tenAsys®

USER'S MANUAL

INtime® 3.1 Software

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Before you begin

This guide describes INtime® software, an extension for Microsoft Windows, that provides the tools you need to create and run real-time (RT) applications—robust, high-performance applications with predictable responses to external events.

This guide assumes that you know how to develop programs for Windows and understand RT system concepts.

Note
In this guide, the term “Windows” means any one of Windows XP, Windows XP Embedded, Windows 2000, or Windows Server 2003.

About this guide

Guide contents

This guide introduces you to INtime software: how it makes RT applications possible, and how to use the INtime development tools. Use this guide to get acquainted with INtime software, then refer to Help for detailed information about INtime components. For more information about accessing help, see *Where to get more information* later in this chapter.

Note
For a quick start, read *Chapter 1, Overview* to introduce you to all the basic INtime software concepts and to learn where to find detailed information about INtime software, then read *Chapter 10, INtime application development*, to learn about developing RT applications using INtime software.

Part I: Introducing INtime software

This part introduces INtime software and explains how INtime software and Windows work together to create RT applications.

Chapter		Description
1	Overview	Describes how INtime software works together with Windows to create and run RT applications, and lists INtime software’s features. It also tells you where to find detailed information about INtime software topics.
2	Understanding INtime software architecture	Explains how INtime’s RT kernel works with Windows to provide RT functionality. It also lists and describes INtime components.

Chapter		Description
3	About INtime software's RT kernel	Describes the RT kernel and its objects, the basic building blocks that application programs manipulate.
4	About RT programming	Describes processes unique to RT programming.
5	Designing RT applications	Provides general guidelines for RT system design.

Part II: Using INtime software

This part explains how to start INtime software and how to use the INtime software development tools.

Chapter		Description
6	Installation	Explains how to install and uninstall INtime software.
7	Configuration	Describes how to configure INtime software.
8	Preparing an RT node	Explains how to set up an RT node to run INtime software.
9	Operation	Describes how to start and run INtime software.

Part III: Appendices

The appendices provide additional information about INtime software.

Appendix		Description
A	INtime software system calls	Lists and describes system calls that threads in the RT portion of INtime applications use to communicate with each other and with Windows threads. You can find detailed information, including syntax and parameter values, in Help.
B	The iwin32 subsystem	Describes the iwin32 subsystem, which provides a Win32 API for the INtime kernel. It is a parallel API to the INtime API that makes porting of existing Win32 applications easier.
C	INtime software components	Lists and describes INtime software program files.
D	Visual Studio .NET debugging for older INtime projects	Describes how existing INtime projects may be upgraded to use the Visual Studio .NET product and its debugger.
E	Adding INtime software to an XP Embedded configuration	Lists and describes how to add INtime components to a Windows XP Embedded development environment so that XP Embedded images can be produced that include these INtime components.
F	Troubleshooting	Lists problems you may encounter while running INtime software, and explains how to avoid or resolve those problems.

Glossary

The glossary defines terms used to describe INtime software.

Notational conventions

This manual uses the following conventions:

- All numbers are decimal unless otherwise stated.
- Bit 0 is the low-order bit. If a bit is set to 1, the associated description is true unless otherwise stated.
- `Data structures and syntax strings appear in this font.`

Note	Indicates important information about the product.
Tip	Indicates alternate techniques or procedures that you can use to save time or better understand the product.
CAUTION	Indicates potentially hazardous situations which, if not avoided, may result in minor or moderate injury, or damage to data or hardware. It may also alert you about unsafe practices.
WARNING	Indicates potentially hazardous situations which, if not avoided, can result in death or serious injury.
DANGER	Indicates imminently hazardous situations which, if not avoided, will result in death or serious injury.

Where to get more information

About INtime software

You can find out more about INtime software from these sources:

- **World Wide Web**: TenAsys maintains an active site on the World Wide Web. The site contains current information about the company and locations of sales offices, new and existing products, contacts for sales, service, and technical support information. You can also send e-mail to TenAsys using the web site:

  `www.tenasys.com`

  You can contact TenAsys by email:

  `info@tenasys.com`

  You can contact TenAsys technical support by email:

  `support@tenasys.com`

Note
When sending e-mail for technical support, please include information about both the hardware and software, plus a detailed description of the problem, including how to reproduce it.

Requests for sales, service, and technical support information receive prompt response.

- **INtime Help**: Describes INtime software concepts and explains how to use INtime tools. Help includes all system calls, including their syntax which you can cut and paste directly into your code. To access Help, do one of these:
  - **Within Microsoft Visual Studio 6**: Select Help>Contents. INtime Help displays.
  - **Within Microsoft Visual Studio .Net 2003**: INtime content is integrated with the Visual Studio help collections. INtime content may be filtered with the keyword "INtime".
  - **Within source code**: Highlight a system call in your source code, then press F1. Help for that system call displays.

    Before you can access context-sensitive Help within source code, you must enable context-sensitive Help with the Microsoft Visual Studio. To enable context-sensitive Help:

    i. In Microsoft Visual Studio, select the Help menu's Use Extension Help option. This disables the Microsoft online books, and enables INtime Help.

    ii. To display information for any INtime software call, click on the call and press F1.

    To re-enable the Microsoft online books, select the Use Extension Help option entry again.
  - **Readme file**: Lists features and issues that arose too late to include in other documentation.
  - **Other**: If you purchased your TenAsys product from a third-party vendor, you can contact that vendor for service and support.

About Windows

For more information about Windows operation and program development, see these documents:

- Documentation that came with Windows.
- Documentation that came with Microsoft Visual Studio.

Contents

Figures

Tables

I Introducing INtime software

This part acquaints you with INtime software: its components, how they're put together, and how they work with Windows to run RT applications.

This part contains:

Chapter 1: Overview

Describes how INtime software works together with Windows to create and run RT applications, and lists INtime software's features. It also tells you where to find detailed information about INtime software topics.

Note
Read this chapter first. It introduces you to all the basic INtime software concepts and tells you where to find detailed information.

Chapter 2: Understanding INtime software architecture

Explains how INtime's RT kernel works with Windows to provide RT functionality. It also lists and describes INtime components.

Chapter 3: About INtime software's RT kernel

Describes the RT kernel and its objects, the basic building blocks that application programs manipulate.

Chapter 4: About RT programming

Describes processes unique to RT programming.

Chapter 5: Designing RT applications

Provides general guidelines for RT system design.

1 Overview

INtime software extends Windows to provide the tools you need to create and run RT (real-time) applications. INtime software consists of:

- **Development environment**: tools you use to create RT applications that run in the INtime runtime environment under Windows.
- **Runtime environment**: additions to your Windows system that provide an RT platform for INtime applications.

This chapter describes how INtime software works together with Windows to create and run INtime applications, and lists INtime software features. It also tells you where to find detailed information about INtime software.

How does INtime software work?

You install INtime software on a system that already runs Windows. Once installed, Windows and INtime software work together to provide deterministic, RT support for INtime applications.

INtime software works with the following versions of Windows:

- Windows 200, Service Pack 4
- Windows XP, Service Pack 2
- Windows XP 64-bit encryption
- Windows XP Embedded
- Windows Server 2003 and Windows Server 2003 Release 2
- Windows Vista (32-bit version)

Running an INtime application in Windows

Note

For detailed information about how INtime software and Windows work together to run INtime applications, see *Chapter 2, Understanding INtime software architecture.*

An INtime application includes these components:

- **RT processes**: RT processes contain threads that typically handle time-critical I/O and control. RT threads preempt Windows threads.

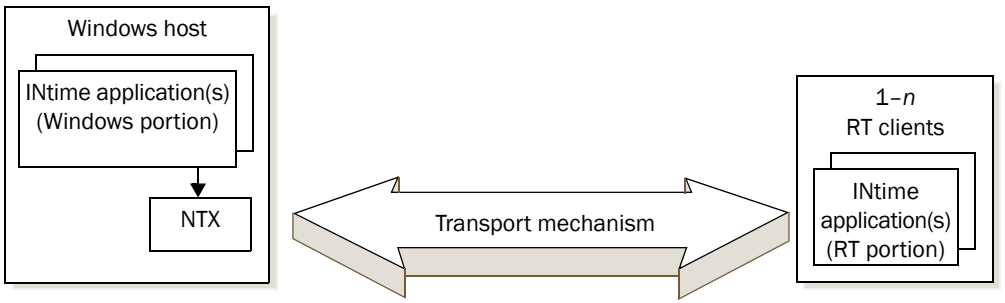
- **Windows processes**: Windows processes contain threads that handle aspects other than time-critical I/O and control, including the user interface, network communication, data manipulation and computation, and data storage.

Communication between Windows and RT threads

When an INtime application runs, Windows threads communicate with RT threads via the Windows extension (NTX) API.

The RT threads in your INtime application(s) may reside on the same PC as the Windows threads or in a remote computer accessed via serial or Ethernet cable. The NTX API automatically detects the connection type and determines the transport mechanism to use between Windows and RT threads: in-memory (local), serial, or Ethernet:

Figure 1-1. Transport mechanism for NTX communication



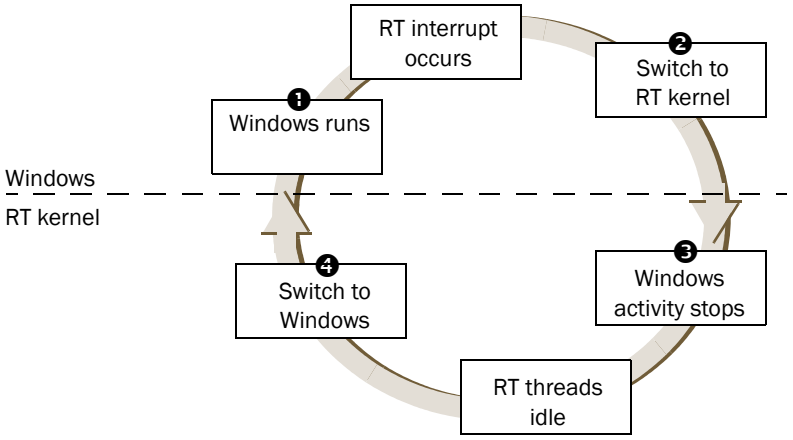
Note

For detailed information about INtime software's transport mechanisms, see *Transport mechanisms* in *Chapter 2, Understanding INtime software architecture*

Considerations for INtime applications running on a single processor PC

When both the Windows and RT portions of an INtime application run on a single CPU, INtime software transfers control between the Windows and RT environments as shown in this figure:

Figure 1-2. Transferring control between Windows and INtime software's RT kernel



❶) When a Windows thread runs, the full Windows environment exists, including its interrupts, interrupt masks, and handlers.

❷) When an RT interrupt occurs, control immediately switches to the RT kernel, where an RT interrupt handler deals with the event. This, in turn, may cause one or more RT threads to execute.

❸) Windows processes and interrupts stop until the RT threads complete.

❹) When all RT threads complete their work, leaving no RT threads ready to run, control switches back to the Windows environment, and standard Windows scheduling resumes.

When running on a single microprocessor, the INtime runtime environment encapsulates all Windows processes and threads into a single RT thread of lowest priority. As a result, RT threads always preempt running Windows threads, guaranteeing determinism for RT activities within the system.

The RT and Windows threads can share sections of memory allocated by INtime applications. A Windows thread can obtain a handle for this shared memory, then map the memory referenced by that handle into the thread's address space.

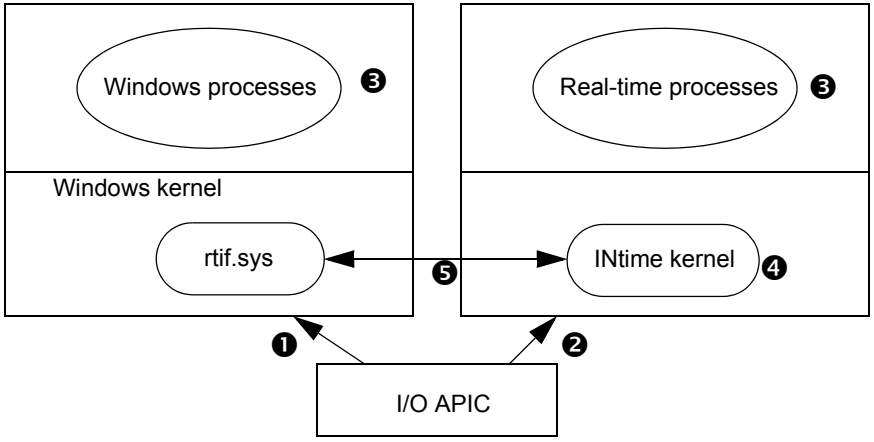
Note
For detailed information about memory usage, go to Help and select About INtime software, RT kernel objects, then Memory Management.

Considerations for INtime applications running on a multiprocessor PC

When Windows and INtime run on a multiprocessor PC, by default the INtime kernel and Windows share one of the CPUs and Windows uses the others. The shared CPU behaves in the same way as the single-CPU case above.

INtime software may alternatively be configured such that an entire CPU may be dedicated to the INtime kernel. In this case the architecture is rather different, as shown in this figure:

Figure 1-2. Control flows in a dedicated multiprocessor configuration



❶) When a Windows interrupt occurs, the I/O APIC delivers the interrupt to the Windows CPU only.

❷) When an RT interrupt occurs, the I/O APIC delivers the interrupt to the INtime CPU only.

❸) Windows processes are never preempted by real-time interrupt and processes and vice-versa, because each OS has a dedicated CPU.

❹) When all RT threads complete their work, leaving no RT threads ready to run, the INtime CPU executes an idle task until the next real-time interrupt occurs.

❺) The Windows and INtime kernels signal using IPIs and shared memory.

When running on a single microprocessor, the INtime runtime environment encapsulates all Windows processes and threads into a single RT thread of lowest priority. As a result, RT threads always preempt running Windows threads, guaranteeing determinism for RT activities within the system.

On multiple processors configured so that Intime has a dedicated processor, the RT kernel does not need to encapsulate the Windows system in the same way because there are separate processors for each OS.

In both cases, RT and Windows processes can share sections of memory allocated by INtime applications. A Windows thread can obtain a handle for this shared memory, then map the memory referenced by that handle into the thread's address space

Developing an INtime application

Design considerations

Note

For detailed information about designing INtime applications, see *Chapter 5, Designing RT applications*.

When designing INtime applications, you must divide the labor appropriately between Windows processes and RT processes and, to a finer degree, between the threads in each process. For the best performance, limit RT processes to performing only time-critical functions, and determine which Windows threads require the greater relative priority.

Code development

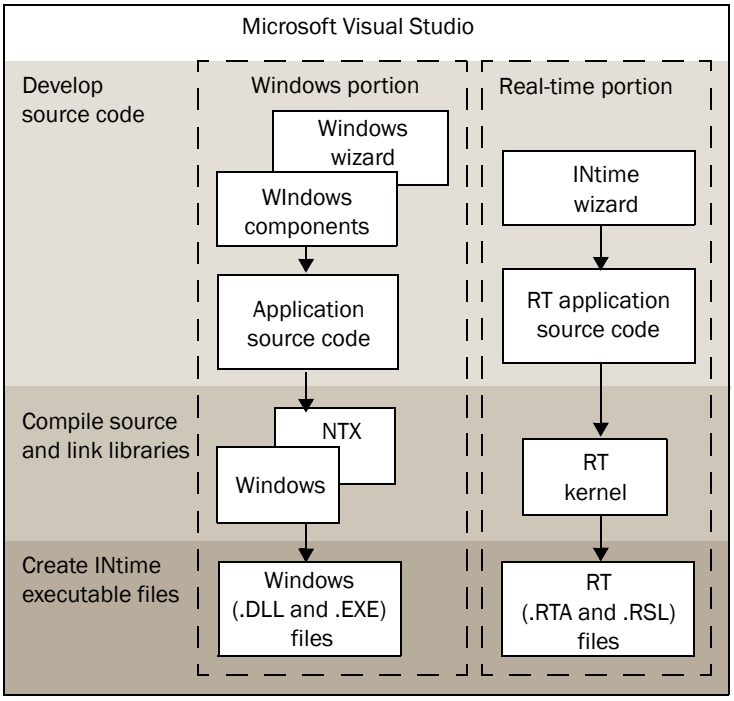
Note

For detailed information about developing INtime applications, see *Chapter 10, INtime application development*.

To develop an INtime application, you use Microsoft Visual Studio, including INtime wizards and Microsoft Visual Studio extensions for RT processes, a standard Windows debugger, and a Windows-based RT dynamic debugger that supports on-target debugging of RT threads. INtime includes a debugger which integrates with the Visual Studio debugger. This integration supports the Visual Studio versions from 2003 onward.

When developing INtime applications with Microsoft VIsual Studio, you create executable files for both RT and Windows environments as shown in this figure:

Figure 1-3. Creating INtime applications



Features

Note

For detailed list of INtime software components, see *Appendix C, INtime software components*. For information about using these components, see *Chapter 10, INtime application development*.

Development environment

To develop INtime applications, you use standard Windows tools together with these INtime software tools:

Wizards

Accessed from within Microsoft Visual Studio, INtime wizards automatically prompt you for the information needed to create projects that contain source code for the RT portion of your INtime applications. Once you create the project, you manually edit the code.

INtime software provides these wizards:

- **RT Process wizard**: develops the RT portion of INtime applications.
- **RT Process Add-in wizard**: adds supplemental files to the already-generated RT portion of INtime applications.
- **RT Shared Library wizard**: develops RT shared library (RSL - RT equivalent to Windows DLL)

> **Note**
> For information about using the INtime wizards, see *Chapter 10, INtime application development*.

Libraries

INtime software provides interface libraries that your threads use to obtain RT kernel services. These libraries support mailboxes, semaphores, and shared memory. INtime software libraries include:

- **Windows extension (NTX) library**: Contains system calls that the Windows portion of an INtime application uses to communicate with the RT portion of the system.
- **Real-time (RT) application library**: Contains system calls that the RT portion of an INtime application uses to access RT kernel services such as memory management and inter-thread communication.
- **Real-time (RT) DSM library**: Contains system calls that implement sponsorship and dependency registration of INtime RTAs (real-time applications) with their counter-part Windows applications.
- **Real-time C and EC++ libraries**: Contains system calls that the RT portion of an INtime application uses to access standard ANSI C and EC++ functions.
- **RT services library**: Contains additional calls required to implement INtime Services.
- **PCI library**: Contains system calls that provide access to the PCI bus configuration space.
- **iWin32 library**: Contains system calls which emulate a subset of the Win32 API.
- Windows iWin32x library: Contains system calls that the Windows portion of an INtime application uses to access real-time objects created using the iWIn32 library.

> **Note**
> For an overview of system calls included in the APIs, see *Appendix A, INtime software system calls*. For detailed information, including syntax and parameter values, see Help.

Debuggers

You debug the Windows portion of INtime applications using the debug tools provided in Microsoft Visual Studio. To debug the RT portion of INtime applications, you use the debug tools provided with INtime software:

- **Visual Studio debugger:** The INtime debug engine is integrated with the Visual Studio .Net 2003 IDE to provide debugging capabilities from within Microsoft Visual Studio.
- **Spider debugger (SPIDER.EXE)**: A Windows application that provides source level, multi-tasking debug capabilities. Spider can debug multiple RT threads simultaneously while other threads continue to run.
- **System debug monitor (SDM)**: A command-line interface that provides low-level, static debugging capability. SDM requires a separate serial debug terminal for its user interface.
- **System Debugger (SDB.RTA)**: An extension to SDM which provides information about RT kernel objects, threads, and processes.

You can debug the Windows and RT portions of an INtime application simultaneously.

Note

For detailed information about Spider, see Spider's Help. For detailed information about SDM, see INtime Help. For detailed information about using SDM, access INtime Help, then select Debuggers>Low-level debugger>System Debug Monitor (SDM).

Sample applications

INtime software contains several sample applications that you can use as examples for your own program development.

- **EventMsg DLL Project**: This DLL allows you to customize event messages.
- **INtime API Sample**:This test application exercises a subset of the INtime software.
- **INtime Serial Driver Sample**: This demo provides a high-speed serial driver in both binary and source form, plus an RT application that uses this driver to communicate with a terminal.
- **INtime Graphical Jitter**: This application measures the minimum, maximum, and average times between consecutive INtime low-level clock ticks via an Alarm Event Handler. Because this application consists of both RT and Windows executables, it shows both INtime threads and Windows NTX API usage.
- **Real-time Interrupt Sample**: This application tests the INtime RT Interrupt system calls using the Transmitter Ready interrupt from COM1.
- **C and C++ Samples for Debugger**: These simple C and C++ programs are provided as a vehicle to demonstrate the Spider debugger's capabilities. The C++ program

also demonstrates several components of the C++ language available to RT applications, as well as basic classes, dynamic instantiation, operator overloading, and so on. It also shows the libraries and startup modules needed.

- **TCPIP>TCP-IP Server Sample**: Sample TCP/IP application that waits for 130Kbyte messages and returns them to the sender.
- **TCPIP>TCIP-IP Client Sample**: Sample TCP/IP application that looks for a TCP/IP server and then sends 130KByte messages to it and waits for the reply.
- **Fault Handling (ntrobust)**: This INtime application has both a Windows and a RT portion. The Windows portion allows the user to set up timing parameters that control how often a thread in the RT portion causes a hardware fault. The application demonstrates how another RT thread can detect and log the failure, delete the offending thread, and recreate it, all without affecting Windows or other RT processes.
- **Floating Point Exception Handling**: This sample program demonstrates floating point exception handling.
- **RSL Example**: This RT program demonstrates the creation and use of RT Shared Libraries, the RT analog for Windows DLLs.
- **NTX Sample (MsgBoxDemo)**: This INtime application has both a Windows and a RT portion. The Windows portion looks up an RT mailbox created by the RT portion, and then waits at the mailbox. When an RT thread sends a message to the mailbox, the Windows portion displays the received data in a message box on the Windows side. RT semaphore and RT shared memory usage are also demonstrated.
- **INtime Windows STOP Detection sample (STOPmgr)**: This sample application shows how an INtime application can detect either a Windows Crash (blue screen) or Windows Shutdown event and prevent Windows from completing its normal actions until the RT application has had a chance to do a “graceful” shutdown.

Note

For detailed information about these sample applications, see *Chapter 10, INtime application development*.

Runtime environment

INtime’s runtime environment includes RT enhancements to Windows, memory protection, and blue screen protection. INtime software uses these features only for INtime applications that run on a single computer, unless otherwise noted. Runtime features are described in detail in the following sections.

RT enhancements to Windows

These features enable Windows and the RT kernel to work together:

- **RT kernel**: (used in both INtime and RT nodes) provides deterministic scheduling and execution of RT threads.
- **OS encapsulation mechanism (OSEM)**: (used only with INtime nodes) manages the simultaneous operation and integrity of the Windows kernel and the RT kernel.
- **Interception of certain HAL functions**: (required only for INtime nodes) ensures the determinism of INtime applications.

> **Note**
>
> For information about the RT kernel, see *Chapter 3, About INtime software's RT kernel*. For information about the OSEM and HAL, see *Chapter 2, Understanding INtime software architecture*

Memory protection

During INtime node system initialization, memory is allocated through the OSEM for use by the RT kernel and INtime applications. This memory is "locked down" so that it does not page to disk. It is also removed from the memory pool available for Windows applications.

