial operating systems fall in this category.

With such a variety of operating systems and features to choose from, it can be difficult to decide which is the best for your project. Try putting your processor, real-time performance, and budgetary requirements first. These are criteria that you cannot change, so you can use them to narrow the possible choices to a smaller set of products. Then contact all of the vendors of the remaining operating systems for more detailed technical information.

At this point, many people make their decision based on compatibility with their choice of cross-compiler, debugger, and other development tools. But it's really up to you to decide what additional features are most important for your project. No matter what you decide to buy, the basic kernel will be about the same. The differences will most likely be measured in processor support, minimum and maximum memory requirements, availability of add-on software modules (for example, networking protocol stacks, device drivers, and flash filesystems), and compatibility with third-party development tools.

The best reason to choose a commercial operating system is the advantage of using something that is better tested and, therefore, more reliable than a kernel you have

developed inhouse. So one of the most important things you should be looking for from your OS vendor is experience.

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RTOS Product Names

- AMX (KADAK)
- AvSYS Real-Time (Avocet Systems)
- Blackhawk OS (Blackhawk)
- BlueCat Linux (LynuxWorks)
- BSD/OS (Wind River)
- C Executive (JMI Software)
- CMX-RTX, CMX-Tiny+, CMX-RTXS (CMX Systems)
- Diamond (3L)
- DR-DOS 7.03 (The SCO Group)
- eCos (Red Hat)
- Embedix RT (Lineo)
- embOS (SEGGER)
- ERCOSEK (ETAS)
- eRTOS (JK Microsystems)
- EUROS (EUROS Embedded Systems)
- Eyrx (Eyring)
- Fusion RTOS (DSP OS)
- icWORKSHOP (Integrated Chipware)
- INTEGRITY (Green Hills Software)
- iRMX III, iRMX/INtime for Windows (TenAsys)
- Jbed (esmertec)
- Linux for Real-Time (OnCore Systems)
- LynxOS (LynuxWorks)
- mC/OS-II (Micrium)
- Microwave OS-9 (RadiSys)
- MontaVista Linux (MontaVista Software)
- NetBSD Embedded (Wasabi Systems)
- Neutrino (QNX Software Systems)
- Nucleus uiPLUS, Nucleus OSEK, Nucleus PLUS (Accelerated Technology/Mentor Graphics)
- On Time RTOS-32 (On Time Software)
- OnCore OS (OnCore Systems)
- OSE RTOS (OSE Systems)
- OSEKturbo (Metrowerks/Motorola)
- OSEKWorks (Wind River)
- PDOS (Eyring)
- pF/x (FORTH)
- PharLap Real-time ETS Kernel (VenturCom)
- pmDOS (Micro Digital)
- Precise/MQX (ARC International)
- PSMX Portable smx (Micro Digital)
- pSOSystem 2.5/3 (Wind River)
- PSX (JMI Software Systems)
- PXROS (HighTec EDV-Systeme)

- QNX (QNX Software Systems)
- Quadros (RTXC)
- QuickTask (Softtools)
- RAVEN (Aonix)
- REAL/IX PX (MODCOMP)
- Realogy Real-Time Architect (LiveDevices)
- REALOS (Fujitsu Microelectronics)
- Real-Time OS: DSP/BIOS (Texas Instruments)
- Red Hat Embedded (Red Hat)
- REDICE-Linux (REDSonic)
- ROM-DOS (Datalight)
- RTexec (Applied Dynamics International)
- RTEMS (OAR)
- RTKernel (On Time Software)
- RTKernel-RISC (EBSnet)
- RTX for Windows (VenturCom)
- RTX51/RTX51 Tiny, RTX166/RTX166 Tiny (Keil)
- Salvo (Pumpkin)
- SKYmpx (SKY Computers)
- smx/smx++ (Micro Digital)
- Spartos (Ardro Engineering)
- Starlight Linux (Auriga)
- SuperTask (Lantronix)
- TargetOS (Blunk Microsystems)
- ThreadX (Express Logic)
- Tics (TICS Realtime)
- TimeSys Linux/RT, Real-Time Mach (TimeSys)
- TronTask3.0 (Lantronix)
- TTPos (TTTech Computertechnik)
- TurboTask (Softtools)
- TxOS - Titanic (Incantation Systems)
- VRTX (Mentor Graphics)
- VSPWorks (Wind River)
- VxWorks, VxWorks AE (Wind River)
- Windows CE .NET, Windows XP Embedded (Microsoft)