INtime's RT kernel provides several protection levels for RT memory:

- **32-bit segmentation**: (used in both INtime and RT nodes)
  - **Local configurations**: INtime software keeps Windows and each RT process in separate segments. Keeping Windows separate from the RT kernel isolates and protects addresses not only between complex RT processes but between RT processes and Windows processes.
  - **Remote configurations**: INtime software keeps RT processes in separate segments. Keeping them separate from the RT kernel isolates and protects addresses between complex RT processes.
- **Paging**: (used in both INtime and RT nodes) The RT kernel uses the processor's paging mode for virtual address translation, but does not implement demand paging. Each RT process is loaded into its own virtual address space, defined by a 32-bit virtual segment. Because code, data, and stack are automatically placed in non-contiguous areas of the application's virtual memory, memory overruns are trapped as page faults.
- **Virtual addressing**: (used in both INtime and RT nodes) Since each RT process resides in a separate memory space defined by a virtual segment created by the RT Application Loader, RT processes cannot address beyond the virtual segment. This effectively partitions every RT process into its own address space.

Blue screen protection

On an INtime node, the RT kernel enables successful execution of RT threads even in the event of a total Windows failure, also known as a "blue screen crash."

- **Failure diversion**: HAL modifications capture Windows failures. Once captured, control transfers to the RT kernel, Windows operation is suspended, and RT threads continue to run, unaffected by the failure.
- **Application-specific recovery**: (used only in local INtime system configurations) In the event of a Windows failure, your crash recovery RT threads run and you can execute an orderly shutdown of the hardware your INtime application controls.

> **Note**
>
> Remote INtime configurations do not require blue-screen protection because RT processes execute on dedicated hardware, separately from Windows. This means a crash, reboot, or restart of the Windows system does not interrupt execution of remote RT processes.

In the event of a Windows blue screen crash, INtime software keeps running until a graceful shutdown occurs. To start INtime software again, you must first restart Windows.

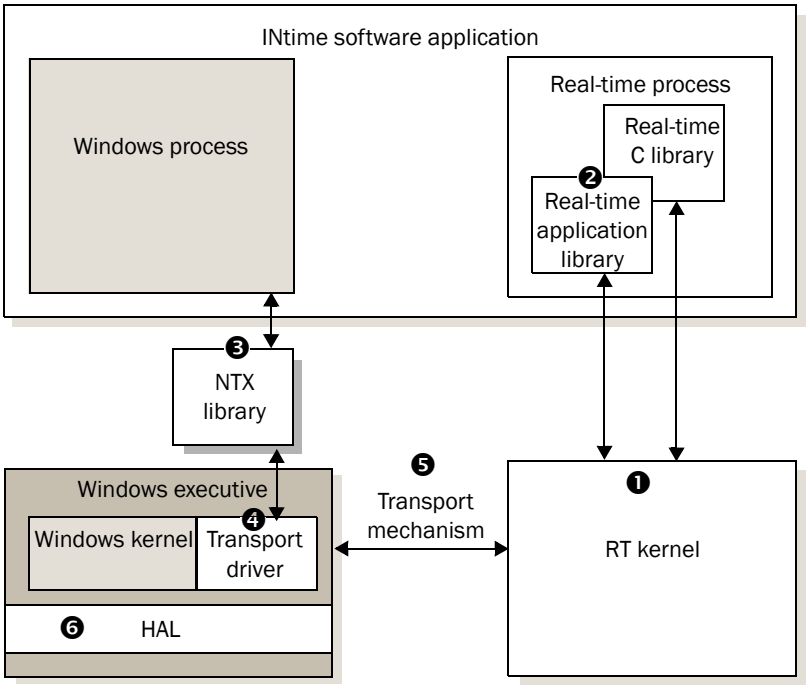
2 Understanding INtime software architecture

This chapter explains how the RT kernel works with Windows to provide real-time functionality. It also lists and describes INtime components.

How INtime software and Windows work together to run RT applications

When an INtime application runs on an INtime node, Windows threads communicate with RT threads via the Windows extension (NTX) library as shown in this figure:

Figure 2-1. How Windows threads and RT threads communicate with each other on an INtime node



The INtime components include:

❶ **RT kernel**: Provides deterministic scheduling and execution of RT threads within RT processes. For detailed information about the kernel, see *Chapter 3, About INtime software's RT kernel*.

❷ **Real-time application, C, and EC++ libraries**: Gives direct access to the RT kernel services for RT threads. For an overview of calls in the RT libraries, see *Appendix A, INtime software system calls*. For detailed information on all calls, including syntax and parameter values, see Help.

❸ **NTX library**: Provides RT interface extensions for the Win32 API that allow Windows threads to communicate and exchange data with RT threads within the application. For an overview of calls in this library, see *Appendix A, INtime software system calls*. For detailed information, including syntax and parameter values, see Help.

❹ **Transport driver**: A driver that converts information to the protocol needed by the specified transport mechanism. For details, see *Transport mechanisms* later in this chapter.

❺ **Transport mechanism**: The communication protocol or method used by NTX to communicate between Windows and RT threads. Whether the various portions of your INtime applications reside on a single PC, or on multiple computers accessed via serial or Ethernet cable, NTX provides this essential communication. For details, see *Transport mechanisms* later in this chapter.

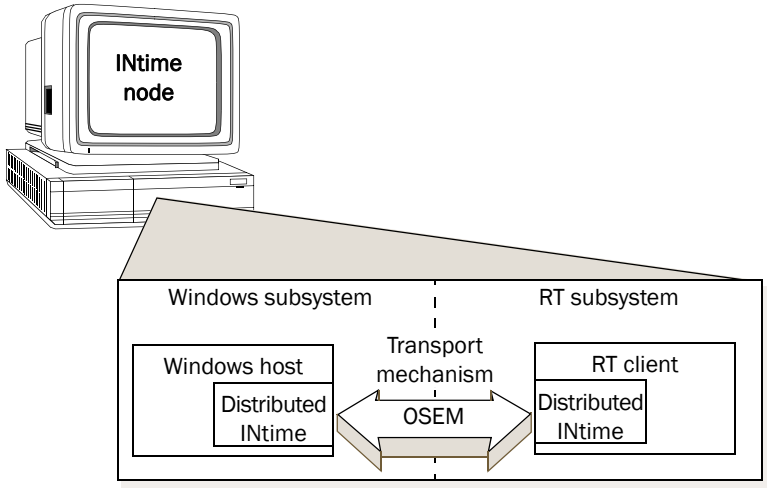
❻ **Windows hardware abstraction layer (HAL)**: INtime software intercepts some HAL calls to ensure real-time performance. For details, see *About the Windows HAL"*later in this chapter.

Topology terminology

INtime on a single PC

When INtime software runs as an INtime node, the Windows host communicates with the RT client via the OSEM.

Figure 2-2. How INtime operates on a single PC



If the PC has more than one logical CPU, one of the CPUs is normally shared between Windows and INtime, and the other CPUs are dedicated to Windows.

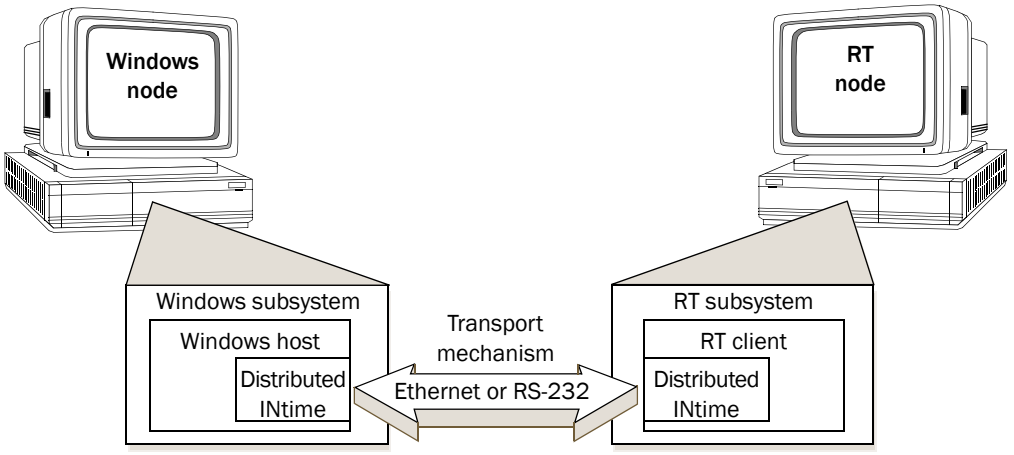
INtime distributed across multiple PCs

When INtime software runs between computers, the Windows host communicates with the RT client via RS-232 or Ethernet.

The Windows node is a computer that requires a Windows subsystem which contains the Windows host software.

The RT node is a computer that requires an RT subsystem which contains the RT client software.

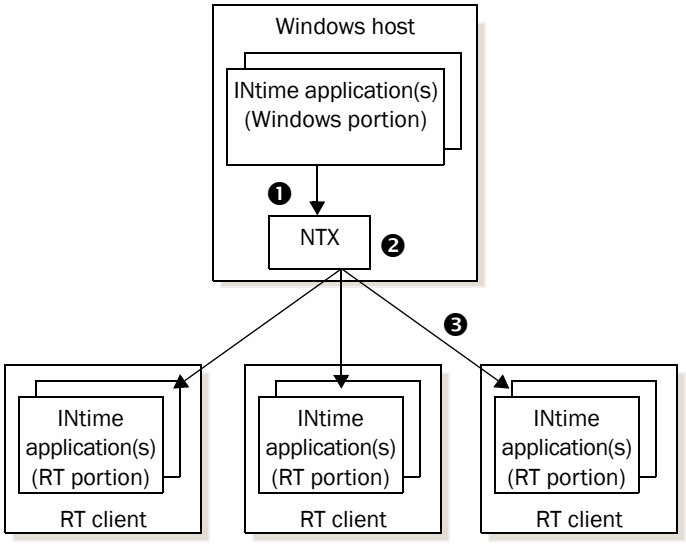
Figure 2-1. How INtime runs between computers



Transport mechanisms

With INtime software, NTX communicates between Windows and RT portions of INtime applications whether they reside on a single PC, or on separate computers accessed via serial or Ethernet cable:

Figure 2-2. How NTX communicates with RT nodes



❶ The Windows portion of INtime applications, located on a Windows host, makes NTX calls that communicate to RT clients.

❷ NTX determines RT client locations, detects the connection method, and determines how to communicate between Windows and RT threads.

❸ NTX uses the appropriate transport method to communicate with the RT portion of the INtime applications, located on RT clients.

Transport methods available to NTX include:

Transport mechanism	Transport driver	Description
OSEM	RTIF.SYS	Used when the Windows host and RT client co-exist on a single PC. For details, see *About the OSEM* and *How the RT interface driver works* later in this chapter.
Ethernet	UDP/IP	Used for Windows hosts and RT nodes connected via a local area network (LAN) cable. For details, see *About remote NTX* later in this chapter.

About the OSEM

The OSEM manages the simultaneous operation of Windows and the RT kernel on the same CPU. It encapsulates all of Windows as an RT thread, and then transparently switches execution to the appropriate kernel, based on interrupt activity and thread scheduling. Once encapsulated, Windows (with all its processes and threads) execute as a single, low priority, RT thread in the context of the RT root process.

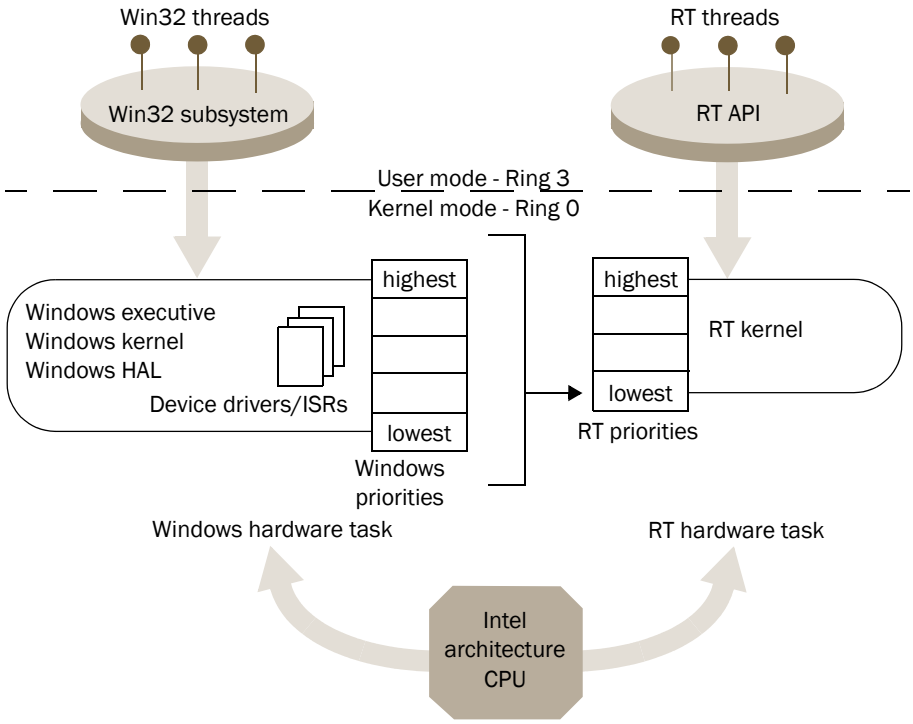
The OSEM provides:

- **Isolated processes**: Uses standard Intel architecture support for hardware multi-tasking to maintain proper address space isolation and protection between Windows processes and RT processes. This approach also ensures RT responsiveness, regardless of Windows activity.
- **Transparent thread creation and switching**: Transparently creates a hardware task for the RT kernel, and manages the switching and execution of both the standard Windows and INtime system hardware tasks.

  In a standard Windows configuration, the bulk of the OS runs in the confines of a single hardware task. Additional hardware tasks are defined only to handle catastrophic software-induced failures, such as stack faults and double faults, where a safe and known environment is required from which to handle the failure. INtime software's task switching approach guarantees the integrity of both Windows and the RT kernel, and enables the successful operation of RT threads even in the event of a total Windows failure (a blue screen crash).
- **Additional address isolation via 32-bit segmentation**: Provides additional address isolation and protection between complex RT processes, and between RT processes and Windows code. The RT kernel accomplishes this by using multiple sets of 32-bit segments, separate from those used by Windows.
- **Easy-to-use interface**: Provides a clean, well defined interface, which minimizes interaction with Windows to a few key areas. The result is improved product reliability and simplified compatibility between Windows releases.

With INtime applications running on a single PC, the INtime runtime environment encapsulates all Windows processes and threads into a single RT thread of lowest priority as shown in the next figure. As a result, RT threads always preempt running Windows threads, guaranteeing hard determinism for all RT activities within the system.

Figure 2-5. Encapsulating Windows processes and threads into an RT thread



When an interrupt occurs, the INtime runtime environment responds in one of these ways:

Interrupt type	Windows in control	RT in control	Shared control
Windows	Windows maintains control.	RT maintains control.	RT determines whether to maintain or relinquish control.
RT	RT takes control, pre-empting Windows activity.	RT maintains control.	RT maintains control.

How the RT interface driver works

RTIF.SYS is a Windows device driver that provides centralized support for the OS encapsulation mechanism (OSEM). The RT Interface Driver facilitates communications between RT kernel threads and Windows threads.

The RTIF driver begins execution as a Windows system service, early in the Windows boot process. During initialization, it allocates physically contiguous memory for the RT kernel's memory pool.

The RTIF driver cooperates with the RT Application Loader to load and start the RT kernel in its own environment. The driver queries the registry for various kernel parameters and passes them to the RT kernel at the kernel's initialization time. Parameters include:

- The number of Windows threads that can simultaneously make NTX library calls. The default is 64.
- The low-level tick duration used by the RT kernel.

If the RT kernel is running, the RTIF driver:

- Routes the clock interrupt (IRQ 0), based on who needs the next clock tick, to either the RT kernel or to the Windows clock interrupt entry point for processing.

  When neither environment needs the tick, the driver sends an EOI to the PIC for this level and returns control to the interrupted Windows thread.
- Immediately routes all other real-time interrupts to the RT kernel for processing.
- Relays NTX library requests to the RT kernel and blocks the calling Windows thread until the RT kernel responds to the request and/or until resources are available to complete the request.

  Otherwise, the RTIF driver terminates NTX library requests. When the RT kernel announces its termination, the RTIF driver terminates all pending requests.
- Manages the Windows portion of controlled shutdown during a Windows blue screen crash: the handler notifies the RT kernel to handle the RT portion of the controlled shutdown. If the kernel is not running, control is returned to Windows.

In summary, the RTIF.SYS device driver contains the Windows portion of the OSEM. It also acts as the NTX transport driver for a co-resident, or local, RT kernel. RTIF.SYS allocates physical memory for the RT kernel and locks that memory in place so it will not be used or paged to disk by the Windows kernel. A Windows service loads the RT kernel into the allocated memory and issues a "start kernel" command to RTIF.SYS. In response to the start command, the driver establishes a separate hardware task for the RT kernel and hands off control to the kernel's initialization code. After initializing its environment, the RT kernel creates a low-priority thread (priority level 254) which returns to Windows and becomes the Windows thread.

About remote NTX

The INtime RT kernel may be installed and run on a standalone PC platform, and connected to the Windows workstation. Such an installation is called an "RT Node". Communication between a Windows application and an RT application running on the RT node uses the same NTX interface as with the local kernel, with Ethernet or a serial line as the communications medium. All the calls are available and work identically, except for shared memory.

About the Windows HAL

INtime software uses the Windows HAL, but intercepts certain functions to perform the following actions:

- Traps attempts to modify the system clock rate so that the RT kernel can control the system time base.
- Traps attempts to assign interrupt handlers to interrupts reserved for RT kernel use.
- Ensures that interrupts reserved for RT kernel use are never masked by Windows software.

INtime software is compatible with all the HAL files shipped with the standard Windows products.

About thread scheduling

The RT kernel switches between threads and makes sure the processor always executes the appropriate thread. The kernel's scheduling policy is that the highest priority thread that is ready to run is/becomes the running thread. The kernel maintains an execution state and a priority for each thread and enforces its scheduling policy on every interrupt or system call.

Priority-based scheduling

A priority is an integer value from 0 through 255, with 0 being the highest priority.

Range	Usage
0–127	sed by the OS for servicing external interrupts. Creating a thread that handles internal events here masks numerically higher interrupt levels.
128–130	Used for some system threads.
131–252	Used for application threads.

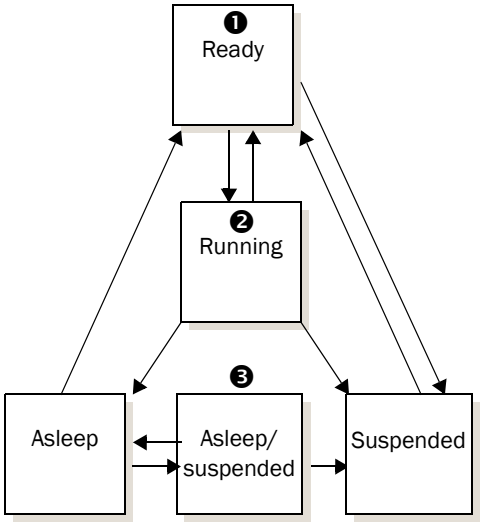
Interrupt threads mask lower-priority (numerically higher) interrupt levels. When you assign interrupt levels, give a higher-priority (numerically lower) level to interrupts that can't wait, such as serial input, and a lower priority (numerically higher) to interrupts that can wait, such as cached input.

Execution state

The execution state for each thread is, at any given time, either running, ready, asleep, suspended, or asleep-suspended. The RT kernel enforces the scheduling policy in which the highest priority ready thread is always the running thread.

Threads run when they have the highest (numerically lowest) priority of all ready threads in the system and are ready to run. Threads can change execution state, as shown in the next figure.

Figure 2-5. Execution state transitions for threads



❶ Threads are created in the ready state.

❷ The running thread, the ready thread with the highest priority, does one of these:

- ❶ Runs until it removes itself from the ready state by making a blocking system call.
- ❶ Runs until its time slice expires (when running with a priority lower—numerically higher—or equal to the configured round robin threshold priority with other threads at the same priority.
- ❶ Runs until preempted by a higher priority thread which has become ready due to the arrival of an interrupt, or through the receipt of a message/unit at an exchange at which the higher priority thread was blocked.

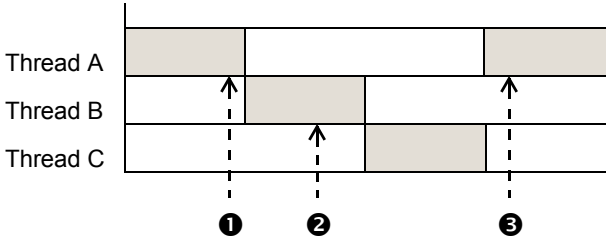
❸ A thread in any state except ready cannot run, even if it has the highest priority.

A thread can put itself to sleep or suspend itself by using system calls for that purpose. The RT kernel might indirectly put a thread to sleep if the thread makes a “blocking” call by, for example, waiting at a mailbox until a message arrives. The kernel puts the thread in the ready state when the message arrives.

Round-robin scheduling

INtime software also provides round-robin scheduling, where equal-priority threads take turns running. Each thread gets a time slice. If a thread is still running when its time slice expires, that thread moves to the end of a circular queue for that priority level where it waits until all threads ahead of it use up their time slices, as shown in the next figure. You adjust the length of the time slice and set the priority level threashold where round-robin scheduling occurs.

Figure 2-5. Round-robin scheduling



Threads A, B, and C are of equal priority below the round-robin priority threshold.

❶ Thread A, the running thread, stops running when its time slice runs out. Thread A's state is saved and it moves to the end of the queue.

❷ Thread B, a ready thread, then becomes the running thread.

❸ Thread A runs again when all threads in the queue either finish running or are preempted when their time slice expires.

Higher-priority threads still preempt any running thread in the round-robin queue, regardless of the amount of time left in its time slice.

Note
Round-robin scheduling cannot guarantee a predictable worst-case response to events because the number of threads in the queue varies.

Handling interrupts

System hardware invokes an interrupt handler in response to an asynchronous interrupt from an external source, based on its entry number in the IDT (Interrupt Descriptor Table). The handler takes control immediately and saves the register contents of the running thread so it can be restarted later. There are two ways you can service an interrupt:

- Using a handler alone
- Using a handler/thread combination

Interrupt handler alone

An interrupt handler alone can process only interrupts that require very little processing and time. Handlers without threads can:

- Accumulate data from the device in a buffer. The data must have an associated thread to process the data.
- A handler begins running with all interrupts disabled. It must execute quickly and then exit to minimize its effect on system interrupt latency.
- Find the interrupt level currently serviced. This is useful if one handler services several interrupt levels.
- Send an EOI (End of Interrupt) signal to the hardware.

By itself, an interrupt handler can only do very simple processing, such as sending an output instruction to a hardware port to reset the interrupt source. Handlers can use only a few system calls. For a list and description of system calls, see *Appendix A, "INtime software system calls".*

During the time the interrupt handler executes, all interrupts are disabled. Since even very high level interrupts are disabled, it is essential that the handler execute quickly and exit.

When the handler finishes servicing the interrupt, it sends an EOI to the PIC (Programmable Interrupt Controller) via an INtime software system call, restores the register contents of the interrupted thread, and then returns to the interrupted thread.

Interrupt handler/thread combination

An interrupt handler/thread combination provides more flexibility. Although the handler may perform some processing, it typically signals the corresponding interrupt thread to do most or all interrupt processing. In general, use an interrupt handler/thread combination if the processing requires more than 50 microseconds or requires system calls that interrupt handlers cannot use.

When an associated interrupt thread exists, the handler can put accumulated information into a memory address, if the interrupt thread has set one up. The interrupt thread can access data in the memory address and perform the required processing.

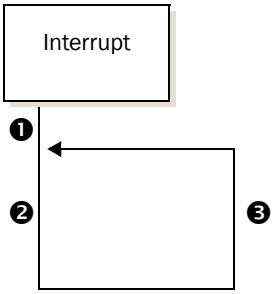
Interrupt threads have access to the same resources and use the same system calls as ordinary threads. The RT kernel assigns an interrupt thread's priority, which is based on the interrupt level associated with the handler. Ordinary threads have a priority assigned by the process.

In addition to the usual thread activities, an interrupt thread can also:

- Cancel the assignment of an interrupt handler to an interrupt level.
- Wait for an interrupt to occur.
- Enable and disable interrupts.

This shows how an interrupt thread enters an event loop where it waits to service an interrupt:

Figure 2-5. Thread execution model



❶ Upon creation, the interrupt thread uses an RT system call to set up an RT interrupt and associate itself with this interrupt. Normally, it then waits for a signal that indicates an interrupt occured.

❷ When signaled, the interrupt thread executes the required operations.

❸ The interrupt thread releases control by waiting for the next signal from the interrupt handler, which restarts the cycle shown in this figure.

Managing time

INtime software enables threads to:

- Create alarm events that wake up the current thread at a regular interval.
- Start and stop scheduling by the RT kernel.

3 About INtime software's RT kernel

This chapter describes objects provided by the RT kernel.

What does the RT kernel provide?

The RT kernel provides:

Object management	Includes creating, deleting, and manipulating object types defined by the kernel. Memory for high-level kernel objects is automaticallly taken from your processor's memory pool. You must provide memory for low-level kernel objects and may allocate memory beyond the kernel's needs to store application specific state information associated with the low-level object.
Time management	Includes an RT clock, alarms that simulate timer interrupts, and the ability to put threads to sleep.
Thread management	Includes scheduling locks which protect the currently running thread from being preempted.
Memory management	Implements memory pools from which it allocates memory in response to application requests.

RT kernel objects

Objects, data structures that occupy memory, are building blocks that application programs manipulate. Each object type has a specific set of attributes or characteristics. Once you learn the attributes of, for example, a mailbox, you know how to use all mailboxes.

Object-based programming, which concentrates on objects and operations performed on them, is compatible with modular programming. Typically a single thread performs only a few related functions on a few objects.

The RT kernel provides basic objects and maintains the data structures that define these objects and their related system calls. When you create an object, the RT kernel returns a handle that identifies the object:

- **High-level objects** consume memory, but also a slot in the system GDT (Global Descriptor Table). Therefore, the maximum number of high-level objects allowed in the system at any one time is approximately 7600 (8192 slots in a GDT minus slots used by the operating system).
- **Low-level objects** consume only memory. Therefore, only the amount of system memory controls how many low-level objects can be present at a given time.

The RT kernel provides these objects. Each object is discussed on the indicated page:

Object	Description	Page
Threads	Do the work of the system and respond to interrupts and events.	30
Processes	Environments where threads do their work.	30
Exchange objects	Used by threads to pass information.	34
Mailboxes	Used by threads to pass objects and data. INtime software includes both object and data mailboxes.	34
Semaphores	Used by threads to synchronize.	35
Regions	Used by threads to provide mutual exclusion.	36
Ports	Used by threads to synchronize operations, pass messages, and access INtime services.	37
Dynamic memory	Addressable blocks of memory that threads can use for any purpose.	32

Note

For detailed information about RT kernel objects, how they operate, and system calls associated with each object, see INtime Help.

Threads

Threads, or threads of execution, are the active, code-executing objects in a system.

Threads typically respond to external interrupts or internal events. External interrupts include events such as a keystroke, a system clock tick, or any other hardware-based event. Internal events include events such as the arrival of a message at a mailbox. Threads have both a priority and an execution state, whether the thread is running or not.

There are system calls to create and delete threads, view and manipulate a thread's priority, control thread readiness, and obtain thread handles. For a list and description of these system calls, see *Appendix A*, "*INtime software system calls*".

Processes

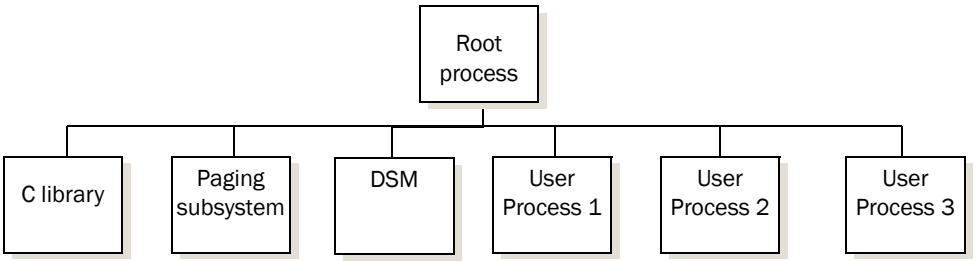
A process is an RT kernel object that contains threads and all their needed resources. Processes make up your INtime applications. The RT kernel processes have these characteristics:

- Cannot make system calls ; they are passive.
- May include one or more threads.
- Isolate resources for their threads, particularly for dynamically allocated memory. Two threads of one process compete for the memory associated with their process. Threads in different processes typically do not.

- Provide error boundaries. Errors within one process do not corrupt other processes or the OS because they reside in separate virtual address spaces.
- When you delete processes, the objects associated with them also are deleted.

Each INtime application's executable loads as a separate, loadable process. The processes in a system form a process tree. Each application process obtains resources from the root:

Figure 3-1. Processes in a process tree



The RT Application Loader creates RT processes when an INtime application loads. There are system calls you can use to delete RT processes from within an application.

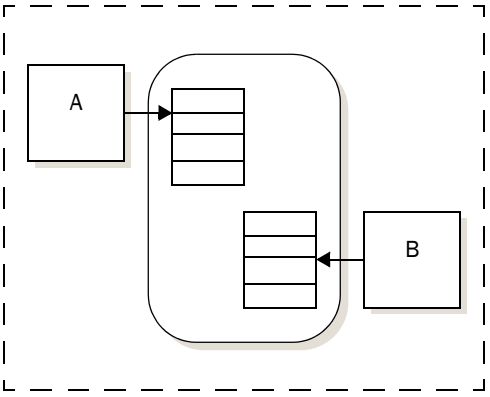
Virtual memory

Each process has an associated VSEG whose size is the amount of Virtual Memory available to the process. The VSEG size must be large enough to contain all the memory dynamically allocated by the threads within the process.

Memory pools

Each process has an associated memory pool, an amount of memory with a specified minimum and maximum, allocated to the process. Minimum memory is always contiguous. Usually, all memory needed for threads to create objects in the process comes from the process's memory pool, as shown in the next figure.

Figure 3-2. Threads using their process's memory pool



Threads A and B obtain memory from the process's memory pool.

If not enough contiguous memory exists (up to the maximum size of the process's memory pool), the RT kernel tries to borrow from the root process.

You can also statically allocate memory to processes, but you cannot free memory allocated in this manner for other processes. The system's total memory requirement is always the sum of the memory requirements of each process. Static memory allocation uses more memory than dynamic allocation, but may be safer.

Dynamic memory

Dynamic memory supports many uses, including communicating and storing data. The memory area is usually allocated from the memory pool of the thread's process, as shown in *Figure 3-2."Threads using their process's memory pool"*. If there is not enough memory available (up to the maximum size of the process's memory pool), the kernel tries to borrow from the root process.

INtime software includes system calls that allocate and free memory and create handles for allocated memory to share with other processes. For an overview of these calls, see *Appendix A, INtime software system calls*. For detailed information, including syntax and parameter values, see Help.

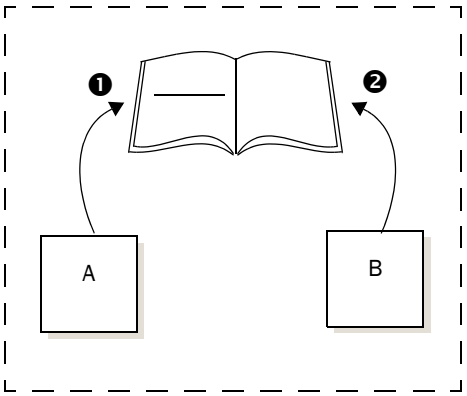
Object directories

Each process has an associated object directory. When a thread creates an object, the RT kernel creates a handle for it. A thread can catalog a high-level object, with its handle and a corresponding name, in the object directory of its own process or any other process it knows about. Typically, you catalog objects in the root directory so that threads in other processes can access them.

Threads in the same process and threads that know the name can use the object directory to look up and access objects, or they can use global variables within their address space to identify and access system objects contained within their process.

Note
You cannot catalog the handle for a low-level object in an object directory.

Figure 3-2. Threads using the root process's object directory



❶ Thread A catalogs an object such as a data mailbox in the root process's object directory.

❷ Thread B looks up the object in the object directory to use it.

Now thread A can send data to the mailbox and thread B can receive it.

Exchange objects

Validation levels

INtime software provides two levels of system calls for exchange objects:

Level	Description	Exchange objects
High (validating)	Provides lower performance and higher protection and validation features. Memory is allocated automatically from the process's pool. High-level objects: Validate parameters. Are protected against unexpected deletion.	Object mailboxes Data mailboxes Counting semaphores Regions (for mutual exclusion with priority inversion protection)
Low (non-validating)	Provide higher performance and lower protection and validation features. Low-level objects provide functionality beyond that of high-level objects. You must allocate memory for low-level objects and may allocate memory beyond low-level object needs. You can use this additional memory to store application-specific state information associated with the object. Low-level objects: Do not validate parameters. If you need parameter validation, use high-level system calls instead. Are not protected against unexpected deletion. **Note**: System calls that manipulate low-level objects assume that all memory reference pointers received are valid.	Data mailboxes Single-unit semaphores Region semaphores (with priority inversion protection) Software alarm events (virtual timers) that invoke alarm event threads that you write.

Write, test, and debug your application using high-level calls with their protection and validation features. When the application runs as you desire, increase performance by substituting low-level system calls where appropriate.

For more information about validation levels, see RT calls in *Appendix A, INtime software system calls*.

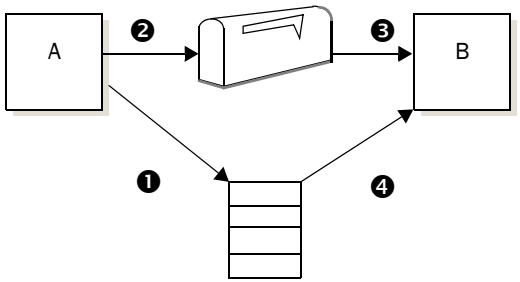
Mailboxes

Mailboxes provide communication between threads in the same process or in different processes. They can send information and, since a thread may have to wait for information before executing, they can synchronize thread execution. There are two mailbox types:

- **Object mailboxes**: Send and receive object handles. Available only as high level objects.
- **Data mailboxes**: Send and receive data. Available as both high- and low-level objects. High-level data mailboxes have a maximum limit of 128 bytes.

The next figure shows how threads use an object mailbox to send a handle for a memory address.

Figure 3-2. Threads using an object mailbox



❶ Thread A allocates a block of memory and creates a shared-memory handle for it. Data is placed in this shared memory object.

❷ Thread A sends the shared memory handle to a mailbox.

❸ Thread B waits to receive the shared memory handle at the mailbox. You can specify whether or not thread B should wait if the handle isn't in the mailbox.

❹ Thread B obtains the handle and accesses the data in the memory object by mapping the memory associated with the memory object into its memory address space.

Mailboxes have thread queues, where threads wait for messages, and message queues, where messages wait threads to receive them. The thread queue may be FIFO- or priority-based; the message queue is always FIFO-based.

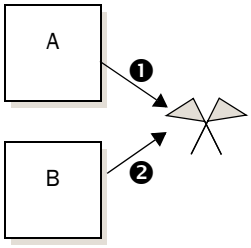
You use the same system calls to create and delete object and data mailboxes. However, you use different calls to send and receive messages or data.

Semaphores

A semaphore is a counter that takes positive integer values. Threads use semaphores for synchronization by sending units to and receiving units from the semaphores. When a thread sends *n* units to a semaphore, the value of the counter increases by *n*; when a thread receives *n* units from a semaphore, the value of the counter decreases by *n*.

The next figure shows a typical example of a binary (one-unit) semaphore used for synchronization.

Figure 3-2. Threads using a semaphore for synchronization



To ensure that thread A can do its work before thread B starts running, thread A creates a semaphore that contains one unit. To enable synchronization, threads A and B should request and obtain the unit before running.

❶ Thread A begins to run and obtains the semaphore unit, leaving the semaphore empty. While the semaphore has no units, thread B cannot run.

❷ When thread A completes, it returns the unit to the semaphore. Thread B can now obtain the unit and start running.

Semaphores:

- Enable synchronization; they don't enforce it. If threads do not request and obtain units from the semaphore before running, synchronization does not occur. Each thread must return the unit to the semaphore when it is no longer needed. Otherwise, threads can be permanently prevented from running.
- Provide mutual exclusion from data or a resource as follows:
  1. Thread A requests one unit from a binary semaphore, and uses the resource when it receives the unit.
  2. Thread B requests one unit from the semaphore before using the resource. Thread B must wait at the semaphore until thread A returns the unit.
- Enable mutual exclusion; they do not enforce it.
- Have a queue where threads wait for units. The queue may be FIFO- or priority-based. There are system calls to create and delete semaphores, and to send and receive units.

Regions

A region is a single-unit semaphore with special suspension, deletion, and priority-adjustment features. Regions provide mutual exclusion for resources or data; only one thread may control a region at a time; only the thread in control of the region can access the resource or data protected by a region. Once a thread gains control of a region, the thread cannot be suspended or deleted until it gives up control of the

region. When the running thread no longer needs access, it exits the region, which enables a waiting thread to obtain control of the region and thus access the resource or data protected by that region.

Regions have a thread queue where threads wait for access to the region. The queue may be FIFO- or priority-based.

Priority inversions

Regions also have a priority-inversion avoidance mechanism when the region's thread queue is priority based.

Then, if a higher-priority thread tries to enter a busy region, the priority of the thread in the region is raised temporarily so that it equals the waiting thread's priority. This helps prevent priority-inversion, as shown in this example:

1. Thread A is the running thread. It is a low-priority thread with control of a region, accessing some data. The region has a priority queue. The only other thread that uses the data is thread C, a high-priority thread that is not ready to run.
2. Thread B, a medium-priority thread, becomes ready to run and preempts A.
3. Thread C becomes ready to run and preempts B. It runs until it tries to gain control of the region. Thread A's priority is raised to equal thread C's priority until thread A releases the region; then its priority returns to its initial level.
4. When thread A releases the region, thread C receives control of the region and uses the data. When thread C completes, thread B runs.

Without the priority inversion avoidance mechanism, thread B would have preempted A while A had control of the region; C would have preempted B, but would have been unable to use the data because A had control of the region.

Regions require careful programming to avoid deadlock, where threads need simultaneous access to resources protected by nested regions, and one thread has control of one region while the other thread has control of another. To avoid deadlock, all threads must access nested regions in the same, arbitrary order, and release them in the same reverse order.

Ports

A port is the object which allows access to the features provided by an INtime service. A process that uses a port object can send messages through the port to the INtime service, or can receive messages through the port from the service. Other operations possible on ports include:

- Attach a heap object to the port for use by the service to store received messages.
- Link ports to a sink port, allowing a single thread to service multiple ports.

Services

An INtime service is an INtime real-time application (RTA) which provides access to one or more interfaces. Each interface is associated with a service descriptor. The interface generates events which are handled by the service. A process which uses a service creates a port for access to that service. A service may support more than one port and more than one user process may use a given port. A user process communicates with the service by sending and receiving messages via the port.

Heaps

A heap is an INtime memory object that manages the chunk of dynamic memory allocated to it. A heap can be used by multiple processes that need to share large amounts of information. For instance, a heap can be associated with a port. Data placed in memory obtained from the heap by threads in one process (the thread using a port to communicate with an INtime service) can be manipulated by threads in another process (thread within the service accessing data passed through the port to the service).

4 About RT programming

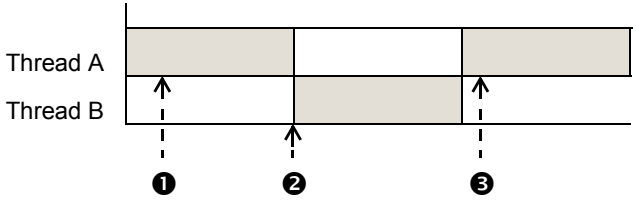
This chapter describes mechanisms appropriate to RT programming:

Note
For information about developing an RT application using INtime software, see *Chapter 10, INtime application development*.

Multi-threading

Multithreading means the computer stops running one thread and starts running another, as shown in the next figure. INtime software manages thread switching, saving the old thread's context on the old thread's stack and loads the new thread's context before starting execution. An INtime software thread is a thread of execution, similar to a Windows thread.

Figure 4-1. Thread switching in a multithreading environment



❶ The processor executes thread A.

❷ An event happens and a thread switch occurs. The processor then executes thread B.

❸ When thread B finishes, thread A becomes the running thread again.

Multithreading and modular programming go hand-in-hand. You start by breaking down a large, difficult application problem into successively smaller and simpler problems, grouping similar problems where you can. Finally, you solve the small problems in separate program modules. In the INtime software multithreading environment, each module is a thread.

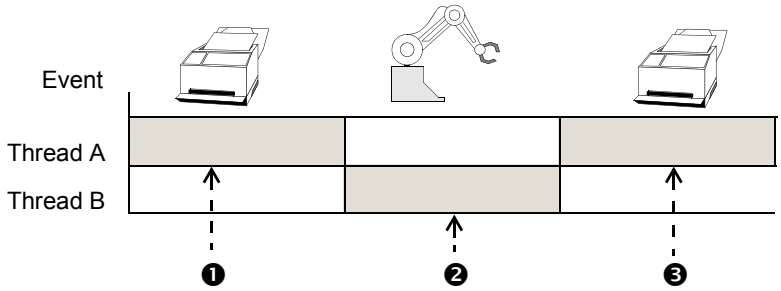
Multithreading simplifies building an application. When you need a new function, you just add a new thread.

When you combine multithreading with preemptive, priority-based scheduling, your application can switch as appropriate: from relatively unimportant threads, to important threads, to critical threads, and back again.

Preemptive, priority-based scheduling

In a preemptive, priority-based system, some threads are more critical than others. Critical threads run first and can preempt less critical threads, as shown in this figure:

Figure 4-2. Multithreading and preemptive, priority-based scheduling



❶ Thread A, a low-priority thread, prints data accumulated from the robotic arm in report form.

❷ Thread B, a high-priority thread, controls the robotic arm. If the arm needs to move while thread A runs, thread B preempts the print thread, then starts and moves the arm.

❸ After thread B repositions the arm, thread A finishes printing.

Multithreading allows an application to respond to internal events and external interrupts, such as clock ticks from the system clock or receiver ready from a serial device, based on how critical they are. You determine the priority of threads in your application; INtime software provides the thread scheduling algorithms.

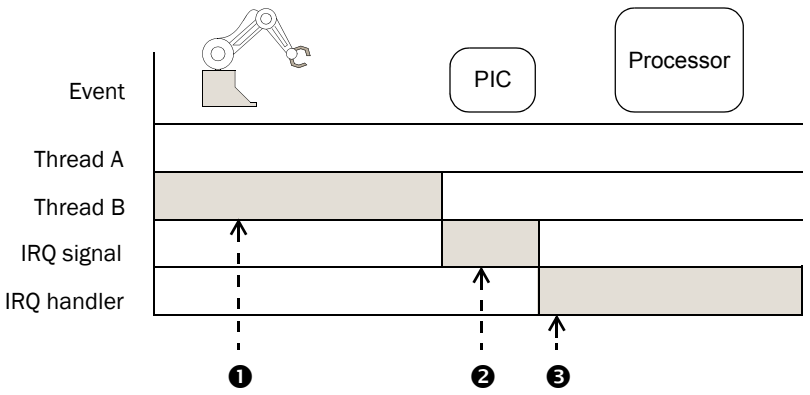
When you add interrupt processing to multithreading and preemptive, priority-based scheduling, your application can respond to interrupts as they occur. Your application becomes event-driven.

Interrupt processing

Interrupts are signals from devices such as a malfunctioning robot or interactive terminal. You connect interrupt sources to the processor through the PC's two PICs (Programmable Interrupt Controllers).

With interrupt processing, your application can handle interrupts occurring at random times (*asynchronously*) and can handle multiple interrupts without losing track of the running thread, or those threads waiting to run. Interrupts can occur while the processor is executing either an unrelated thread or a related thread, as shown in the next figure.

Figure 4-3. Interrupt handler interrupting a thread



❶ Thread B, the running thread, repositions the robotic arm.

❷ The robotic arm malfunctions and sends an interrupt signal through the PIC.

❸ As soon as it receives the signal, the microprocessor stops the running thread and starts an interrupt handler. The interrupt handler runs in the context of thread B. No new thread is loaded; thread B's state does not need to be saved. It remains loaded in RAM until the scheduler runs it again. Thread A, the print thread, is still waiting to run.

Typically, numerous sources of interrupts exist in an application. Some of them, like the malfunctioning robotic arm, are critical; some of them are not. You assign interrupt levels (which map directly to priorities) to the interrupt sources by the order in which you connect your external sources to the PIC. INtime software handles more critical interrupts first, and keeps track of which interrupts occurred, the order in which they occurred, and which ones have not been handled.

Interrupt handlers can perform very limited operations, so you typically write an interrupt handler to signal an interrupt thread. The interrupt thread's priority can be automatically assigned, based on the interrupt level of the external source.

Multithreading and interrupt processing simplify expanding an application. Because of the one-to-one relationship between interrupts and threads, you add a new thread

when you need to respond to a new interrupt. Interrupt processing is also more efficient, since your system spends all of its time running threads, not polling for interrupts.

Determinism

INtime software provides deterministic response by establishing a predictable, worst-case response time to a high-priority interrupt. Deterministic response time includes these components:

- **Interrupt response time**: The time that elapses between a physical interrupt and the start of interrupt handler execution. A predictable worst-case response time to interrupt processing ensures that incoming data is handled before it becomes invalid.
- **Thread switch time**: The time that elapses between exiting one thread and starting another. To exit a thread, the RT kernel must save data registers, stack and execution pointers (the thread state) of one thread. Minimized thread switch time also provides a predictable response time to a high-priority thread.

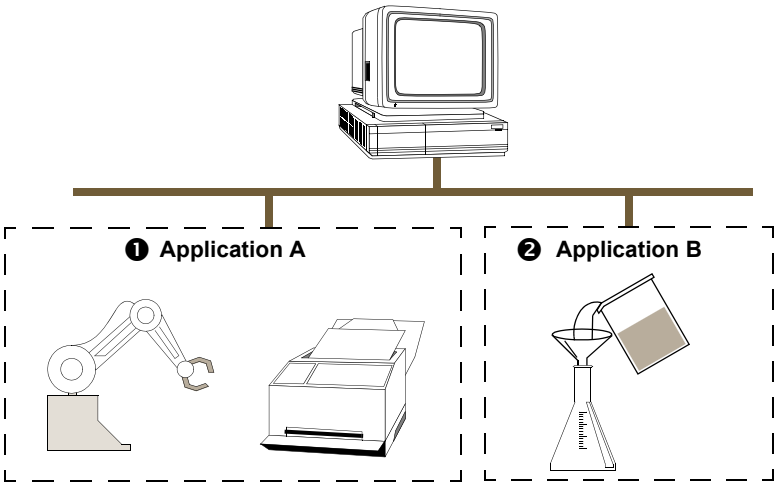
Since the typical response to an interrupt includes invoking a handler and then performing a thread switch to an interrupt thread, the deterministic response time includes both the interrupt response and thread switch times.