RTOS Vendor List

The following vendors make commercial real-time operating systems (RTOSes). Product names are included directly below the vendor URLs and also are listed alphabetically in the sidebar. For detailed information about these RTOSes, visit the Embedded.com online Buyer's Guide. You'll find the real-time operating systems category under software.

3L

104 (2F3) Spring Gardens
Edinburgh EH8 8EY
Scotland
United Kingdom
44-131-662-4333
<http://www.shen.myby.co.uk/threel>
Diamond

Applied Dynamics International

3800 Stone School Rd.
Ann Arbor, MI 48108
United States
(734) 973-1300
<http://www.adi.com/>
RTexec

Auriga

1 Overlook Dr., Unit 2
Amherst, NH 03031
United States
(603) 673-2300
<http://www.auriga.com/>
Starlight Linux

Blunk Microsystems

6576 Leyland Park Dr.
San Jose, CA 95120
United States
(408) 323-1758
<http://www.blunkmicro.com/>
TargetOS

DSP OS

327 Dahlonge Rd., Ste. 1801A
Cumming, GA 30040
United States
(678) 208-2250
<http://www.dspos.com/>
Fusion RTOS

ETAS

3021 Miller Rd.
Ann Arbor, MI 48103
United States
(888) 382-7462
<http://www.etasinc.com/>
ERCOSEK

Accelerated Technology (Embedded Division of Mentor Graphics)

720 Oak Circle Dr. E.
Mobile, AL 36609
United States
(800) 468-6853
<http://www.acceleratedtechnology.com/>
Nucleus uiPLUS, Nucleus OSEK,
Nucleus PLUS

ARC International

2025 Gateway Place, Ste. 140
San Jose, CA 95110
United States
(408) 437-3400
<http://www.arc.com/>
Precise/MQX

Avocet Systems

P.O. Box 490
Rockport, ME 04856
United States
(800) 448-8500
<http://www.avocetsystems.com/>
AvSYS Real-Time

CMX Systems,

12276 San Jose Blvd., Ste. 119
Jacksonville, FL 32223
United States
(904) 880-1840
<http://www.cmx.com/>
CMX-RTX, CMX-Tiny+, CMX-RTXS

EBSnet

39 Court St.
Groton, MA 01450
United States
(800) 428-9340
<http://www.ebsnetinc.com/>
RTKernel-RISC

Express Logic

11423 W. Bernardo Ct.
San Diego, CA 92127
United States
(888) THREADX
<http://www.expresslogic.com/>
ThreadX

Aonix

5040 Shoreham Place
San Diego, CA 92122
United States
(800) 97-AONIX
<http://www.aonix.com/>
RAVEN

Ardro Engineering

431 Ohio Pike, Ste. 210N
Cincinnati, OH 45255
United States
(800) 369-1009
<http://www.ardro.com/>
Spartos

Blackhawk

3 Eves Dr., Ste. 316
Marlton, NJ 08053
United States
(877) 983-4514
<http://www.blackhawk-dsp.com/>
Blackhawk OS

Datalight

21520 30th Dr. SE, M/S 110
Bothell, WA 98021
United States
(800) 221-6630
<http://www.datalight.com/>
ROM-DOS

esmertec

Lagerstrasse 14
Duebendorf, 8600
Switzerland
+41 1 823 89 00
<http://www.esmertec.com/>
Jbed