RT response does not mean instantaneous execution. A high-priority thread that is very long and performs many calculations uses as much processor time to execute on an RT system as on any other system. The length of time instructions take to execute is a function of processor speed.

Multi-programming

INtime software supports multiprogramming—running several unrelated applications on a single system at the same time.

Figure 4-4. Multiprogramming

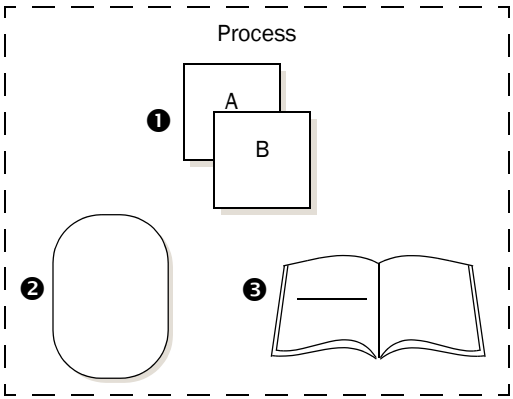


❶ Application A contains all the threads that relate to a robotic arm, including the print thread. It may also contain threads that control other devices on the factory floor.

❷ Application B contains all the threads that relate to an application that controls a chemical mixing system in one part of the factory.

To take full advantage of multiprogramming, you provide each application with a separate environment: separate memory and other resources. INtime software provides this kind of isolation in a process. Typically, a process includes a group of related threads and the resources they need, as shown in the next figure.

Figure 4-5. Resources in a process



❶ A group of related threads.

❷ The memory the threads need.

❸ An object directory where you can catalog thread resources.

You decide what processes to include in your system. INtime software coordinates the use of resources within and between processes so independently-developed applications do not cause problems for each other.

Multiprogramming simplifies adding new applications; you can modify your system by adding new processes (or removing old ones) without affecting other processes.

Inter-thread coordination and communication

INtime software exchange objects are mailboxes, semaphores, regions, and message ports. They enable asynchronous threads, which run in a random order, to coordinate and communicate with one another by:

- Passing messages
- Synchronizing with each other
- Mutually excluding each other from resources

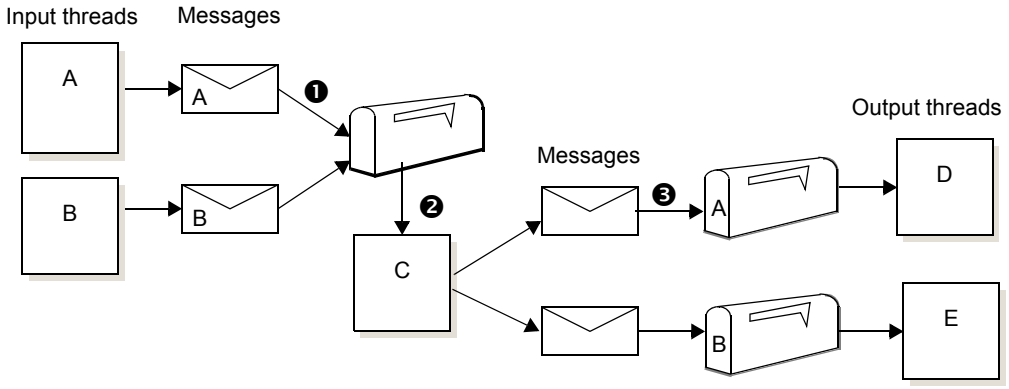
Messages

Threads may need to exchange data, messages, or object handles.

For example, a thread accumulates input from a terminal until it receives a carriage return. The thread then uses an exchange object to send the entire line of input as data to another thread that decodes the input.

This figure summarizes how you can solve a problem that requires routing several input types into several output types using a mailbox object. One mailbox and one manager thread can handle messages from multiple input and output threads.

Figure 4-5. Object-based solution for message passing



❶ System calls move data from input threads A and B to a waiting mailbox.

❷ Thread C, the manager thread, waits at the mailbox and determines which messages go to which output threads. If another message arrives during processing, the message waits in the mailbox queue until the manager thread can handle it.

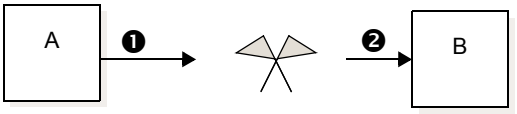
❸ The individual output threads receive data at their mailboxes and execute it.

Synchronization

When one thread needs to run before another thread, it can use an exchange object to signal the second thread when it has completed. For example, the thread that creates the transaction summary in an automated teller application shouldn't run until after the threads that handle withdrawals and deposits run. The transaction summary thread must synchronize with the other threads.

INtime software provides several objects for synchronization that accommodate a wide variety of situations. The next figure illustrates using a semaphore to send a signal to another thread.

Figure 4-6. Threads that use a semaphore for synchronization



Thread A, the running thread, preprocesses some data. Thread B needs to use the data after thread A finishes.

❶ When thread A finishes, it sends a signal (not data) to the semaphore.

❷ When thread B receives the signal, it processes the data.

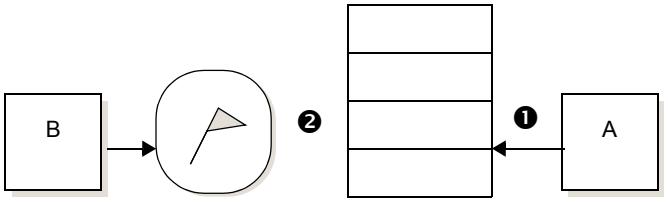
Mutual exclusion

INtime software includes regions that you can use to protect data from being accessed by multiple threads at the same time. This is called mutual exclusion.

When an INtime application runs, multiple threads can concurrently access the same data. This is useful in a multithreading system, such as a transaction processing system where a large number of operators concurrently manipulate a common database.

If a distinct thread drives each client, an efficient transaction system requires that threads share access to database data. When threads run concurrently, this situation ocasionally arises:

Figure 4-6. Multithreading and mutual exclusion



❶ Thread A, the running thread, reads data from the database and performs computations based on the data.

❷ Thread B tries to preempt thread A and update the data while thread A works on it. Mutual exclusion, provided by a region, prevents two threads from accessing the same data concurrently.

Unless thread B is prevented from modifying the data until after thread A has finished, thread A may unknowingly use some old data and some new data, resulting in an invalid computation. It should, however, read and compute the new data after thread B updates it.

Memory pools and memory sharing

Memory pools are the basis of INtime software's memory management. Two types of memory pools exist:

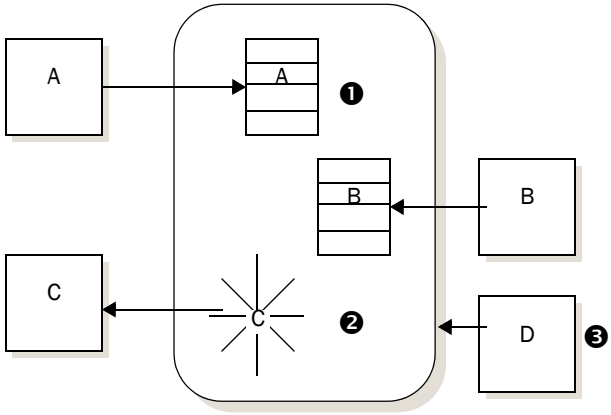
- **Initial memory pool**: All the memory available to the RT kernel (that is, free space memory). Managed by the RT kernel, the initial memory pool belongs to the root process and is allocated to INtime applications on request. Any amount of memory you allocate to the RT kernel is not available to Windows for that session. There is a practical maximum for the amount of memory allocated to INtime software. This value depends on the number and size of INtime applications that run on the RT kernel.
- **Process memory pools**: A portion of the initial memory pool assigned to an INtime application process when that process is created. Each process memory pool has a minimum and a maximum size. Once the minimum memory is allocated to a process, that memory is not available to other processes. When you delete a process, its memory returns to the initial memory pool.

  As threads in a process create and delete objects, the process memory pool's size increases and decreases as needed, provided minimum and maximum values are not yet encountered. This provides dynamic memory allocation of the memory pool.

The RT kernel uses dynamic memory allocation to free unused memory and assign freed memory to other processes. Threads within processes use dynamic memory allocation in the same manner.

For example, some threads periodically need additional memory to improve efficiency such as a thread that allocates large buffers to speed up input and output operations. Such threads can release memory for other threads when they complete, as shown in the next figure.

Figure 4-7. Dynamic memory allocation between threads



❶ Threads A and B use memory in the process's memory pool for objects they create.

❷ Thread C completes and then deletes its objects, and releases its memory to the process's memory pool.

❸ Thread D requests memory.

System calls

Each RT kernel object has an associated set of system calls: programmatic interfaces you use to manipulate objects or control the computer's actions. System calls for one object type cannot manipulate objects of another type. This protects objects from inappropriate actions or changes.

Most system calls have parameters, such as values and names, that you can set to tailor the call's performance. High-level system calls validate these parameters; a condition code returned by the call indicates whether or not the call completed successfully. Invalid parameter usage, such as trying to manipulate an object of the wrong type, or trying to read or write memory to which you have no access, results in the return of a 'call failed' condition code. You can use another system call (GetLastRtError) to determine the failure's exact cause.

Examples of tasks you can perform with system calls include:

Function	System call
Create a new mailbox	CreateRtMailbox
Set a thread's priority	SetRtThreadPriority
Send a handle to an object mailbox	SendRtHandle

Note

For an overview of INtime software's system calls, see *Appendix A, "INtime software system calls"*. For detailed information, including syntax and parameter values, see Help.

Real time shared libraries

You can build libraries that can be shared by one or more real-time applications. These Real time shared libraries (RSLs), function essentially like their Windows DLL counterparts.

An INtime Wizard is provided that integrates with Microsoft Visual Studio to allow you to easily create an RSL. It produces the framework for an RSL, and sets up the various Visual Studio settings to generate an RSL that the INtime loader can manage. For detailed information on creating an RSL, see Help.

Exception handling

While running, an INtime application makes various system calls and interfaces with various hardware devices, the CPU's Numerics Processor, and both self- and system-defined memory structures. Incorrect usage of any of these resources will cause a system exception.

System exceptions include:

System exception	Cause
Programming error	Passing an invalid parameter to a system call.
Environmental error	Requesting resources outside the capabilities/limits of the operating system to grant. For example, a call to malloc can fail with an Environmental exception if the caller's process cannot provide the requested memory.
Numerics exception	Attempting an illegal floating point operation, such as a floating point divide-by-zero operation.
Hardware fault	Attempting to do an operation that violates the protection mechanisms built into the X86 architecture. For example, an integer divide-by-zero operation causes a Divide-by-Zero Fault. Likewise, trying to access a memory address in your VSEG that has not had physical memory assigned to it causes a Page Fault.

Programming and Environmental errors are signaled to threads making system calls as the return value for each call. Application code should check for successful completion of each system call and provide error handling subroutines to handle any possible Programming or Environmental errors.

Proper handling of Numerics exceptions requires that a user exception handler be set up for each thread that makes floating point calls. INtime software provides a Floating Point Exception handler sample project that you can use as a template for your own floating point exception handler.

When a thread causes a Hardware Fault, a system wide Hardware Fault Handler is called. This handler takes one of the following user specified actions:

- Suspends the offending thread (default).
- Deletes the offending thread.
- Deletes the offending thread and its process.

The handler also sends a notification message to the following cataloged data mailboxes:

- HW_FAULT_MBX cataloged in the object directory of the root process.
- HW_FAULT_MBX (if present) cataloged in the object directory of the process whose thread caused the Hardware Fault.

An INtime application can create and catalog a data mailbox in its object directory under the name HW_FAULT_MBX. It can then create a thread that waits at that mailbox for any hardware fault messages and take whatever actions are desired.

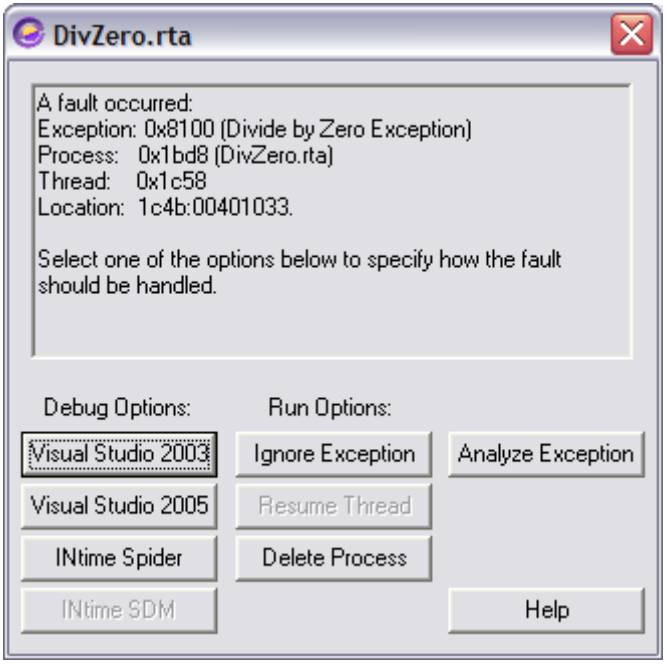
INtime software provides a Hardware Fault Exception handler sample project that shows the use of a local HW_FAULT_MBX mailbox and a thread that manages it.

For detailed information on the HW_FAULT_MBX and its notification messages, see Help.

Fault Manager

INtime software includes an application which handles faults and give the user an opportunity to debug the faulting condition. The Fault Manager is enabled by default in the Development Kit. If a fault occurs, the following dialog box displays:

Figure 4-7. Fault Manager Dialog



The action required to debug the fault may now be selected, or the process containing the faulting thread may be deleted. See the Fault Manager help information for how to configure a default action.

Structured Exception Handling

Any INtime application may use the Structured Exception Handling feature of the Microsoft compilers to handle faults in the application.

For more information about Structured Exception Handling see Microsoft's compiler documentation.

For more information about the iWin32 API see *Appendix C, INtime software components* and the INtime Help file.

5 Designing RT applications

This chapter provides general guidelines for RT system design using INtime software.

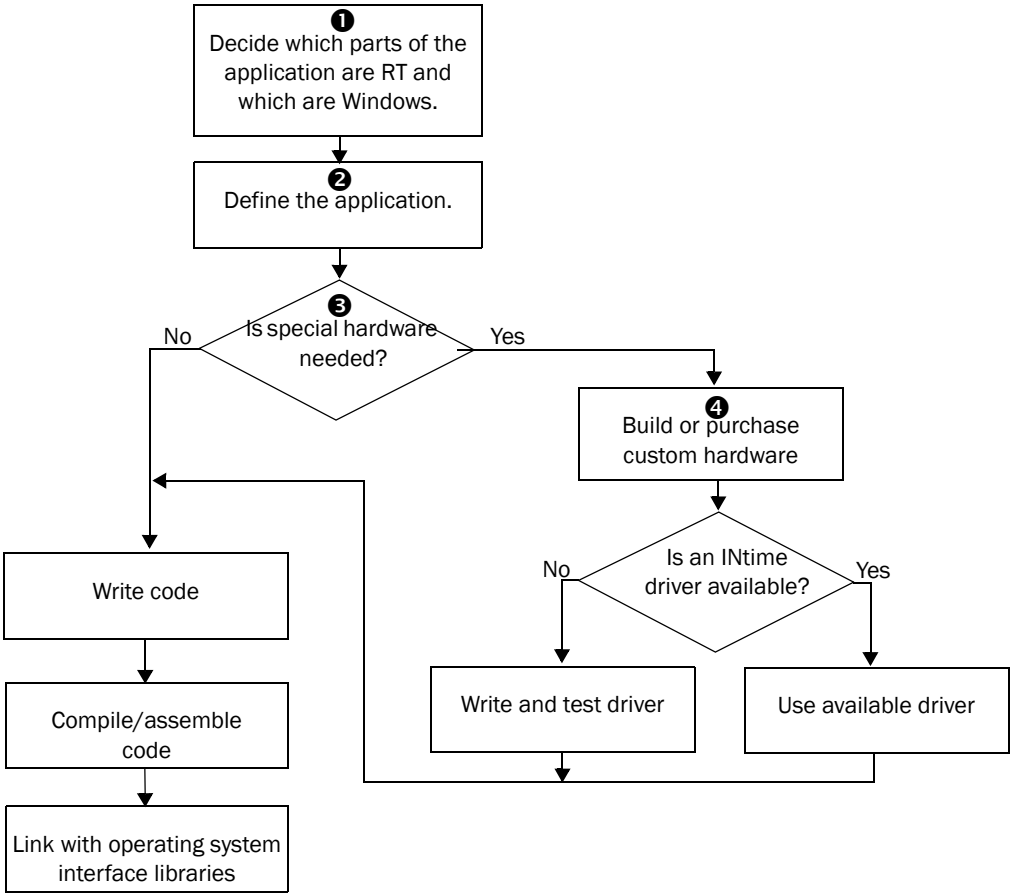
Define the application

When designing an RT application, you should include these steps:

- Partition the application into Windows and RT components.
- List the INtime application's inputs and outputs, and decide whether RT or Windows services each system component. Decide which objects to use for inter-thread synchronization and communication, both within the RT portion and between the RT and Windows portions.
- List all threads that require the input and output. Define interrupts and decide which ones require determinism. Assign interrupt levels and priorities to take advantage of multitasking and preemptive, priority-based scheduling.
- Develop the detail for each thread in a block diagram.
- Decide if the application requires multiple processes, and if so, how they will use shared memory and dynamic memory allocation.
- Design your user interface.
- Determine if you require custom devices and drivers.
- Determine if your application will run on a single system or be distributed over multiple RT nodes.

This flowchart shows steps typically taken by RT software designers. When complete, the prototype system is ready to test, debug, and fine-tune.

Figure 5-1. Typical development cycle for INtime applications



❶ Partition the application into RT and Windows components.

❷ Define processes, then define threads, interrupt levels, and priorities. Decide which objects to use. Define interrupts, handlers, and levels.

❸ Decide on hardware and device drivers. Decide how to implement a multi-user environment and/or an operator interface.

❹ Decide if you need custom hardware that solves a unique problem or gathers data in a unique way.

Target environments

Developing INtime applications involves balancing between the target environments:

- The RT environment, where you create portions of the application that require RT robustness and determinism.
- The Windows environment, where you can add RT object access to a Win32 application.

Methodology

A critical aspect of any INtime application is the division of labor between Windows processes and RT processes and, to a finer degree, between the threads in each process.

Important guidelines for developing RT user applications include:

- **Limit RT processes to performing only time-critical functions**: For maximum performance, applications must be divided appropriately between the RT and Windows portions. The INtime software scheduler gives precedence to RT processes and threads. This preferential scheduling guarantees the best possible RT response.

  For example, to optimize user interface (UI) performance, design INtime applications so that RT activity occurs in event-driven bursts. An INtime application that executes for too long on the RT kernel can consume too many CPU cycles and therefore degrade the system's Windows capabilities. This typically causes a sluggish GUI on the Windows side. Adverse effects in the Windows interface, disk, and network operation become noticeable when RT CPU utilization on your system exceeds 80 percent.

- **Determine which Windows threads require the greater relative priority**: The relative priority given to each of the Windows threads of an INtime application can determine the perceived performance of the application in a heavily loaded system. The higher the relative priority given to a Windows thread, the more likely the thread will perform sufficiently in a heavily loaded system.

  Determining which threads require the greater relative priority depends on the nature of the application. For example, giving higher relative priority to data manipulation and data storage threads can sacrifice data display and user interface performance when the system is heavily loaded. If an application is data-intensive or the system has no keyboard or display, then sacrificing user interface performance may be desirable. Conversely, if a requirement of an application is a responsive user

interface, then data manipulation and data storage can be given a lower relative priority.

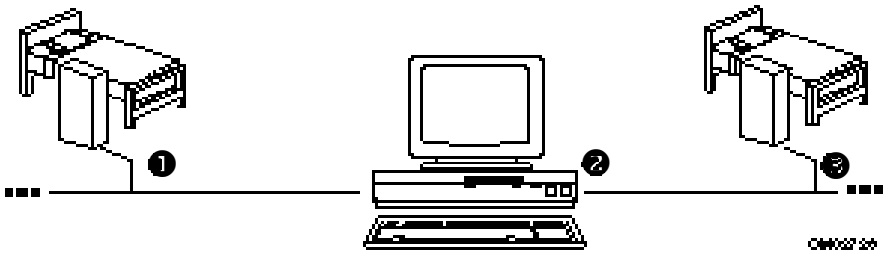
Note

You can use the Windows Performance Monitor to observe CPU usage by Windows and INtime software's RT kernel. For more information, see *Performance monitor* in *Chapter 10, INtime application development*.

A hypothetical system

This hypothetical INtime application monitors and controls dialysis. The application consists of three main hardware components:

Figure 5-1. The hardware of the dialysis application system



❶ A bedside unit is located by each bed. Each unit runs INtime software, which performs these functions:
- Measures the toxins in the blood as it enters the unit
- Adjusts the rate of dialysis
- Removes toxins from the blood
- Generates the bedside display for bedside personnel
- Accepts commands from the bedside personnel
- Sends information to the MCU (Master Control Unit)

❷ The MCU, a PC with a screen and keyboard, runs INtime software. The MCU enables one person to monitor and control the entire system. It performs these functions:
- Accepts commands from the MCU keyboard
- Accepts messages from the bedside units (toxicity levels, bedside commands, emergency signals)
- Creates the display for the MCU screen

❸ A LAN connects the bedside units to the MCU.

The next sections describe how various INtime software features are used in the hypothetical system.

Interrupt and event processing

Interrupts and internal events occur at the bedside units: bedside personnel enter commands asynchronously and the system computes toxicity levels at regular intervals.

Toxicity levels, measured as the blood enters the bedside unit, are not subject to abrupt change. The machine slowly removes toxins while the patient's body, more slowly, puts toxins back in. The result is a steadily declining toxicity level. The bedside units must monitor toxicity levels regularly, but not too frequently. For instance, the bedside units could compute the toxicity levels once every 10 seconds, using a clock for timing. The measurement thread would measure and compute the toxicity, put the information in a mailbox for the MCU, and suspend itself for 10 seconds.

Command interrupts from the bedside unit occur when a medical operator types a command and presses Enter. Interrupts from command entries occur at random times. The interrupt handler signals the interrupt thread. The interrupt thread performs any required processing and waits for the next interrupt.

Processing commands from the bedside units: Each time a medical operator types a command and presses Enter, the bedside unit receives an interrupt signal from the terminal. The bedside unit stops executing the current instruction and begins to execute an interrupt handler.

1. The interrupt handler accumulates the characters in a buffer and puts them in memory. The interrupt handler signals the interrupt thread for bedside commands.
2. The interrupt thread gets the contents of the memory where the handler put the command. It parses the command and does the required processing.
3. The thread puts the command information, along with the number of the bedside unit, into a message.
4. The thread sends the message to the predetermined mailbox for the MCU.
5. The interrupt thread waits for the next interrupt. The system returns to its normal priority-based, preemptive scheduling.

Multi-tasking

Threads in the application run using preemptive, priority-based scheduling. This allows the more important threads, such as those that control the dialysis rate, to preempt lower-priority threads, such as those that update displays. New capabilities can be added to the system by simply adding new threads.

II Using INtime software

This part provides the information you need to install, run, and use INtime software to develop RT applications.

This part contains:

Chapter 6: Installation

Explains how to install and uninstall INtime software.

Chapter 7: Configuration

Describes how to configure INtime software.

Chapter 8: Preparing an RT node

Explains how to set up an RT node to run INtime software.

Chapter 9: Operation

Describes how to start and run INtime software.

Chapter 10: INtime application development

Explains how to use the INtime development environment to create INtime applications.

6 Installation

This chapter explains how to install your INtime software on a Windows system. Follow the directions in this chapter to install INtime software for a development system or a target system.

Note

For information about preparing RT nodes to run INtime applications, see *Chapter 8, Preparing an RT node*.

For descriptions of INtime nodes, Windows nodes, and RT nodes, see *Topology terminology* in *Chapter 2, Understanding INtime software architecture*.

Install INtime software on a Windows system

Requirements

Installation of INtime on a Windows system requires:

- A Pentium (or better) CPU.
- A minimum of 4MB of RAM above that required to run Windows. The default allocation to INtime is 16MB.
- A minimum of 50MB of available disk space.
- A supported version of Microsoft Windows (for a listing, see page 3.

The development environment requires the installation of one of these:

- Visual C/C++ 6.0
- Microsoft Visual Studio .Net 2003
- Microsoft Visual Studio 2005

Before you begin

- Ensure that you are logged on with Administrator privileges.
- Exit all programs prior to installing INtime software.
- If your system has a previously installed version of INtime software, remove it:
  1. Ensure that no INtime services are running. If any are running, be sure they are set to Manual Start (using the Start>Control Panel> Administrative User/ Services applet), and then reboot the system.

2. Select the Add/Remove Programs Applet in the System Control Panel (Select Start>Control Panel>Add/Remove Programs).
3. Highlight INtime 2.23 (or earlier) program, and then click Remove.
4. Reboot the system.

Running the Installation program

To install the INtime software:

1. Review the License Management document received with your Development Kit. This contains instructions specific to the product you purchased.
2. Insert the INtime software CD-ROM into the CD-ROM drive. The Installation program automatically starts and the welcome screen displays.

> **Note**
> If you've disabled the automatic start feature on your system, select:
> `Start>Control Panel>Add/Remove Programs`
> As you browse the CD, select intime300.msi from the list that displays.

   If the Installation program detects a previous version of INtime software, it prompts you to exit the installation and uninstall the previous version as described in *Before you begin* (above).
3. Review the INtime License and note its terms and conditions.

> **Note**
> If you continue and install the INtime software, your action shows that you agree to be bound by the terms and conditions outlined in the INtime License.

4. Review the Readme information for any late-breaking information not included in the product documentation.
5. Select a destination directory for the INtime software files, then click the Next button. The default is C:\Program Files\INtime.

6. Select one of the installation options listed below, then follow the prompts in the installation.

Figure 6-1. Installing INtime software

Option	Description
Local Target Only	Installs the INtime runtime components on the local system. Choose this option to run INtime applications on this system.
Development and Local Target	Installs all product development and runtime components. Choose this option to develop and run INtime applications on this system.
Custom	Installs the product development and runtime feature groups you specify. Choose this option, for example, to install only the development components.

7. At this point you need to refer to the license management document for explicit instructions for your product. Follow the instructions for installing the appropriate licenses.

   When the installation is complete, the Installation program may prompt you to reboot the system.

8. Click the Finish button to complete the installation process.
9. Restart your system using one of these methods:
   - Select YES at the last screen. The Installation program restarts your system.
   - Select NO to manually restart your system at a later time.

Note
You must restart your system before running INtime software.

Installing hardware for use with the RT kernel

Before loading an application to interface to a hardware device, it is necessary to prepare the hardware to make it available to the RT kernel.

The Windows Plug-and-Play software will attempt to automatically configure hardware it detects at boot time. To prevent this, a Windows driver is provided which allows Windows to believe it has claimed the hardware but also isolates it from other Windows hardware so that an RT application can interact with it.

In an INtime system it is necessary to separate the IRQs of devices that are to be controlled by INtime from those that are to be controlled by Windows. If real-time and Windows devices were allowed to share the same interrupt line, deterministic handling of that interrupt is lost, since release of that signal would depend on the Windows kernel.

The INtime Device Configuration tool is provided in order to reserve hardware devices for INtime usage. To run the tool, go to Control Panel->INtime->Device Configuration. Use the tool to select which devices are to be reserved for INtime then the tool will analyze the IRQ resources and make sure that it is possible to make the allocation.

In some cases it is not possible to physically isolate the device, in which case the hardware/motherboard combination in your system is not suitable for running the INtime device driver.

To install two real-time devices, configure both devices at the same time with the Device Configuration tool. It will check that any IRQ resources are not shared with Windows, but allow INtime devices to share the same IRQ if necessary.

7 Configuration

INtime software provides the flexibility to meet a variety of INtime application requirements that you set using configuration options available in the INtime Configuration utility. This chapter describes the following options:

Configuring INtime software

Default configuration

By default, the Install program configures INtime software to:

- Require manual start up for the INtime Kernel service. The installation program configures all other INtime services to start automatically.
- Install INtime software files in the `%SystemDrive%\Program Files\INtime` directory.
- Access INtime application wizards, their components, and Help files from the directory appropriate for the version of Microsoft Visual Studio installed on your system.

The INtime Configuration utility's Help contains step-by-step instructions for many tasks. You can access this Help by running the utility, then pressing the Help button located at the bottom of the window.

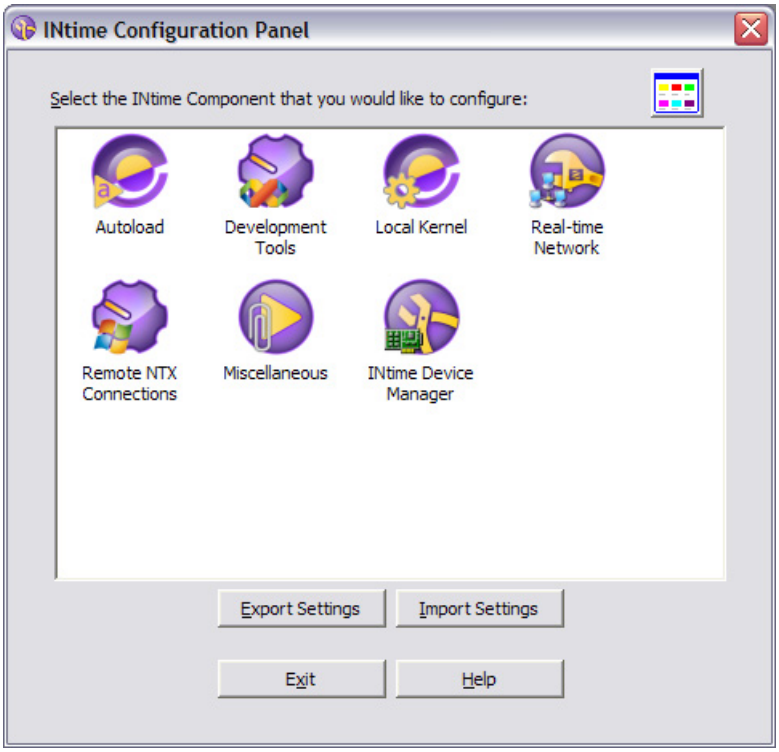
Running the INtime Configuration Utility

To access the Configuration utility, select this program:

`Control Panel->INtime.`

When you start the utility, an explorer interface displays:

Figure 7-1. INtime Configuration Panel



Note
Press F1 to view step-by-step instructions for many configuration tasks.

Tab	Description
Local Kernel	Configures settings that affect RT kernel operation. These include the amount of memory allocated to the RT kernel, and the system clock period as well as other kernel configuration parameters.
AutoLoad	Configures RT processes which are to be loaded automatically when the local RT kernel is started.
License Manager	Collects information for node-locking the installation, and allows the installation of full license codes.

Tab	Description
Development Tools	Installs, uninstalls, and verifies the status of INtime wizards for Microsoft Visual Studio.
Miscellaneous	Configures other settings such as automatic Windows logon, Fault Manager behavior and the size of the console windows where RT applications display text.
Remote NTX Connections	Configures the connection between a Windows host and its RT nodes.
Remote Node Builder	Builds a set of files to install on a new RT node.
Real-time Network	Sets the parameters for the RT Network Stack on an INtime node.
INtime Device Manager	Configures hardware devices for use with RT applications.

Miscellaneous

RTIF.SYS driver

When you install INtime software, the installation process sets up the Windows system to allow RtIf.sys, the RT kernel mode device driver, to load at boot time.

Interrupt resources

By default, INtime software takes over the system clock (IRQ0) and multiplexes the clock interrupt between the RT and the Windows kernels. INtime applications can take over other interrupts, but must ensure that Windows drivers do not try to use the associated devices.

Use the INtime Device Manager applet to assign devices and interrupt resources to the INtime kernel.

Configuring INtime applications

This section details the steps required to configure INtime applications for specific conditions. You can also access this information in the INtime Configuration's Help file.

Configuring Windows for non-interactive logon

Executing Windows and INtime software without an attached keyboard and mouse requires that Windows be configured for non-interactive logon, also known as AutoAdmin Logon. To configure Windows for non-interactive logon:

1. Log on to Windows with Administrator privileges.
2. Create/verify the presence of a Windows user with a password as to which you want to automatically log on.
3. Start the INtime Configuration application
4. Select the Miscellaneous applet tab, then edit these fields:
   - **Automatic Logon Options**: Select Auto Logon Always.
   - **Auto Logon Parameters**: Enter the information in these fields:

     Domain Name
     User Name
     Password

     Note: Be sure to use the User name and Password established in step 2.
5. Exit the INtime Configuration application.
6. Restart Windows.

When Windows restarts, it automatically logs on as the specified user in the specified domain.

⚠ CAUTION
Deploying a Windows system with the non-interactive logon feature enabled represents a potential security breach: the Windows registry stores the specified user, domain, and password in clear text–they are not encrypted.

Configuring INtime Local Kernel service to execute automatically

To configure the INtime Local Kernel service to start automatically during Windows restart:

1. Go to the Local Kernel Configuration applet.
2. Check the “Start INtime Kernel Automatically” checkbox.
3. Click the OK button
4. Restart your system.

Automatic loading of Realtime Applications

INtime software can load your realtime applications automatically when the Local Kernel service starts:

1. Open the “Auto Load Configuration” applet in the INtime Control Panel utlity.
2. Click the “Add” button.
3. Enter the Application Title, and the full path of the application (.RTA file) to load.
4. Add any command-line parameters which you want to specify.
5. For other parameters, click on the “Advanced” button.
6. If your application is dependent on another application being loaded first, enter the name of the dependent application in the Dependencies list by clicking on the “add” button.
7. Click OK. When the Kernel restarts your application will start automatically.

Configuring a Windows service to execute automatically

To configure a Windows service to start automatically during system reboot:

1. Activate the Services applet found in Administrative Tools on the Control Panel (Start>Control Panel>Administrative Tools>Services).
2. Highlight the service you want to start automatically.
3. Click the right mouse button.
4. Select Properties.
5. Select Automatic as the Startup type.
6. Click the OK button.
7. Restart your system. Changes made take effect only after you reboot the system.

Configuring the INtime Network software

To configure the INtime kernel TCP/IP software, use the Real-time Network applet in the INtime Control Panel.

Before you begin

You will have to assign an IP address and host name to the network interface controlled by the INtime TCP/IP software. This should not be the same address used by your Windows networking software. Alternatively you can specify that the address will be obtained automatically from a DHCP server.

Hardware installation

Before configuring INtime TCP/IP software, install and configure the network interface adapter you plan to use. Instructions for installing hardware for RT kernel use may be found in *Installing hardware for use with the RT kernel* in *Chapter 6, Installation*.

Setting the TCP/IP configuration parameters

1. Start the Control Panel INtime applet.
2. Select the Real-time Network Configuration tab.
3. Set the following:

To...	Select this checkbox...
Automatically start real-time networking services	Auto-Start Networking Services

4. Select the Transport Layers you plan to use.
5. Enter the host name.
6. Click the NIC Configuration button. The NIC Configuration Dialog displays. Edit or Add the interfaces you require, as needed. Each configured interface needs these items:

   Check the Enable DHCP box, OR enter the following:
   IP address
   IP interface address mask
   Gateway address

   NIC driver with its associated parameters.
7. Exit the NIC Configuration Dialog.
8. If you want to use a DNS server for name resolution, select the DNS checkbox, then enter the domain name and up to three IP addresses of DNS servers.
9. Click the Apply button.

If the kernel is already loaded, you must restart the system for changes to take effect.

NIC driver configuration

When you add or edit a NIC interface, you will need to select the NIC driver appropriate to your hardware, and configure the parameters appropriate to your hardware. Normally an ISA card requires configuring of the IRQ and Base Address. PCI cards do not normally require any special configuration parameters.

However, if there are multiple PCI NIC cards in the system of the same type (for example, two Intel EtherExpressPro/100 cards), then you must specify the proper instance number for the card you want to manage with the specified INtime driver.

Advanced configuration parameters

In some instances it may be necessary to change default settings for the real-time networking services (e.g. IP, TCP, or UDP). You can configure these parameters by clicking on the Advanced button in the NIC Configuration Dialog. The Advanced Settings Dialog appears which allows you to choose the section you which to configure. Once you choose a section, the parameters for that section are displayed with their values. You can edit these values or add your own.

Static routes and aliases may be added to the configuration using the INtime Configuration utility. See the Configuration help file for further details.

8 Preparing an RT node

This chapter explains how to set up an RT node to run INtime software.

Requirements

Installing INtime software on systems used as RT nodes requires:

- A PC that contains an Intel386† EX or better microprocessor.
- A minimum 4MB of DRAM for the RT kernel.
- PC-compatible local media. (Where the BIOS uses INT13).
- RT node files:

Files/directories	Description
eepro100.rta	An Intel EtherExpress† Pro/100 NIC driver.
ping.rta	An RT application that tests the network connection between two machines.
ne.rta	An INtime driver for the NE2000 compatible NIC (ISA card).
3c59x.rta	A 3COM 3C59XX NIC driver.
rtl8139.rta	A Realtek rtl8139 NIC driver.
Bcom.rta	A Broadcom Gigabit Ethernet driver.
Rt18169.rta	A Realtek Gigabit Ethernet driver.
ntxproxy.rta	An INtime application that manages NTX calls on the RT node.
remote.bin	An RT kernel binary image for use on an RT node.
rtcimcom.rta	An INtime application that manages the serial NTX communications channel.
rtcimudp.rta	An INtime application that manages the UDP NTX communications channel.

Files/directories	Description
serdrvr.rta	An INtime driver for the serial devices on the remote RT node.
loopback.rta	An INtime loopback driver for use with the TCP/IP stack layers.
ip.rta, rip.rta, udp.rta, tcp.rta	TCP/IP stack layers.
rtconfig.sys	A file generated by the Configuration Utility that sets up boot-time configuration parameters for the remote RT kernel.
rtboot.ini	A file generated by the Configuration Utility that sets up boot-time configuration parameters for the remote INtime bootloader.
rtload.sys	A file generated by the Configuration Utility that specifies what files to load at boot time on the RT node. The extension xxx can either be udp if the UDP/IP NTX channel is used, or ser if the Serial NTX channel is used.
mdnsintm.rta	INtime mDNS client which interacts with the WIndows service to automatically configure the NTX connection.
dhcpc1nt.rta	a DHCP client which allows optional automatic configuration of the network interfaces using a DHCP server.
bldflpys.bat	A file generated by the Configuration Utility that is used to create installation floppies used to install the Remote INtime files onto an RT node's Hard Disk or Flash system, or for use in booting the RT node from the floppy disks themselves.

- RtSetup.exe, a DOS program used to make an RT node's boot device bootable. This file is located in either the `\INtime\remote\common` directory or on the INtime RT node setup disk.

Configuring an RT subsystem

To build an RT subsystem:

1. Ensure that INtime software is installed on the Windows system you want to use as the Windows host for your RT nodes.
2. Determine the type of RT subsystem you want to build. Subsystem types are categorized by the type of Boot Media on the remote system:
   - Floppy diskette
   - Hard disk
   - Flash disk
3. Build the RT subsystem floppies. Differences in the directions based on the subsystem type you select will be noted.

Building remote node boot/installation floppies

1. Start the Control Panel INtime applet and select the Remote Node Builder applet.

2. Click the Add button in the Remote Node Builder applet. The Remote Node Builder dialog displays.
3. Complete the fields in the dialog. You have the choice of configuring a statically-addressed node, where you specify each end of the connection, or to configure a dynamically-addressed node, where the RT node and the Windows "INtime mDNS Service" cooperate to generate a link configuration on the fly.
4. If you choose to make a ststic configuration, check the "Make Connection" box to ensure that you configure a connection for your remote node.
5. When you have completed the configuration, click OK and return to the Remote Node Configuration applet.
6. Click the Build button to generate the files. A message will tell you where the files have been generated.
7. Build RT node installation/boot floppy disks:
   A. Double-click the bldflpys.bat file and follow the directions when prompted. This file builds two floppy disks used to boot/install the RT subsystem.
   B. Ensure that no error messages display while the batch file builds the floppies and name (label) the floppy disks when prompted during each FORMAT operation.
   C. Label the floppies as follows:

      If you selected "Floppy" as the Boot Media in step 3 (on page 77), label the two floppy disks as follows:

      Floppy 1: Boot floppy
      Floppy 2: Commands floppy

      If you selected any other option for Boot Media in step 3, label the two floppy disks as follows:

      Floppy 1: Installation Floppy 1
      Floppy 2: Installation Floppy 2

Booting from the Boot floppy disk

If you selected "Floppy" as the Boot Media in step 3 (on page 77):

1. Place the Boot floppy in the RT node's floppy drive.
2. Press Ctrl-Alt-Delete. The system reboots, then loads INtime software's remote RT kernel from Boot floppy.
3. Insert the Commands floppy when prompted to do so. The system loads the system applications from the Commands floppy. After the applications load, the RT Node can communicate with the Windows host.

Copy build files to the hard/flash disk

If you selected “Harddisk” or “Flashdisk”as the Boot Media in step 3 (on page 77):

1. Place the INtime RT node setup disk in the target RT node’s floppy drive and boot. The DOS prompt displays.
2. Partition the hard/flash disk:
   A. Invoke the ‘fdisk’ command. A character-based GUI displays.
   B. Ensure that partition 1 is available for use.
   C. Select the option that creates DOS partition 1.
   D. Specify the amount of memory allocated to the primary DOS partition.

   Note
   The RT kernel can only detect DOS partition 1.

   E. Press the Esc key to exit fdisk and reboot the system. Leave the RT node setup disk in the drive.
3. Format the hard/flash disk by entering:

   ```
   format c: /u
   ```
4. Run the RT setup program by entering:

   ```
   rtsetup c: 1
   ```

   where `c:` is the drive and `1` is the partition number.
5. Copy the contents of Installation Floppy 1 and Installation Floppy 2 (created earlier) to the hard/flash disk:
   A. Insert Installation Floppy 1, prepared by the batch file, into the floppy drive and then enter this command to copy the floppy disk’s contents to the hard/flash disk:

   ```
   copy *.* c:
   ```

   B. Insert Installation Floppy 2, prepared by the batch file, into the floppy drive and then enter this command to copy the floppy disk’s contents to the hard/flash disk:

   ```
   copy *.* c:
   ```

   C. Remove the floppy disk and reboot the system.

   The system reboots and loads the INtime software’s remote RT kernel and system applications. The RT node can now communicate with the Windows host.

Special requirements for Flash disks

- Ensure that DOS can detect the flash disk as the C: drive.

- Ensure that you can format and fdisk the flash disk from DOS.
- Ensure that these basic ROM BIOS functions are available:
  - INT 13H (disk I/O)
  - INT 15H (Extended memory access)
  - INT 10H (video)

Loading a user application on an RT node at boot time

To have one or more user applications load at boot time on an RT node, simply add them to the appropriate RtLoad file after the system applications. For example, to cause the application MyApp.rta to load with input parameters "`base=0x760 irq=5`" on an RT node set up to boot up with a UDP-based NTX interface to its Windows host, modify the RtLoad.udp file as follows:

- After `ntxproxy.rta`, add this line:

  ```
  \myapp.rta "base=0x760 irq=5"
  ```

- Set process-level parameters in RtLoad.sys following the switch setting information described in the next section.

RtLoad.sys file format and switches

The RtLoad.xxx file is generated by the INtime Configuration utility, based on user input. As the RT image boots, it finds the RtLoad file specified in the RtConfig.sys configuration file and parses its contents to determine which applications to load, and in what order. Each line (terminated with a LF character) in the file can indicate the full pathname of an application to load as the RT system initializes. Applications load in the same order as they appear in the file. The load file has the following per-line format:

First character

Mode	Description
;	Treat the entire line as a comment.
#	Print the rest of the line on the current STDOUT device and wait for a response from the STDIN device before proceeding to the next line. This is useful when booting from a floppy device and then pausing to insert the second (or nth) floppy of the set before proceeding. (Only supported if Logging Mode is set to "Stdout" and Printf/Scanf console is set to "Local" on the Loader page of the INtime Configuration utility's Remote Client Settings tab.
\	Indicates that the following characters before the next space represent an application program in the root directory of the boot device.
^	Processes the following character as a command to the Loader (Remote INtime Run-Time Application Loader). Supported command characters include: E — Tells the loader to enlarge the code segment (same as Open Data Segment in the INtime Loader) for the next application listed for loading in the RTLOAD.XXX file.
Other	Any other character is assumed to be the first letter of the application program assumed to be in the root directory of the boot device.

First space

In all lines except those that begin with ';', '#', or "^", the first space character is interpreted as the delimiter of the application file pathname to be loaded. The rest of the line's characters are of two types:

- Parameters passed to the Loader to initially load the file.
- A string passed to the loaded application for its examination via the 'argc' and 'argv' C-library commands.

The Loader-load parameters are all prefixed with a '-' (dash) and the application parameters are contained within a quoted string.

The following Loader-targeted load parameters are as follows:

Parameter	Description
-o	Object directory size (number of entries) of the application being loaded. If not specified, the EIOS default I/O job object directory is used. If not a multiple of 16, the specified value is rounded down to the nearest multiple of 16.
-n	Minimum size of the application's memory pool in bytes. If not specified, the minimum pool size is calculated from information found in the binary of the application being loaded.
-x	Maximum size of the application's memory pool in bytes. If not specified, the maximum pool size will be 0xffffff.

Parameter	Description
-v	Size in megabytes of the VSEG created for Ring 3, Flat applications. If not specified, a default value of 8 megabytes will be used. A value of 0 or 1 causes the Default VSEG_SIZE value specified in the ICU to be used. Values above 512 are reduced to 512. The value specified is multiplied by 4 Mbytes. Note: the VSEG size specified here must be large enough to hold the amount of physical memory needed by the application.
-p	Priority of the initial thread of the application being loaded. If not specified, a default of 136 is used.
-w	Number of seconds the Loader should wait before loading the next application specified in the load file.
-d	Tells the Loader to place an Int 3 instruction at the first instruction of the loaded application so that the system breaks to the monitor when the application begins to run. This is useful for debugging.

Any parameters other than those listed above cause the line to be ignored.

The argument string within a pair of " (double quote) characters can be up to 256 characters in length. It is passed intact. It cannot contain any " (double quote) characters itself. Both the beginning double quote and the ending double quote must be found on the same line, otherwise the line is ignored. Valid load parameters can appear after the argument string on a given line.