Eyring

6912 S. 185 W.
Midvale, UT 84047
United States
(800) 937-7367
<http://www.eyring.com/>
Eyrx, PDOS

EUROS Embedded Systems

Campestrasse 12
Nuremberg D-90419
Germany
+49-911-300328-0
<http://www.kaneff.de/>
EUROS

Green Hills Software

30 W. Sola St.
Santa Barbara, CA 93101
United States
(805) 965-6044
<http://www.ghs.com/>
INTEGRITY

Integrated Chipware

1861 Wiehle Ave., Ste 300
Reston, VA 20190
United States
(888) 430--2447
<http://www.chipware.com/>
icWORKSHOP

KADAK

206 - 1847 West Broadway Ave.
Vancouver, BC V6J1Y5, Canada
(604) 734-2796
<http://www.kadak.com/>
AMX

Lineo

390 S. 400 W.
Lindon, UT 84042
United States
(800) 490-9448
<http://www.lineo.com/>
Embedix RT

Mentor Graphics

8005 SW Boeckman Rd.
Wilsonville, OR 97070
United States
(800) 547-3000
<http://www.mentor.com/>
VRTX
See also Accelerated Technology

Micro Digital

2900 Bristol St. #G-204
Costa Mesa, CA 92626
United States
(800) 366-2491
<http://www.smxinfo.com/>
pmDOS, smx/smx++ , PSMX Portable
smx

FORTH

5155 W. Rosecrans Ave., Ste.1018
Hawthorne, CA 90250
United States
(800) 55-FORTH
<http://www.forth.com/>
pF/x

HighTec EDV-Systeme

Feldmannstr. 98
Saarbruecken, 66119
Germany
+49 (0)681 92613-0
<http://www.hightec-rt.com/>
PXROS

JK microsystems

1403 Fifth St., Ste. D
Davis, CA 95616
United States
(530) 297-6073
<http://www.jkmicro.com/>
eRTOS

Keil Software

1501 10th St., Ste. 110
Plano, TX 75074
United States
(800) 348-8051
<http://www.keil.com/>
RTX51, RTX51 Tiny, RTX166, RTX166
Tiny

LiveDevices

The Innovation Centre
York Science Park
York, England YO10 5DG
United Kingdom
+44 1904 562580
<http://www.livedevices.com/>
Realogy Real-Time Architect

Metrowerks / Motorola

9801 Metric Blvd.
Austin, TX 78758
United States
(512) 997-4700
<http://www.metrowerks.com/>
OSEKturbo

Microsoft

One Microsoft Way
Redmond, WA 98052
United States
(425) 882-8080
<http://www.microsoft.com/>
Windows CE .NET, Windows XP
Embedded

Fujitsu Microelectronics

3545 N. First St.
San Jose, CA 95134
United States
(800) 866-8608
<http://www.fujitsumicro.com/>
REALOS

Incantation Systems

Northern Ireland Science Park,
Queen's Rd., Queen's Island,
Belfast, Ireland
United Kingdom
+44 (0)28 90534560
<http://www.incantationsystems.com/>
TxOS -- Titanic

JMI Software Systems

Box 237
Dover, NH 03821
United States
(408) 287-7090
<http://www.jmi.com/>
PSX, C Executive