A SPACE character must precede both load parameters and argument strings. No SPACE character is allowed between a load parameter ID and the parameter itself. For example, `testfile -o128 "This is a test"` is a valid entry that causes the file testfile to load with an object directory size of 128, and with the string “This is a test” passed to it as an argument. Likewise, the example `testfile1 -v 16 "This is a test"` is invalid since:

- There is a SPACE between the ‘v’ and the 16, and
- There is no SPACE preceding the argument string “This is a test”.

Editing the RtLoad.sys file in-line

Once the Remote node is configured and started, you may need to edit the RtLoad.xxx file to, for example, add or delete applications loaded at startup. You can use the INtime Configuration utility to edit this file:

1. Open the INtime Remote Maintenance utility from theINtime Start Menu.
2. Click the Nodes button and choose the remote client node that you want to configure. Once an active node is selected, the root directory displays in the pane.
3. Navigate to the file you want to edit. You can navigate through the directory structure by double-clicking into folders and by pressing the “Up One Level” button. Highlight the text file you want to edit.

4. Click the “Edit Remote File” button. The utility copies the file to the host system and opens the file in an editor. Be sure to save any desired changes and exit the editor when you are finished.
5. Click the OK button in the dialog box to copy the updated file to the remote node.

You can also use the utility to transfer files to and from the remote node, and to restart the remote node.

9 Operation

This chapter describes how to start and operate INtime software.

You can treat the RT kernel and associated INtime applications as Windows services and start them automatically when Windows initializes.

In the event of a Windows blue screen crash, INtime software keeps running until a graceful shutdown occurs. To start INtime software again, you must first restart Windows.

Starting the RT kernel and related components

1. Open the Windows Service Manager (Start>Control Panel>Administrative Tools>Services).

   The Windows Services table lists these INtime services:

Table 9-1. INtime software's Windows services

Service	Description
INtime Kernel Loader	Loads the RT kernel binary image into memory and starts it. Uses loadrtk.exe.
INtime Clock Synchronization service	A Windows program that synchronizes RT client time-of-day clock with the Windows host's time-of-day clock.
INtime Event Log service	A Windows program that acts as a gateway to allow RT applications to log events in the system event log on the Windows host.
INtime I/O service	A Windows program that acts as a server to RT "C" library to obtain a console window for display (via printf) of application data and to receive (via scanf) user input from the system keyboard. This service also provides Windows file system support to the RT "C" library.
INtime Node Detection service	A Windows program that detects RT clients, both local and remote. This program checks for and registers RT clients that exist in both of these locations: RT clients configured in INconfCpl.cpl. RT clients available to the system.
Intime Remote Connection manager	A Windows program that detects and manages connections between the Windows host and its RT nodes. The manager includes NtxRemote2.exe, which is required for a Windows host to communicate with RT nodes.
INtime Registry service	A Windows program that provides Windows registry access to RT processes via the RT application library.

Table 9-1. INtime software's Windows services

Service	Description
INtime mDNS service	A WIndows program that uses the mDNS protocol to automatically configure RT node connections.
INtime Monitor service	A WIndows program which displays an icon in the system tray, allowing access to some basic functions such as start/stop the local kernel.

2. Start each INtime software service as desired. By default all services except the INtime Kernel service start automatically.
3. You can also start the Local Kernel service using the button on the INtime Kernel configuration Control Panel applet.
4. You can also start the Local Kernel service by right-clicking on the INtime icon in the system tray and selecting the Start Local Kernel menu item.

After you start INtime software

- Use Microsoft Visual Studio to develop your INtime application.
- Use a debugger to load and debug your RT applications.
- Use the INtime Loader to load and run your RT applications. You can start this program by selecting Start>All Programs>INtime>RT Application Loader.
- INtime tools available from the Start>All Programs>INtime software menu include:

Note
One or more of these tools are installed, depending on which INtime Environment option you selected when you installed INtime software.

Tool	Description
INtime Configuration	A Windows program that configures INtime software.
RT Application Loader	A Windows program that loads/starts the RT portion of INtime applications.
Spider Debugger	A Windows program that communicates using NTX calls, with the INtime debug server to provide dynamic source level, multi-tasking debug capabilities for RT applications. Note: For detailed information about usingSpider, see Spider's Help.

Tool	Description
INtime Explorer	A Windows program that uses NTX calls to communicate with its self-loaded RT counterpart to display objects inside an INtime node.
INscope Real-time Performance Analyzer	A Windows program that uses NTX calls to communicate with its self-loaded RT counterpart to trace execution of INtime applications.

Also available from the Start>All Programs>INtime software menu are these resources:

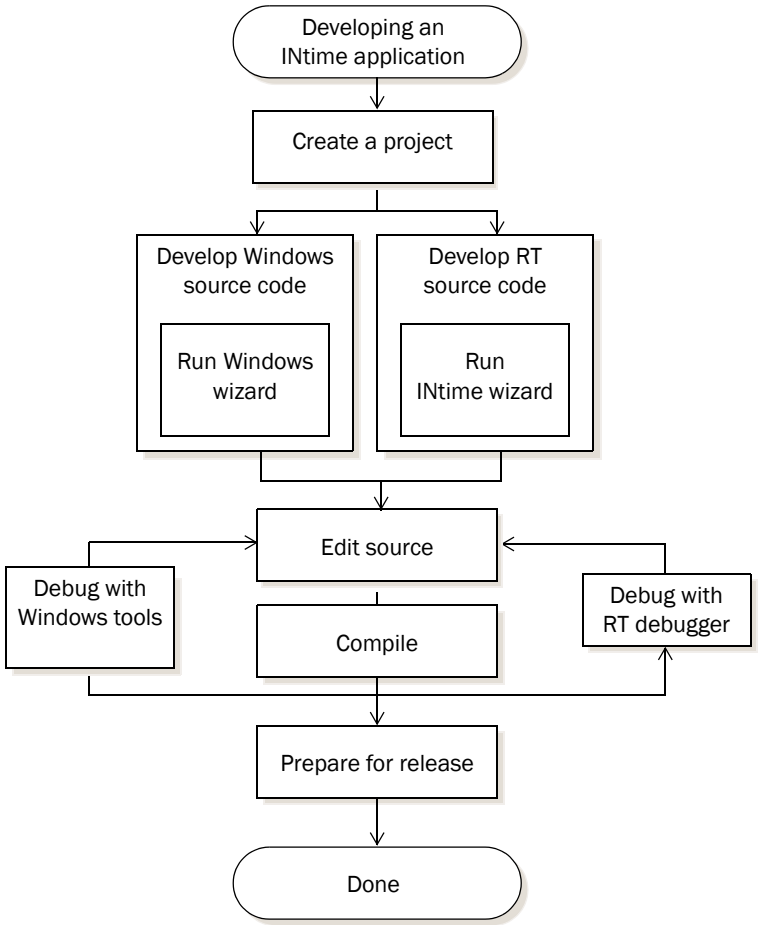
- **INtime Help**: Describes INtime software concepts and explains how to use INtime tools. Help includes all system calls, including their syntax which you can cut and paste directly into your code.
- **INtime Release Notes**: Lists features and issues that arose too late to include in other documentation.
- **Dinkum EC++ Help**: Describes the Dinkumware EC++ software included with the INtime product.
- **Sample Code and Projects**: Menu of MSVC projects that demonstrate various aspects of INtime application programming.
- **Quick Start Projects:** Menu of projects described in the Quick Start Guide.

10 INtime application development

This chapter ribes how to create INtime applications.

Typically, you develop both Windows and RT source code as shown in this illustration. The remainder of this chapter details each of these steps.

Figure 10-1. Developing an INtime application



Create a project

To develop RT applications using INtime software, you must have INtime installed on your system, and Microsoft Visual Studio (version 6.0 or .Net 2003) running.

Before creating the project, decide how to set it up. Typical structures for INtime applications include:

- Set up the Windows portion as a project, and the RT portion as a sub-project. Use this approach when you want to start your INtime application in Windows and invoke the RT functions.
- Set up the RT portion as a project, and the Windows portion as a sub-project.
- Set up each portion as a project.

Keep in mind that an INtime application results in a minimum of one Windows executable (a .DLL or .EXE file) and one RT executable (an .RTA file).

Develop Windows source code

To develop the Windows portion of an INtime application, use Microsoft Visual Studio as you normally would:

1. With Microsoft Visual Studio running, select a standard application wizard. Use the wizard to build the Windows portion of your INtime application.
2. Use the Microsoft Visual Studio's editor to edit the generated code and link the application.
3. When editing your Windows source code, use the NTX calls provided with INtime software to access RT functionality.
4. Debug with the debugger included as part of Microsoft Visual Studio.

Adding the INtime RT Client Browser to your INtime application

The INtime RT Client Browser (INBROW.OCX) is an ActiveX control that you can add to your INtime applications. Add the browser by selecting Project/Add to Project/ Components and Controls on the Microsoft Visual Studio menu. Select Registered ActiveX Controls/INtime Node Browser and add it to your project. The Node Browser then appears as an available control on the Controls Toolbar. Add the control to the dialog you desire. For information about including ActiveX controls in projects, see the Microsoft Visual Studio documentation.

Once in your project, the control offers these functions:

Function	Description
GetCurrentName	Obtains the name of the item highlighted in the INtime RT Client Browser.
GetCurrentState	Obtains the state of the item highlighted in the INtime RT Client Browser. Valid states include: 0 Not an INtime node 1 ACTIVE 2 OFFLINE 4 CONFIG Where: ACTIVE RT nodes the browser currently can communicate with. OFFLINE RT nodes the browser has but cannot currently communicate with. CONFIG RT nodes the browser has not communicated with. These nodes may not exist.
GetMask	Indicates which RT nodes display in the INtime RT Client Browser.
SetCurrentName	Not supported.
SetCurrentState	Not supported.
SetMask	Displays in the INtime RT Client Browser only the nodes with the state(s) you specify: 0 Not an INtime RT node 1 ACTIVE 2 OFFLINE 3 ACTIVE + OFFLINE 4 CONFIG 5 CONFIG + ACTIVE 6 CONFIG + OFFLINE 7 CONFIG + OFFLINE + ACTIVE Where: ACTIVE RT nodes the browser currently can communicate with. OFFLINE RT nodes the browser has but cannot currently communicate with. CONFIG RT nodes the browser has not communicated with. These nodes may not exist.
SetSelected	Identifies which INtime RT node to select in the browser window when you specify a pointer to a string that contains a node name. This function returns TRUE if the name is valid and selected; otherwise it returns FALSE.

Develop RT source code

To develop the RT portion of an INtime application, use the INtime wizards available in Microsoft Visual Studio. The INtime wizards guide you through the decisions required to develop the RT portion of an INtime application and generate the

corresponding code framework which you fine-tune in the Microsoft Visual Studio's editor.

You can select one of these INtime wizards:

- **RT process wizard**: develops the RT portion of RT applications.
- **RT Process Add-in wizard**: adds supplemental files to the already-generated RT portion of INtime applications. This wizard supports only code written in EC++.
- **RT device driver wizard**: develops RT drivers.

> **Note**
> The RT portion of INtime applications support only source code written in C or EC++. They do not support applications written using MFC.

- **RT RSL Wizard**: generates code for a Realtime Shared Library.

Running the INtime RT process wizard

To create the RT portion of an INtime application:

1. Select what you want to generate:
   - An empty project (the wizard simply sets up the correct compiler and linker settings for you). If you select this option, go to step 4.
   - A simple "Hello World" application (the wizard creates a simple source file and adds it to the project). If you select this option, go to step 4.
   - A full-featured INtime application. If you select this option, continue to the next step.
2. Add elements to your process:
   A. Select one or more elements from the main screen to add to your RT application:
      - Mailbox or semaphore server thread
      - Thread that operates at a regular interval
      - Interrupt handling
      - Shared memory allocation
      - Client thread

> **Note**
> For detailed information about the fields on these screens, see Help. For information about accessing help, see *Where to get more information* on page v.

B. Click the Add element button. That element's detail screen displays.

C. Specify element parameter values.

D. When satisfied with an element's settings, click the OK button. The wizard's main screen displays again.

3. (Optional) Change the global process settings:

A. Select -global- option from the main screen.

Note: You must click in the Name column to access this detail screen.

B. Specify global process values.

C. When satisfied with the global settings, click the OK button. The wizard's main screen displays again.

Note: If you don't access this screen now, the wizard will prompt you to verify global settings before generating the process.

4. Generate the process. The wizard creates a project from the settings you specified.

A. Click the Generate Process button. If you did not access the Global Settings screen, the wizard prompts you to edit or accept the global process settings. The wizard then displays the New Project Information screen and prompts you to verify the process information.

Note: You must click in the Name column to access this detail screen.

B. Click the OK button. The wizard creates a process from the settings you specified. A process includes, at a minimum, these files:

- Main file (which has the project name) with a .C or .CPP extension; for example: TEST.C.
- Project file TEST.DSP and TEST.DSW.
- Project header file with a .H extension.
- Utility function file, UTIL.C.
- A C source file with a .C extension for each thread.
- A text file called README.TXT that describes each generated file.

Running the INtime RT process add-in wizard

To modify an existing RT process:

1. Add elements to your process:

A. Select one or more elements from the main screen to add to your RT application:

- Mailbox or semaphore server thread
- Thread that operates at a regular interval
- Interrupt handling
- Shared memory allocation
- Client thread

Note

For detailed information about the fields on these screens, see Help. For information about accessing help, see *Where to get more information* on page v.

B. Click the Add element button. That element's detail screen displays

C. Specify element parameter values.

D. When satisfied with an element's settings, click the OK button. The wizard's main screen displays again and a message indicates what the wizard added to that process.

E. When satisfied with the global settings, click the OK button. The wizard's main screen displays again.

2. When you are satisfied with your additions, click the Close button to exit the wizard.

Running the INtime RT device driver wizard

To create an RT device driver:

1. Specify parameter values on the screen that displays.
2. When satisfied with an element's settings, click the Next button. The wizard's next screen displays.
3. Repeat steps 1 and 2 for each of these screens:
   - General service information
   - Options for the service
   - Sizes of information for the service
   - Port number ranges for the service

   The last screen is one of these:
   - Implementation details for polling
   - Implementation details for interrupt handling
   - Implementation details for port-based event

- Implementation details for custom event

> **Note**
> The last screen that displays depends on the information you provided on the first screen. For detailed information about the fields on these screens, see Help. For information about accessing help, see *Where to get more information* on page v.

4. Click the Finish button. The wizard prompts you to verify new project information.
5. Click OK. The wizard creates a project from the settings you specified. A project includes these files:

- Main file (which has the project name) with a .C extension; for example: TEST.C.
- Project file TEST.DSP and TEST.DSW.
- Project header file with a .H extension.
- Utility function file, UTIL.C.
- Implementation file, IMPL.C
- A text file called README.TXT that describes each generated file.

Running the INtime RSL wizard

The INtime RSL (Real-time Shared Library) wizard generates the framework for a Real-time Shared Library. The code generated illustrates how to export both function and variable names, and also initializes the project settings to correctly generate an RSL.

The generated files include:

- Main file (which has the project name) with either a .C or a .CPP extension, depending on which option was chosen, for example TEST.C.
- Project files, for example TEST.DSP and TEST.DSW.
- Project header file, for example TEST.H.
- Utility function file, UTIL.C.

The main file contains a function RslMain which you can modify, if required. A default RslMain function is linked if this function is deleted from the source file. For further details about RSLs, see Help.

Compile

Use Microsoft Visual Studio to compile and link the application. The RT portion of INtime applications requires certain project settings. If you use the INtime wizards to develop the RT portion of your application, the wizards will set up your project

properly. Settings vary, depending on whether you configured Microsoft Visual Studio to build a debug or a release version.

To view and verify settings required by INtime software, select Microsoft Visual Studio's Build>Settings menu option.

Note
Only required RT portion settings are listed; checkboxes and radio buttons are disabled (not checked) unless otherwise noted. You can enter the values you want in fields for which no setting is listed.

Visual Studio settings vary, depending on the version you use. Go to the appropriate section to see the settings for your version:

- **Visual Studio 2005 (aka Visual Studio 8)**: continue reading in the next section.
- **Visual Studio .NET (aka Visual Studio 2003 or Visual Studio 7.1)**: go to page 96.
- **Visual Studio 6**: go to page 98.

Visual Studio 2005 (aka Visual Studio 8)

General

Dbg	Rel	Field	Value
X	X	Use of MFC	Use Standard Windows Libraries
X	X	Use of ATL	Not Using ATL
X	X	Minimize CRT Use in ATL	No
X	X	Character Set	Not Set (Unicode not supported)
X	X	Common Language Runtime support	No Common Language Runtime support

Debugging

Dbg	Rel	Field	Value
X	X	Debugger Type	Auto
X		SQL Debugging	No

Custom Build

This tab requires no special settings.

C/C++

Dbg	Rel	Category	Field	Value
X	X	General	Additional Include Directories	Must include %INtime%rt\include
X			Debug Information Format	Program Database (recommended for Debug configuration only)
X	X	Preprocessor	Preprocessor definitions	Add VS7_CPP if using C++
X	X		Ignore Standard Include Files	Yes
X	X	Code Generation	Enable C++ Exceptions	If Yes, select the Exception handling C++ libraries
X	X		Buffer Security Check	No
X	X	Language	Enable Run-Time Type Info	No

Linker

Dbg	Rel	Category	Field	Value
X	X	General	Version	21076.20052
X	X		Enable Incremental Linking	No
X	X		Additional Library Directories	Must include %INtime%rt\lib
X	X	Input	Additional Dependencies	rt.lib and a selection of iwin32.lib, pcibus.lib, etiff3m.lib, ciff3m.lib, rmxiff3m.lib, rtpp*.lib ecpp7*.lib
X	X		Ignore All Default Libraries	Yes
X	X	System	Subsystem:	Console
X	X		Heap Reserve Size	0 (zero) which sets this value to the maximum pool size (in bytes)
X	X		Heap Commit Size	0 (zero) which sets this value to the minimum pool size (in bytes)
X	X		Stack Reserve Size	Virtual segment (size in bytes)
X	X		Stack Commit Size	Stack size for the main thread (in bytes)

In the list of object/library modules, the following choices depend on other settings:

1. For C++ projects that use the INtime RT classes, add rtppd.lib for the debug version and rtpp.lib for the release version.

2. For C++ projects, add ecpp7*X*.lib, where *X* is one of these:

null	No exceptions, no namespaces.
E	Using exceptions, no namespaces.
N	No exceptions, using no namespaces.
EN	Using exceptions and namespaces.

3. The C runtime library is named ciff3m8.lib.

Resources

This tab requires no special settings. Only a version resource makes sense here.

Browse Info

This tab requires no special settings.

Visual Studio .NET (aka Visual Studio 2003 or Visual Studio 7.1)

General

Dbg	Rel	Field	Value
X	X	Microsoft Foundation Classes or Use of MFC	Not using MFC

Debug

This tab requires no special settings.

Custom Build

This tab requires no special settings.

C/C++

Dbg	Rel	Category	Field	Value
X	X	Code Generation	Calling convention	__cdecl *
X		Preprocessor	Preprocessor definitions	_WIN32, _DEBUG _VS7_CPP (for Visual Studio .NET and later)
	X			_WIN32 _VS7_CPP (for Visual Studio .NET and later)
X	X		Additional include directories	$(INtime)\rt\include
X	X		Ignore standard include paths	Enabled (checked)

Link

Dbg	Rel	Category	Field	Value
X	X	General	Output filename	Should have an .RTA or .RSL extension
X	X	Output or General	**Important**: You must add value: /heap:0x100000,0x2000 to set the memory pool for the process	
X	X	General or Input	Ignore all default libraries	Enabled (checked)
X	X	Input or General	Additional library path	$(INtime)rt\lib
X	X	Input	Object/library modules or Additional Dependencies	rtpp[d].lib ecppXY.lib ciff3m[8].lib rt.lib rtserv.lib pcibus.lib netiff3m.lib rmxiff3m.lib
		Output		
X	X	Stack allocations	Reserve Commit	0x100000 0x2000
X	X	Version information	Major Minor	21076 20052

In the list of object/library modules, the following choices depend on other settings:

1. For C++ projects that use the INtime RT classes, add rtppd.lib for the debug version and rtpp.lib for the release version.
2. For C++ projects, add ecpp7*X*.lib, where *X* is one of these:

   null No exceptions, no namespaces.
   E Using exceptions, no namespaces.

N	No exceptions, using no namespaces.
EN	Using exceptions and namespaces.

3. The C runtime library is named ciff3m.lib.

Resources

This tab requires no special settings. Only a version resource makes sense here.

Browse Info

This tab requires no special settings.

Visual Studio 6

General

Dbg	Rel	Field	Value
X	X	Microsoft Foundation Classes or Use of MFC	Not using MFC

Debug

This tab requires no special settings.

Custom Build

This tab requires no special settings.

C/C++

Dbg	Rel	Category	Field	Value
X	X	Code Generation	Calling convention	__cdecl *
X		Preprocessor	Preprocessor definitions	_WIN32, _DEBUG _VS7_CPP (for Visual Studio .NET and later)
	X			_WIN32 _VS7_CPP (for Visual Studio .NET and later)
X	X		Additional include directories	$(INtime)\rt\include
X	X		Ignore standard include paths	Enabled (checked)

Link

Dbg	Rel	Category	Field	Value
X	X	General	Output filename	Should have an .RTA or .RSL extension
X	X	Output or General	**Important**: You must add value: /heap:0x100000,0x2000 to set the memory pool for the process	
X	X	General or Input	Ignore all default libraries	Enabled (checked)
X	X	Input or General	Additional library path	$(INtime)rt\lib
X	X	Input	Object/library modules or Additional Dependencies	rtpp[d].lib ecppXY.lib ciff3m[8].lib rt.lib rtserv.lib pcibus.lib netiff3m.lib rmxiff3m.lib
		Output		
X	X	Stack allocations	Reserve Commit	0x100000 0x2000
X	X	Version information	Major Minor	21076 20052

In the list of object/library modules, the following choices depend on other settings:

1. For C++ projects that use INtime RT classes, add rtppd.lib for the debug version and rtpp.lib for the release version.
2. For C++ projects, add ecpp*X*.lib, where *X* is one of these:

null	No exceptions, no namespaces.
E	Using exceptions, no namespaces.
N	No exceptions, using no namespaces.
EN	Using exceptions and namespaces.

3. The C runtime library is named ciff3m.lib.

Resources

This tab requires no special settings. Only a version resource makes sense here.

Browse Info

This tab requires no special settings.

Debug

You must debug both portions of your INtime application using the appropriate tools:

- **Windows portion**: Use standard Windows development tools, including the Microsoft Visual Studio debugger.
- **RT portion**: Use Visual Studio .Net debugger or Spider plus the other debug tools provided with INtime software

Using the two debuggers, you can simultaneously view and debug on-target application code in both the Windows and the RT environments.

- **Spider (SPIDER.EXE)**: A Windows-based RT debugger that supports on-target debugging of RT threads. The Spider debugger fully comprehends the RT constructs supported by INtime and supports dynamic debugging. Spider can debug multiple RT threads simultaneously while other threads continue to run.
- **System debug monitor (SDM)**: A command-line interface that provides low-level, static debugging capabilities. SDM requires a separate serial debug terminal for its user interface.

Note

For detailed information about using Spider, see Spider's Help. For detailed information about using SDM, select Debuggers>Low-level debugger>System Debug Monitor (SDM) in INtime Help.

- **Fault Manager:** This application pops up a dialog when a hardware fault is detected on the INtime kernel. The user may then choose one from a list of actions to handle the fault condition.
- **INtime Explorer (Intex)**: A Windows-based RT object browser. The INtex program, through its self-loaded RT counterpart, is able to show the state of all RT processes,

threads, and objects. It can also display the code (via Microsoft Visual Studio) of a process that has been suspended due to a hardware fault (crash analysis).

- **INscope**: The INScope Real-time Performance Analyzer is a Windows application that allows you to trace execution of INtime applications. Trace information for thread switches, system calls, and interrupt handling is displayed in a graphical user interface with various tools available to allow system analysis.

Debugging tips

Performance monitor

To view CPU usage in both the Windows and RT kernels, you can run the Windows Performance monitor. Viewing CPU activity provides the feedback you need to determine if you divided labor appropriately between Windows processes and RT processes. For more information about designing your INtime applications, see *Chapter Chapter 5, "Designing RT applications"*.

To view Windows and RT kernel activity in the Windows Performance Monitor:

1. Open the Performance Monitor by selecting this option from the Start menu:

   Control Panel>Administrative Tools>Performance>System Monitor

2. Open a chart by selecting the File menu's New Chart option.
3. Identify the performance metrics you want to view by choosing the Edit menu's Add to Chart option, then select these options:

Object	Counter	Purpose
Processor	% Processor time	Displays the percent of time devoted to Windows work.
INtime RT kernel	RT Kernel CPU usage (%)	Displays the percent of time devoted to RT work.

You can now run your INtime application and observe the CPU usage of both the Windows and RT kernels. When viewing the CPU usage, keep in mind that the Performance Monitor displays total CPU usage which includes more than the activity generated by an INtime application.

Status messages

When the RT kernel is running, a protection fault which occurs in the RT portion of an INtime application is handled by the default system hardware exception handler which suspends the faulting thread. Such threads display in the INtime Explorer with a Thread State of 2 and a Delay Request of 0xffff. For threads in this state, the CPU frame displays the thread's CPU context when the hardware fault occurred, including the CS:EIP address of the faulting instruction.

The error code indicates the fault encountered as follows:

Fault	Code	Description
EH_ZERO_DIVIDE	0x8100	Divide by Zero error
EH_SINGLE_STEP	0x8101	Single Step
EH_NMI	0x8102	NMI
EH_DEBUG_TRAP	0x8103	Debug Interrupt (Ignored by handler)
EH_OVERFLOW	0x8104	Overflow error
EH_ARRAY_BOUNDS	0x8105	Array Bounds error
EH_INVALID_OPCODE	0x8106	Invalid Opcode error
EH_DEVICE_NOT_PRESENT	0x8107	NPX device not present
EH_DOUBLE_FAULT	0x8108	Double Fault error
EH_DEVICE_ERROR	0x8109	NPX device error
EH_INVALID_TSS	0x810A	Invalid TSS error
EH_SEGMENT_NOT_PRESENT	0x810B	Segment Not Present error
EH_STACK_FAULT	0x810C	Stack Fault
EH_GENERAL_PROTECTION	0x810D	General Protection Fault
EH_PAGE_FAULT	0x810E	Page Fault

If a debugger is running when the protection fault occurs, the debugger traps the fault and allows you to debug or delete the offending program.

Prepare for release

Before you begin

- On the target system, ensure that you are logged on with Administrator privileges.
- Exit all programs prior to installing INtime software.
- If your system has a previously installed version of INtime software, remove it using the Add/Remove Programs Applet in the System Control Panel (select: Start>Control Panel>Add/Remove Programs. Highlight INtime 2.14 (or earlier) program, and then click Remove). Make sure none of the INtime services are running. If they are running, you must make sure they are set to Manual Start (using the Start>Control Panel>Administrative User/Services applet) and reboot the system before you can successfully complete the uninstall operation.

Using Runtime300.msi

To install INtime runtime software:

1. Start the runtime300.msi program:

A. Select the Start>Settings>Control Panel>Add/Remove Programs Applet.

B. Select runtime300.msi. You can use the Browse feature to quickly find the runtime300.msi program that originally came on the INtime 3.0 CD-ROM.

   If the Installation program detects a previous version of INtime software, it prompts you to exit the installation and uninstall the previous version.

   If your system does not have the Microsoft Installer product, the Installation program prompts you to install it. After installation, you may need to reboot.

   The Installation program automatically resumes.

2. Review the INtime License and note its terms and conditions.
3. Select a destination directory for the INtime software files, then click the Next button. The default is c:\Program Files\INtime.
4. Click the Next button to install the software.

   The runtime300.msi program creates the directory you specified, then installs the INtime software files.
5. Click the Finish button to complete the installation process.
6. Restart your system using one of these methods:
   - Select OK at the last screen. Runtime restarts your system.
   - Restart your system at a later time. You must restart your system before running INtime software.

Note

The runtime300.msi executable installs those portions of INtime software that you can include in your derivative works. Use of runtime300.msi is governed by the INtime Software Redistribution License Agreement you must enter into in order to include INtime Software in your product. For information about obtaining a Software Redistribution License and on the associated per unit royalty due to TenAsys Corporation for use of the INtime software in your product, contact support@tenasys.com.

Sample INtime applications

INtime software has a number of sample applications that you can use as samples for your own INtime applications.

The source code for these applications are provided in both Visual Studio 6.0 and VS .Net 2003 project formats, and reside in separate directories per demo. For instance, the INtime API test program source files reside in the My Documents\INtime\Projects\rttest directory.

You can open the projects for these applications from the Start>All Programs>INtime>Sample Code and Projects menu.

EventMsg DLL Project

This DLL allows you to customize event messages.

Item	Source
Pathname	My Documents\INtime\Projects\eventmsg
Runtime requirements	The EventMsg Project builds the EventMsg.DLL file properly only if you first build the project under release mode from within the Microsoft Visual Studio. After building the project under release mode, you may then build the project under debug mode.

INtime API Sample

This test application exercises most INtime software system calls.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\rttest	My Documents\INtime\Projects\ rttest\debug

INtime Serial Driver Sample

This sample application consists of a working INtime serial driver plus an INtime application that utilizes the driver to communicate with a serial terminal connected to the specified COMn channel. The driver provides an RT application with high-speed serial I/O communications capabilities.

The driver (c:\Program Files\INtime\Projects\serialio\debug\serdrvr.rta) operates as an INtime service that manages a serial device attached to COM1 or COM2 on an INtime system. The demo (c:\Program Files\INtime\Projects\ serialio\debug\serialio.rta) uses an INtime Message Port to obtain read/write access to the COMn channel managed by the Serdrvr.rta service. Both components are provided in source and binary form. For more information, see the README.TXT file in the source code directory for this sample application.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\serialio	My Documents\INtime\Projects\ serialio\debug

INtime Graphical Jitter

This application measures the minimum, maximum, and average times between low-level ticks via an Alarm Event Handler. Because this application is made from both an RT and Windows executables, it shows both INtime and NTX API usage.

INtime Graphical Jitter includes these executables:

- **Jitter.exe**: The Windows executable. Automatically starts ClkJitr0Rt.rta, then processes output and displays a histogram.
- **ClkJitr0Rt.rta**: The RT executable. Started by Jitter.exe.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\jitternt My Documents\INtime\ Projects\jitterrt	My Documents\INtime\Projects\jitternt\ debug My Documents\INtime\Projects\jitterrt\ debug
Invocation	Invoke the Windows jitter.exe program.	

Real-time Interrupt Sample

This application tests the INtime RT Interrupt system calls using the Transmitter Ready interrupt from COM1.

The INtime RT Interrupt API Test takes over COM1 and toggles its Transmitter Ready Interrupt. When the test ends, COM1 is disabled. Make sure COM1 is available on your system before running this test application. When you run the test, continuous activity occurs on the RT side, preempting Windows activity for eight 10-second time periods.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\inttest	My Documents\INtime\Projects\ inttest\debug

C and C++ Samples for Debugger

These simple C and C++ programs are provided as a vehicle to demonstrate the Spider debugger's capabilities. The C++ program also demonstrates several components of the C++ language available to RT applications, as well as basic classes, dynamic instantiation, operator overloading, and so on. It also shows the libraries and startup modules needed.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\csamp (C program) My Documents\INtime\ Projects\cppsamp (C++ program)	My Documents\INtime\Projects\ csamp\debug My Documents\INtime\Projectss\ cppsamp\debug
Invocation	Use Spider to load these programs.	

TCPIP>TCP-IP Server Sample

Sample TCP/IP application that waits for 130Kbyte messages and returns them to the sender.

Item	Source	Executable
Pathname	My Documents\INtime\ Projects\tcpserv	My Documents\INtime\Projects\ tcpserv\debug
Invocation	See the ReadMe.txt file in the source code directory.	

TCPIP>TCIP-IP Client Sample

Sample TCP/IP application that looks for a TCP/IP server and then sends 130KByte messages to it and waits for the reply.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ tcpcInt	My Documents\INtime\Projects\ tcpInt\debug
Invocation	See the ReadMe.txt file in the source code directory.	

Fault Handling (ntrobust)

This INtime application has both a Windows and a RT portion. The Windows portion allows the user to set up timing parameters that control how often a thread in the RT portion causes a hardware fault. The application demonstrates how another RT thread can detect and log the failure, delete the offending thread, and recreate it, all without affecting Windows or other RT processes.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ NtRobust My Documents\INtime\Projects\ NtRobust\RtRobust\	My Documents\INtime\Projects\ NtRobust\Debug My Documents\INtime\Projectss\ NtRobust\RtRobust\Debug
Invocation	See the ReadMe.txt file in the source code directory.	

Floating Point Exception Handling

This simple program demonstrates floating point exception handling.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ FpExcep	My Documents\INtime\Projects\ FpExcep\Debug
Invocation	See the ReadMe.txt file in the source code directory.	

RSL Example

This RT program demonstrates the creation and use of RT Shared Libraries, the RT analog for Windows DLLs.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ RslTest	My Documents\INtime\Projects\ RslTest\Debug
Invocation	See the ReadMe.txt file in the source code directory.	

NTX Sample (MsgBoxDemo)

This INtime application has both a Windows and a RT portion. The Windows portion looks up an RT mailbox created by the RT portion, and then waits at the mailbox. When an RT thread sends a message to the mailbox, the Windows portion displays the received data in a message box on the Windows side. RT semaphore and RT shared memory usage are also demonstrated.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ MsgBoxDemo My Documents\INtime\Projects\ MsgBoxDemo\RtMsgBox	My Documents\INtime\Projects\ MsgBoxDemo\Debug My Documents\INtime\Projects\ MsgBoxDemo\RtMsgBox\Debug
Invocation	See the ReadMe.txt file in the source code directory.	

INtime Windows STOP Detection sample (STOPmgr)

This sample application shows how an INtime application can detect either a Windows Crash (blue screen) or Windows Shutdown event and prevent Windows from completing its normal actions until the RT application has had a chance to do a "graceful" shutdown.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ stopmgr	My Documents\INtime\Projects\ stopmgr\debug

INtime USB Client sample

This sample application demonstrates how to use the INtime USB subsystem. It monitors a USB keyboard and prints a dump of each keystroke as it occurs.

Item	Source	Executable
Pathname	My Documents\INtime\Projects\ usbsamp	My Documents\INtime\Projects\ usbsamp\debug

III Appendices

The appendices include:

Appendix A: INtime software system calls

Lists and describes system calls that threads in the RT portion of INtime applications use to communicate with each other and with Windows threads. You can find detailed information, including syntax and parameter values, in Help.

Appendix C: INtime software components

Lists and describes INtime software program files.

Appendix E: Adding INtime software to an XP Embedded configuration

Lists and describes how to add INtime components to a Windows XP embedded development environment so that XP Embedded images can be produced that include these INtime components.

Appendix F: Troubleshooting

Lists problems you may encounter while running INtime software, and explains how to avoid or resolve those problems.

A INtime software system calls

This appendix lists and describes INtime software system calls. Use this appendix to identify the system calls you want to use for each RT kernel exchange object. The calls are arranged first by system call types, and then by objects available to that object type: NTX, high-, or low-level. Other calls are listed at the end of the appendix.

Note

For detailed information about system calls, including syntax and parameter values, refer to Help. For more information about accessing Help, see *Where to get more information* on page page v

System call types

Several types of calls exist, and each kernel exchange object has calls of one or more type associated with it:

- **Windows eXtension (NTX) calls**: Windows uses these calls to communicate with the INtime kernel. NTX calls allow Windows applications to operate on objects created by, stored in, and controlled by the RT kernel.
- **Real-time (RT) calls**: The RT kernel uses these calls to run the RT portion of INtime applications and communicate with Windows. INtime software provides two levels of system calls for RT kernel exchange objects:
  - **High-level (validating) calls**: Write, test, and debug your application using high-level calls with their protection and validation features.
  - **Low-level (non-validating) calls**: When the application runs as you desire, increase performance by substituting low-level system calls where appropriate.
- **RT services**: INtime real-time applications (RTAs) which process messages from a user and events from an interface, and the service handlers required to perform service-dependent functions of the system calls.

RT kernel objects provide these RT call levels:

Object	NTX	High-level	Low-level
Distributed system manager	X	X	
Exception handling		X	
Interrupts		X	
Mailboxes	X	X	X
Memory	X	X	
Object directories	X	X	
Ports	X	X	
Processes	X	X	
Regions		X	
Scheduler			X
Semaphores	X	X	X
Status	X	X	
System accounting		X	
Threads		X	
Time management			X

Regarding INtime software system calls:

- System call names correspond to related Windows functions, where appropriate. Where it is confusing to associate the function of an INtime software object with a Windows object, the names reflect the difference.

For example, no Windows object corresponds closely to an INtime software region, so these are left as regions. On the other hand, INtime software alarms are encapsulated as an object which somewhat correspond to a specialized Windows event object, so this is called AlarmEvent. It does not, however, perform all the same functions as a Windows event.

- To avoid confusion with similarly-named Windows calls, INtime software system call names usually include the letters 'Rt'.
- RT kernel objects and the kernel interface which differ substantially from corresponding items in the other INtime software layers, include a 'kn' prefix to indicate calls that map to low-level RT kernel functions and deal with low-level kernel objects.

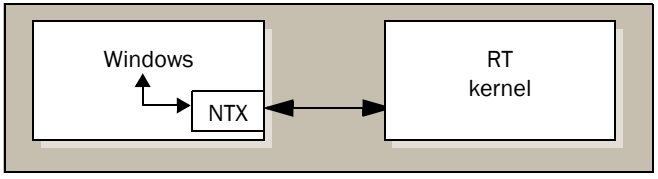
NTX calls

NTX calls allow Windows applications to operate on objects created by, stored in, and controlled by the RT kernel. This allows Windows and INtime applications to communicate and coordinate their activities.

Handle conversion

The NTX DLL converts in transit NTXHANDLES sent to the RT kernel to RTHANDLES, and vice-versa. This is necessary as the RT kernel cannot operate on NTXHANDLES and NTX can't operate on RTHANDLES.

Figure A-1. Converting NTXHANDLES to RTHANDLES



If a handle passes from RT to Windows in data, ntxImportRtHandle must convert it. Object directories and object mailboxes are converted automatically.

RT calls

You use these calls when developing the real-time portion of an INtime application.

High-level (validating) calls

High-level calls provide lower performance, plus higher protection and validation features. Memory is allocated automatically from the process's pool. Each high level object consumes a slot from the system GDT (8000 objects maximum)

High-level system calls validate a call's parameters; a condition code returned by the call indicates whether you used invalid parameters. Condition codes for trying to read or write memory to which you have no access also exist.

High-level exchange objects validate parameters and are protected against unexpected deletion. High-level calls exist for these exchange objects:

- Object and data mailboxes
- Counting semaphores
- Regions (for mutual exclusion with priority inversion protection)

Low-level (non-validating) calls

Low-level calls provide higher performance, but lower protection and validation features. Low-level objects provide functionality beyond that of high-level objects.

You must allocate memory for low-level objects and may allocate memory beyond low-level object needs. You can use this additional memory to store application-specific state information associated with the object.

Low-level objects are not protected against unexpected deletion and do not validate parameters (if you need parameter validation, use high-level system calls). Low-level calls use the flat, 4 Gbyte addressing capabilities of the microprocessor. They do not use segmentation. Therefore, they do not consume a slot from the system GDT.

Use low-level objects in these situations:

- For well-tested code.
- For isolated parts of the application, such as signaling ordinary threads from an interrupt handler.
- When performance is critical, such as high-performance, unvalidated sending and receiving of data mailbox messages and semaphore units.

Note

System calls that manipulate low-level objects assume that all memory reference pointers received are valid.

Low-level calls exist for these exchange objects:

- Data mailboxes
- Single-unit semaphores
- Region semaphores (with priority inversion protection)
- Software alarm events (virtual timers) that invoke alarm event threads that you write.

RT services

Real-time services include:

- **RT service calls**: An INtime real-time application (RTA) which processes messages from a user and events from an interface. A service is defined by the set of messages and the actions provoked by those messages. Each interface is associated with a service descriptor.
- **RT service handlers**: Subroutines invoked by the kernel to perform service-dependent functions of the system calls.

RT system calls

Exception handling

High-level calls

System call	Description
SetRtExceptionHandler	Assigns an exception handler and exception mode or changes the current mode for any of the following: • Current thread exception handler • Current process exception handler • System-wide exception handler
GetRtExceptionHandlerInfo	The GetRtExceptionHandlerInfo function returns the address and exception-handling mode for any of the following: • Current thread's exception handler • Current process' exception handler • System-wide exception handler • System-wide hardware exception handler (trap handler)

Interrupts

This group provides the system calls required to manage interrupts. Interrupt requests are encoded to indicate their source; the resulting coding is called the interrupt level. This encoded interrupt level is required in a number of the system calls in this group. Macros are provided in the header files for the 15 standard PC interrupt levels, IRQ0_LEVEL to IRQ15_LEVEL.

High-level calls

System call	Description
SetRtInterruptHandler SetRtInterruptHandlerEx	Assigns an interrupt handler to the specified interrupt level, and optionally makes the calling thread the interrupt thread for that level.
ResetRtInterruptHandler	Cancels the assignment of the current interrupt handler to the specified level and disables the level.
EnterRtInterrupt	Allows the interrupt handler to have access to static data belonging to the RT process which owns the handler. This function is called from an interrupt handler.
GetRtInterruptLevel	Returns to the calling thread the highest (numerically lowest) level that an interrupt handler has started servicing but has not yet finished.
SignalRtInterruptThread	Sends an EOI signal to the interrupt hardware then schedules the interrupt thread associated with the specified level. This function is called from an interrupt handler.
SignalEndOfRtInterrupt	Sends an EOI signal to the interrupt hardware. This function is called from an interrupt handler.
WaitForRtInterrupt	Used by an interrupt thread to signal its readiness to service an interrupt. It blocks for the given number of milliseconds.
DisableRtInterrupt	Disables the specified interrupt level. It has no effect on other levels.
EnableRtInterrupt	Enables a specific interrupt level which must have an interrupt handler assigned to it.

Mailboxes

These calls manage various RT kernel mailbox object types.

INtime software includes two kinds of RT mailboxes:

- Object mailboxes manage RTHANDLES.
- Data mailboxes manage short sections of arbitrary data.

NTX calls

System call	Description
ntxCreateRtMailbox	Creates an RT mailbox.
ntxDeleteRtMailbox	Deletes an RT mailbox.
ntxReceiveRtHandle	Receives RTHANDLES from an object mailbox.
ntxSendRtHandle	Sends RTHANDLES to an object mailbox.
ntxSendRtData	Copies arbitrary data to a data mailbox (up to 128 bytes).
ntxReceiveRtData	Copies arbitrary data out of a data mailbox (up to 128 bytes).

High-level calls

System call	Description
CreateRtMailbox	Creates a new mailbox and returns an RTHANDLE for the object. The mailbox type is determined by the flags parameter.
DeleteRtMailbox	Deletes the mailbox specified by the RTHANDLE given.
SendRtHandle	Sends an RT object RTHANDLE to a mailbox which has been created to pass RT objects.
ReceiveRtHandle	Receives an RTHANDLE from an object mailbox.
SendRtData	Copies arbitrary data to a data mailbox (up to 128 bytes).
ReceiveRtData	Copies arbitrary data out of a data mailbox (up to 128 bytes).

Low-level calls

System call	Description
knCreateRtMailbox	Creates a kernel mailbox with the given specifications.
knDeleteRtMailbox	Deletes the kernel mailbox associated with the given kernel handle.
knSendRtData	Sends a data message to the given kernel mailbox.
knSendRtPriorityData	Sends high-priority data to a kernel mailbox, bypassing the queue.
knWaitForRtData	Requests a message from a specific kernel mailbox.

Memory

The Windows and RT portions of INtime applications can share regions of memory created by the RT portion of INtime applications.

These system calls implement the flat-model memory management interface for RT applications. There are additional calls for the management of page-aligned segments for sharing between applications (both RT and Windows applications). Also included are the calls that an application requires to allocate memory from its own virtual segment.

Physical memory may be allocated and mapped into an application's virtual segment and then an RTHANDLE created for this allocated memory so that it may be shared between applications (both RT and Windows applications)

NTX calls

System call	Description
ntxMapRtSharedMemory ntxMapRtSharedMemoryEx	Obtains a Windows pointer to the section of RT memory defined by the call's SharedRTMemoryHandle parameter.
ntxGetRtSize	Determines the size of the call's RT object parameter
ntxUnmapRtSharedMemory	Removes the mapping of a RT memory section and returns Windows system resources mapped to that memory.
ntxCopyRtData	Copies data directly to/from Windows application space from/to an RT memory object.

High-level calls

System call	Description
AllocateRtMemory	Allocates memory from the current process's memory pool to the current thread's virtual segment.
FreeRtMemory	Frees physical memory associated with the calling thread's virtual segment.
CreateRtMemoryHandle	Creates a handle for an area of memory in the process's virtual segment.
DeleteRtMemoryHandle	Deletes a memory handle created with CreateRtMemoryHandle.
MapRtSharedMemory	Maps a memory area, previously created by another process using CreateRtMemoryHandle, into the current thread's memory space.
MapRtPhysicalMemory	Maps a physical memory area, defined by its absolute address and contiguous length before any translation imposed by the paging system, into the current process' virtual segment.
GetRtPhysicalAddress	Returns the physical address for a valid buffer described by the call parameters.
GetRtSize	Returns the number of bytes in a previously allocated segment.
CreateRtHeap	Creates a heap object by allocating a segment of *cbHeapSize* bytes (plus overhead) and creating the heap structure in this segment.
DeleteRtHeap	Deletes a heap object, given its handle. Any flat-model mappings are deleted.
RequestRtBuffer	Allocates a memory buffer from a heap object and returns a pointer to the caller.
ReleaseRtBuffer	Returns a previously-allocated buffer to its heap.

System call	Description
GetRtHeapInfo	Returns a structure containing information about a heap object.
GetRtBufferSize	Returns the allocated size of a buffer previously allocated from a heap.
CopyRtData	Copies data directly between RT memory objects.

Object directories

The object directory provides a rendezvous mechanism between RT threads or between an RT thread and a Windows thread in an INtime application. The RT portion of an INtime application creates shared objects and catalogs those it wants to share. The Windows portion of the application awaits their cataloging.

These system calls manage RT object directories. Objects may be cataloged, looked up, and uncataloged. The default directory is the one for the current process. Handles for the other processes may be obtained using the GetRtThreadHandles call. Catalog names may be up to 14 characters long and are case-sensitive.

NTX calls

System call	Description
ntxLookupNtxhandle	Looks up a name-to-handle association. Given a name, an RT or Windows application can look up the handle associated with it.
ntxImportRthandle	Obtains an NTXHANDLE corresponding to an RTHANDLE.
ntxCatalogRtHandle	Creates a name-to-handle association in the object directory of the RT process specified in the call.
ntxUncatalogRtHandle	Removes the name-to-handle association in the object directory of the RT process specified in the call.
ntxGetRootRtProcess	Obtains the root RT process handle for the NTX location specified in the call.
ntxGetType	Checks the RT object's type.