Lantronix

15353 Barranca Pkwy.
Irvine, CA 92618
United States
(949) 453-3990
<http://www.lantronix.com/>
SuperTask, TronTask3.0

LinuxWorks

2239 Samaritan Dr.
San Jose, CA 95124
United States
(800) 255-5969
<http://www.linuxworks.com/>
LynxOS, BlueCat Linux

Micrium

949 Crestview Circle
Weston, FL 33327-1848
United States
(954) 217-2036
<http://www.micrium.com/>
mC/OS-II

MODCOMP

1650 W. McNab Rd.
Ft. Lauderdale, FL 33309 U.S.A.
(954) 974-1380
<http://www.modcomp.com/>
REAL/IX PX

MontaVista Software

1237 East Arques Ave.
Sunnyvale, CA 94085
United States
(408) 328-9200
<http://www.mvista.com/>
MontaVista Linux

OSE Systems

1731 Technology Dr.
San Jose, CA 95110
United States
(866) 844-RTOS
<http://www.ose.com/>
OSE RTOS

Quadros

275 Grove St., Ste. 2-400
Newton, MA 02466
United States
(866) 879-QUAD
<http://www.quadros.com/>
RTXC

REDSonics

1740 E. Garry Ave., #212
Santa Ana, CA 92705
United States
(866) 899-1688
<http://www.redsonic.com/>
REDICE-Linux

The SCO Group

355 S. 520 W., Ste. 100
Lindon, UT 84042
United States
(801) 426-5001
<http://www.sco.com/>
DR-DOS 7.03

Texas Instruments

12500 TI Blvd.
Dallas, TX 75243
United States
(800) 477-8924
<http://www.ti.com/>
Real-Time OS: DSP/BIOS

TTTech Computertechnik

Schoenbrunnerstrasse 7
Vienna, A-1040
Austria
+43 1 585 34 34 0
<http://www.tttech.com/>
TTPos

On Time Software

88 Christian Ave.
Setauket, NY 11733
United States
(888) 667-8200
<http://www.on-time.com/>
On Time RTOS-32, RTKernel

Pumpkin

750 Naples St.
San Francisco, CA 94112
United States
(415) 584-6360
<http://www.pumpkininc.com/>
Salvo

RadiSys

5445 NE Dawson Creek Dr.
Hillsboro, OR 97124
United States
(800) 950-0044
<http://www.radisys.com/>
Microwave OS-9

SEGGER Microcontroller System

Kleinhülsen 4
Hilden, NRW 40721
Germany
+49-2103-8958-99
<http://www.segger.com/>
embOS

Softools

81 Norwood Rd.
West Hartford, CT 06117
United States
(860) 236-4201
<http://www.softools.com/>
TurboTask, QuickTask

TICS Realtime

3333 Bowers Ave., Ste. 130
Santa Clara, CA 95054
United States
(408) 727-3100
<http://www.cris.com/~Tics/>
Tics

VenturCom

5 Cambridge Center
Cambridge, MA 02142
United States
(617) 661-1230
<http://www.vci.com/>
PharLap Real-time ETS Kernel, RTX
for Windows

OnCore Systems

795 Main St.
Half Moon Bay, CA 94019
United States
(866) 4-ONCORE
<http://www.oncoresystems.com/>
Linux for Real-Time, OnCore OS

QNX Software Systems

175 Terence Matthews Crescent
Kanata, ON K2M 1W8
Canada
(800) 676-0566
<http://www.qnx.com/>
QNX, Neutrino

Red Hat

2600 Meridian Pkwy.
Durham, CA 27713
United States
(866)-2REDHAT, x3004
<http://www.redhat.com/>
eCos, Red Hat Embedded

SKY Computers

27 Industrial Ave.
Chelmsford, MA 01824
United States
(800) 486-3400
<http://www.skycomputers.com/>
SKYmpx

TenAsys

1600 NW Compton Dr., Ste. 104
Beaverton, OR 97006
United States
(877) 277-9189
<http://www.tenasys.com/>
iRMX III, iRMX for Windows, INtime
for Windows

TimeSys

4516 Henry St., Ste. 401
Pittsburgh, PA 15213
United States
(888) 432-TIME
<http://www.timesys.com/>
TimeSys Linux/RT, Real-Time Mach

Wasabi Systems

104 W. 14th St., 4th Flr.
New York, NY 10011
United States
(646) 638-2424
<http://www.wasabisystems.com/>
NetBSD Embedded

Wind River

500 Wind River Wy.
Alameda, CA 94501
United States
(800) 545-WIND
<http://www.windriver.com/>
BSD/OS, OSEKWorks, pSOSystem
2.5, pSOSystem 3, VSPWorks,
VxWorks, VxWorks AE

OAR

4910-L Corporate Dr.
Huntsville, AL 35805
United States
(256) 722-9985
<http://www.rtems.com/>
RTEMS