High-level calls

System call	Description
CatalogRtHandle	Creates a name-to-handle association in the object directory of the RT process specified in the call.
LookupRtHandle	Searches the given process' object directory for a given name and returns the object handle, if found.
UncatalogRtHandle	Removes an entry from a process' object directory.
InspectRtProcessDirectory	Returns the contents of a process' object directory.
GetRtHandleType GetRtHandleTypeEx	Returns a value indicating the type of an RT object. The handle must be for a valid RT object.

Ports

NTX calls

System call	Description
ntxBindRtPort	Binds an address to a port.
ntxCreateRtPort	Creates a port for access to an RT service module.
ntxDeleteRtPort	Destroys an RT port created by a Windows process.
ntxConnectRtPort	Creates a connection between one local port identified by a handle, and another port identified by an address.
ntxAttachRtPort	Forwards messages from one port to another on the same service.
ntxDetachRtPort	Stops forwarding messages from the specified port.
ntxGetRtPortAttributes	Obtains information about the specified port.
ntxSendRtMessage	Sends a message from a port to a service.
ntxSendRtMessageRSVP	Sends the request part of an RSVP transaction.

System call	Description
ntxCancelRtTransaction	Cancels an RSVP message transmission in progress, or the status reporting phase of an asynchronous send operation.
ntxReceiveRtMessage	Receives a message at a port.
ntxReceiveRtReply	Receives the reply phase of an RSVP transaction.
ntxGetRtServiceAttributes	Allows the caller to receive parameters from the service.
ntxSetRtServiceAttributes	Allows the caller to specify run-time parameters for the service.
ntxRequestRtBuffer	Allocates a memory buffer from the heap object associated with a port connected to a service, and returns a pointer to the Windows mapping of the buffer.
ntxReleaseRtBuffer	Returns memory to the heap object from which it was taken.

Service support

System call	Description
InstallRtServiceDescriptor	Adds a service to the operating system by linking the service descriptor to the service descriptor list.
UninstallRtServiceDescriptor	Removes a service from the operating system by unlinking the service descriptor from the service descriptor list.
GetRtServiceAttributes	Interrogates certain attributes of the interface controlled by the service.
SetRtServiceAttributes	Sets or changes some attributes of the interface controlled by the service.

Port object management

System call	Description
AttachRtHeap	Makes a heap's memory resources available to one or more message port objects.
AttachRtPort	Enables an application to monitor several ports simultaneously.
BindRtPort	Binds an address to a port.
ConnectRtPort	Creates a connection between a local port and a remote port.
CreateRtPort CreateRtPortEx	Creates a message port for access to a given service.
DeleteRtPort	Deletes a port object. Any messages queued at the port are discarded and, if the port is forwarded, forwarding is severed.
DetachRtHeap	Ends the association between a heap object and a message port.
DetachRtPort	Ends message forwarding from the specified message port.
GetRtPortAttributes	Returns a structure giving information about the port object indicated by the supplied handle.

Message transmission

System call	Description
SendRtMessage	Sends a data message from a port to a service.
SendRtMessageRSVP	Sends the request phase of a transaction and allocates a storage for the response part of the transaction.
SendRtReply	Sends a response message to an earlier receive SendRtMessageRSVP message.
CancelRtTransaction	Performs synchronous cancellation of RSVP message transmission.

System call	Description
ReceiveRtMessage	Receives a message at a port.
ReceiveRtReply	Receives a reply message to an earlier RSVP transmission. The port cannot be a sink port.
ReceiveRtFragment	Receives a fragment of an RSVP data message request.

Processes

NTX calls

System call	Description
ntxCreateRtProcess	Creates a process.
ntxRegisterDependency	Creates a dependency relationship between the calling process and the specified sponsor.
ntxUnregisterDependency	Removes the dependency relationship between the calling process and the specified sponsor.
ntxRegisterSponsor	Registers the calling process as a Sponsor with the given name.
ntxUnregisterSponsor	Removes the current sponsor name from the active sponsor state.
ntxNotifyEvent	Blocks until one of the desired notifications has been received.

High-level calls

System call	Description
ExitRtProcess	Deletes the current process, all of the process' threads, and all objects created by the threads.
RegisterRtDependency	Looks up the name in the sponsor list and creates a dependency relationship to that sponsor process.
UnregisterRtDependency	Removes the dependency relationship from the database between the RT process and the Windows sponsor registered with the given name.
RegisterRtSponsor	Allows the RT process to register as a sponsor under the given name.
UnregisterRtSponsor	Removes the RT process registered as a sponsor from the database

Regions

High-level calls

System call	Description
CreateRtRegion	Creates a region object.
DeleteRtRegion	Deletes a region object.
AcceptRtControl	Receives ownership of a region object only if it is immediately available.
WaitForRtControl	Gains ownership of a region. This function blocks until the current owner gives up the region.
ReleaseRtControl	Releases this thread’s most recently obtained region object.

Scheduler

Low-level calls

System call	Description
knRtSleep	Puts the calling thread to sleep for the specified number of kernel ticks.
knStartRtScheduler	Cancels one scheduling lock imposed by the knStopRtScheduler function.
knStopRtScheduler	Temporarily locks the scheduling mechanism or places an additional lock on the mechanism for the running thread.

Semaphores

Semaphores contain units. These system calls deal with semaphore objects and the units associated with them.

RT semaphores differ from Windows semaphore objects in these respects:

- Choice of FIFO or priority queuing.
- A thread may wait for multiple units from a semaphore.
- Waiting times are defined as “wait for the specified number of clock ticks” rather than “wait for at least the specified number of milliseconds”.
- Multiple-object waiting is not supported. High-level semaphores differ from the low-level semaphores in the following respects:
    - High-level semaphores have parameter validation..
    - Multiple units may be sent to and received from high-level semaphores.
    - High-level semaphore may be created with any initial count other than one or zero (low-level semaphores may be created only with zero or one unit).
    - Low-level handles may not be cataloged.

NTX calls

System call	Description
ntxCreateRtSemaphore	Creates an RT semaphore.
ntxDeleteRtSemaphore	Deletes an RT semaphore.
ntxWaitForRtSemaphore	Waits for and removes units from an RT semaphore.
ntxReleaseRtSemaphore	Adds units to an RT semaphore.

High-level calls

System call	Description
CreateRtSemaphore	Creates a semaphore with the given initial and maximum number of units.
DeleteRtSemaphore	Deletes a semaphore.
WaitForRtSemaphore	Waits for and removes a specified number of units from a semaphore.
ReleaseRtSemaphore	Sends a given number of units to a semaphore.

Low-level calls

System call	Description
knCreateRtSemaphore	Creates 1 of 3 kinds of kernel semaphores with 0 or 1 initial units.
knDeleteRtSemaphore	Deletes a kernel semaphore.
knWaitForRtSemaphore	Waits for and removes a unit from the specified kernel semaphore.
knReleaseRtSemaphore	Sends a single unit to a specified kernel semaphore.

Status

NTX calls

System call	Description
ntxGetLastRtError	Returns the status code of the last failing NTX call made in this Windows thread.
ntxGetRtErrorName	Returns a pointer to a constant string.
ntxLoadRtErrorString	Copies a short sentence (no punctuation) that describes "Status" into the buffer at *lpBuffer*.
ntxGetRtStatus	Verifies whether the RT kernel is currently running.

High-level calls

System call	Description
GetLastRtError	Returns the status code of the last failing RT system call made by this RT thread.
SetLastRtError	Sets the calling thread's last error field.
CopyRtSystemInfo	Copies the contents of the RQSYSINFO segment, cataloged in the root process, into the SYSINFO structure
ReportRtEvent	Collects log data in the same format as the Windows ReportEvent function, and passes it to the INtime Registry Service for logging in the Windows Registry.

System accounting

High-level calls

System call	Description
GetRtThreadAccounting	Returns information about when a thread was created and the amount of time the thread has run.
SetRtSystemAccountingMode	Toggles accounting tracking. You can return accounting information using GetRtThreadAccounting.

System data

NTX calls

System call	Description
ntxGetLocationByName	Gets a handle to a specified location.
ntxGetFirstLocation	Returns a handle to the first known location.
ntxGetNextLocation	Gets the handle that follows the one return by the last location call.
ntxGetNameOfLocation	Gets the name NTX uses for a handle.
NtxFindINtimeNode	Invokes the INtime RT Client Browser to allow target INtime node selection.

TCP/IP calls

System call	Description
accept	Accepts a connection on a socket.
bind	Assigns a name to an unnamed socket.
bstring	Executes binary string operations.

System call	Description
byteorder	Converts short and long quantities between network byte order and host byte order.
connect	Initiates a connection on a socket.
gethostname	Gets and sets the local host name.
getpeername	Returns the socket name of the connected remote socket.
getsockname	Returns the current name for the specified socket.
getsockopt	Returns or sets options associated with a socket.
inet	Manipulates Internet addresses.
listen	Listens for connection requests on a socket.
recv	Receives a message from a socket.
select	Checks the sockets specified in the sets of descriptors supplied as parameters to see if any of the sockets are ready for receiving or sending, or have out-of-band data pending.
send	Sends a message from one socket to another.
shutdown	Shuts down all or part of a full-duplex connection.
socket	Creates an endpoint for communication.
socktout	Defines a maximum time to wait for completion of any subsequent calls on the specified socket.

Threads

High-level calls

System call	Description
CreateRtThread	Creates a thread to execute within the context of the calling process.
DeleteRtThread	Deletes a thread referenced by the given handle.
GetRtThreadPriority	Returns the specified thread's current priority.
GetRtThreadHandles	Returns a handle for either the calling thread, the calling thread's process, the parameter object of the calling thread's process, the root process, or the parent process of the calling thread's process, depending on the encoded request.
SetRtThreadPriority	Dynamically changes the priority of a non-interrupt thread. The new value must not exceed the containing process' maximum priority.
SetRtProcessMaxPriority	Dynamically change the maximum priority of threads in a process.
RtSleep	Places the current thread in the sleep state until the required number of system ticks have occurred. System ticks are always 10ms apart.
GetRtThreadAccounting	Returns information about when a thread was created and the amount of time the thread has run.
SuspendRtThread	Increases by one the suspension depth of a specified thread.
ResumeRtThread	Decreases by one the suspension depth of the specified non-interrupt thread.
GetRtThreadInfo	Returns information about a thread, including such items as priority, exception handler, containing process, and execution state.
GetRtThreadState	Returns information about the state of any thread in the system, including such items as the execution state and the CPU registers for that thread's execution context (if the thread has been suspended due to its causing a hardware fault).

Time management

INtime software provides low-level time management calls that allow threads to create alarm events and to sleep for a specified amount of time. The kernel also provides a RT clock.

An alarm event is an object which is signaled when a pre-determined time interval has expired. The alarm event mode may be single-shot or repeatable.

The kernel's RT clock is a counter that the kernel uses to keep track of the number of kernel clock ticks that have occurred. When the kernel is initialized, the count is set to

0 (zero). The period of a kernel clock tick is configurable via the INtime Configuration utility and you can read the current configuration using CopyRtSystemInfo.

Low-level calls

System call	Description
knCreateRtAlarmEvent	Creates an alarm event object which is triggered by an alarm.
knWaitForRtAlarmEvent	Waits at an alarm object for the given time interval, or until the alarm triggers.
knResetRtAlarmEvent	Resets a one-shot alarm after it has triggered.
knDeleteRtAlarmEvent	Deletes an alarm event object and releases the memory used to store its state for reuse.
knGetKernelTime	Returns the value of the counter the kernel uses to tally the number of low-level ticks that have occurred.
knSetKernelTime	Sets the value of the counter that the kernel uses to tally the number of low-level ticks that have occurred.

RT services

Registry calls

System call	Description
RtRegCloseKey	Releases a handle to a key.
RtRegConnectRegistry	Establishes a connection to a registry handle on another computer.
RtRegCreateKeyEx	Creates a key.
RtRegDeleteKey	Deletes a subkey from the registry.
RtRegDeleteValue	Deletes a value from a registry key.
RtRegEnumKeyEx	Enumerates subkeys of an open registry key.
RtRegEnumValue	Enumerates a value for an open registry key.
RtRegFlushKey	Writes attributes of an open key into the registry.
RtRegLoadKey	Creates a subkey and stores registration information into that subkey.
RtRegOpenKeyEx	Opens a key.
RtRegQueryInfoKey	Retrieves information about a registry key.
RtRegQueryValueEx	Retrieves type and data for a value name associated with an open registry key.
RtRegReplaceKey	Replaces the file backing a key and all its subkeys with another file.
RtRegRestoreKey	Reads registry information in a file and copy it over a key.
RtRegSaveKey	Saves a key and all its subkeys and values to a new file.
RtRegSetValueEx	Sets the data and type of a value under a registry key.
RtRegUnLoadKey	Unloads a key and subkeys from the registry.

RT service calls

System call	Description
RequestControlBuffer	Requests a control buffer from the service pool.
ReleaseControlBuffer	Returns a control buffer to the service pool.
RequestTransaction	Requests a TRANSACTION buffer from the service transaction pool.
ReleaseTransaction	Returns a transaction structure to the pool.
LookupPortHandle	Looks up a port handle given a port ID.
GetTransaction	Upon receiving a response message from the interface, instructs the service thread to tie the message with its transaction structure.
DeliverMessage	Delivers a complete transactionless message to a port. This call is typically made from the service thread.
DeliverTransaction	Delivers a transaction. This call is used after a service thread receives a response message, and the transaction is complete.
DeliverStatus	Terminates a transmit operation, usually from the service thread.
EnqueueOutPutTransaction	Enqueues a transaction on the service output queue when (for example) the transmitter hardware is busy.
QueryOutputTransactionQueue	Returns the transaction at the head of the service output queue.
DequeueOutputTransaction	Dequeues the transaction at the head of the service output queue and returns a pointer to it.
EnqueueInputTransaction	Enqueues a transaction on the service input queue. This allows the service to maintain an ordered list of requests for later completion by the service thread.
QueryInputTransactionQueue	Returns the transaction at the head of the service input queue.
DequeueInputTransaction	Dequeues the transaction at the head of the service input queue and returns a pointer to it.
GetPortId	Returns the port ID for a given port handle.
SetPortParameter	Sets the port parameter for the given port to a value given by the caller.
GetPortParameter	Retrieves the parameter previously associated with a port by a call to SetPortParameter.
EnterServiceRegion	Enters the region associated with the service. Currently the SendMessage handler is called while in this region. If mutual exclusion is desired between the service thread and the SendMessage handler, the service thread can make this call.
ExitServiceRegion	Exits the service region previously entered with EnterServiceRegion.

RT service handlers

Service handlers are subroutines invoked by the kernel to perform service-dependent functions of the system calls.

For example, calling SendRtMessage causes the kernel to invoke the handler supplied by the service to handle the transmission of the message to the interface. Some of these handlers must be supplied by the service while others are optional.

The control and transaction buffer pools are the static resources used for allocating internal data structures. The size of these pools is determined from parameters in the service descriptor at installation time.

System call	Description
CancelTransaction	implement special actions as a result of calling CancelRtTransaction or DeleteRtPort.
CreatePort	Invoked when CreateRtPort is called. A status of E_OK must be returned for the port to be created, else the port object is deleted and the status code is returned to the caller.
DeletePort	Invoked when DeleteRtPort is called. It must return a status of E_OK for the port to be deleted, else the port object is deleted and the status code is returned to the caller.
Finish	Ensures that any service-dependent resources are cleaned up before the service process is killed.
GetAttributes	Gets attributes from the service when an application calls GetRtServiceAttributes.
GetFragment	Invoked when an application calls ReceiveRtFragment.
Initialize	Performs any service-specific initialization functions and returns a suitable status code to the caller.
SendMessage	Implemented by all services which require a transmission function.
Service	Invoked by the service thread when an event occurs.
SetAttributes	Passes parameters from SetRtServiceAttributes.
UpdateReceiveInfo	Invoked just before returning results to either ReceiveRtMessage or ReceiveRtReply, caused by a service handler calling DeliverStatus. The kernel handles the receipt of a message at a port, and then may call this routine in order that the RECEIVEINFO structure may be filled out.
VerifyAddress	Validates the address parameter passed to the call.

PCI library calls

System call	Description
PciInitialize	Initializes the PCI library by determining the PCI configuration access method used by the local chipset.
PciReadHeader	Reads the PCI configuration header fields to the supplied PCI_DEV structure.
PciFindDevice	Locates a PCI device given the vendor and device IDs, and an instance number.
PciSetConfigRegister	Writes a value to a given PCI configuration register.
PciGetConfigRegister	Reads a value from a given PCI configuration register.
PciVendorName	Returns a text string corresponding to the vendor ID supplied as a parameter.
PciDeviceName	Returns a text string corresponding to the vendor and device IDs supplied as parameters.
PciClassName	Returns a text string corresponding to the class ID supplied as parameters.
PciEnableDevice	Brings a PCI device out of a ACPI power down state to fully operational condition.

Input/Output Calls

System call	Description
inbyte, inhword, inword	Inputs data from an I/O port
outbyte, outhword, outword	Outputs data to an I/O port

B The iwin32 subsystem

This appendix describes the iwin32 subsystem, which provides a Win32 API for the INtime kernel. It is provided as a parallel API to the INtime API, and is intended to make porting of existing Win32 applications easier. A subset of the Win32 functions is implemented, and some extensions are defined to handle INtime features such as interrupt handling and shared memory. The functionality of the subset is broadly similar to the Windows CE version of the Win32 API, since Windows CE and INtime have similar goals. Some groups of functions have been omitted where INtime does not require the functionality, such as with the GUI functions.

The elements covered by the iwin32 API include the following:

- Processes and threads
- Mutexes, critical sections, semaphores and events
- I/O handling
- Registry handling
- Miscellaneous

In addition a number of real-time extension (RTX) functions are provided where more real-time functionality is required; this includes functions for:

- Interrupt handling
- Shared memory
- Timers

This appendix also describes the iwin32x API, which gives access to real-time iwin32 objects from a Windows application, much in the same way that the NTX API gives access to INtime objects from a Windows application.

Handles

Each object is identified by a handle. In INtime an object is uniquely identified by a single handle value (16 bits for INtime, 32 bits for NTX). This handle can be used in any INtime process and in Windows processes (using NTX). When the object is deleted with a type-specific deletion function such as DeleteRtSemaphore, the handle becomes invalid.

Iwin32 has a different handle system: the Create and Open functions return a handle and different callers may receive different handles for the same object. A handle is stored in 32 bits; an iwin32 handle can be distinguished from an INtime handle

because its value is 0x10000 or greater. Every iwin32 object includes a handle count. When the last handle for an object is closed, the object is implicitly deleted.

In Windows, a handle is normally specific to a process and the same handle in different Windows processes may refer to different objects. Iwin32 implements a slightly different method, where all handle values are unique. This allows a handle to be shared between processes, which would be against the Win32 rules.

There is a limit on the number of objects that can exist at any time in the system, because INtime uses a table to define each object; the size of this table (GDT) is configurable up to a maximum of about 8000 entries. Each iwin32 object requires one, two (thread, timer, interrupt), or three (process) INtime objects. Additional handles for a given iwin32 object do not require additional INtime objects. Iwin32 uses a fixed size table for all handles, the size of which is configurable.

iwin32 calls	iwin32x calls
CloseHandle or RtCloseHandle	RtCloseHandle
	RtImportHandle
	RtSetNode

Named objects

Event, mutex, semaphore and shared memory objects have a Create and an Open function. CreateXxx checks if the named object of that type already exists and if so, returns an error and the handle of the found object. If the name exists but belongs to another object type, the function fails. If the name does not occur yet, the object is created and the name remembered. If no name is supplied, the name check does not take place. OpenXxx only does the name check and if that fails, the whole operation fails.

All object types share one name space, which is not process specific but has system scope. Iwin32 allows names up to 128 characters.

There are no specific functions for named objects, so for details look at the online documentation for different object types.

Processes

A process is a container for objects and resources; it includes a virtual address space that is only accessible to the threads in the process. When a process is created, a primary thread is always created inside it (this is the function named main).

A process can refer to itself by a so-called pseudo handle, which is not a fixed value, but must be obtained by the GetCurrentProcess function. A pseudo handle can only be used by the process itself, and it cannot be closed (it is implicitly closed when the process terminates).

A process can be explicitly terminated with the TerminateProcess or ExitProcess functions; implicit termination obeys these rules:

- When the primary thread returns, the process is terminated.
- When the primary thread calls ExitThread explicitly, the process is not
- terminated.
- When any thread terminates and it was the last thread in the process, the process is terminated.

Terminating a process does not necessarily delete the process! It only closes the pseudo handle for the process and only if that is the last handle, the process is deleted. When a process is terminated, all handles created by its threads are closed; again, this need not imply that all objects are deleted.

Waiting for a process to be signaled means waiting until the process has terminated.

Process functions include:

iwin32 calls	iwin32x calls
ExitProcess or RtExitProcess	–
GetCurrentProcess	–
GetCurrentProcessId	–
GetExitCodeProcess or RtGetExitCodeProcess	RtGetExitCodeProcess
OpenProcess or RtOpenProcess	RtOpenProcess
TerminateProcess or RtTerminateProcess	RtTerminateProcess
CreateProcess or CreateRtProcess	RtCreateProcess
WaitForMultipleObjects or RtWaitForMultipleObjects	RtWaitForMultipleObjects
WaitForSingleObject or RtWaitForSingleObject	RtWaitForSingleObjects

Threads

A thread is the active element type in the system. Each thread has a priority, a state and a stack. The priority indicates the importance of the thread when it is in the ready state.

A thread is in one of these states:

- **Ready**: The thread wants to execute; out of the set of ready threads (called the ready list) the thread with the best priority becomes the running thread.
- **Asleep**: The thread waits for an object or one of a set of objects to be signaled, or for a specific timeout, or both. While in this state, the thread will never be running.

- **Suspended**: The thread is waiting for a resume operation. More than one suspend can be done, and each such suspend must be undone by a resume. While in this state, the thread will never be running.
- **Asleep suspended**: While in the asleep state, the thread was suspended. Both the suspend state and the asleep state must be undone before the thread becomes ready again.

A thread has a stack for calling functions and storing local variables and parameters. The stack must be big enough to contain all necessary data; when it overflows, it is not extended but the hardware exception EH_STACK_FAULT occurs.

A thread can refer to itself by a so-called pseudo handle, which is not a fixed value, but must be obtained by the GetCurrentThread function. A pseudo handle can only be used within the owning process, and it cannot be closed (it is implicitly closed when the thread terminates).

Waiting for a thread to be signaled means waiting until the thread has terminated.

Thread handling functions include:

iwin32 calls	iwin32x calls
CreateThread or RtCreate Thread	–
ExitThread or RtExitThread	–
GetCurrentThread	–
GetCurrentThreadId	–
GetExitCodeThread	–
GetLastError or RtGetLastError	–
GetThreadPriority or RtGetThreadPriority	–
RtGetThreadTimeQuantum	–
OpenThread	–
ResumeThread or RtResumeThread	–
SetLastError or RtSetLastError	–
SetThreadPriority or RtSetThreadPriority	–
RtSetThreadTimeQuantum	–
Sleep or RtSleep	–
RtSleepFt or RtSleepFt	RtSleepFt
SuspendThread or RtSuspendThread	–
TerminateThread or RtTerminateThread	–
WaitForMultipleObjects or RtWaitForMultipleObjects	RtWaitForMultipleObjects
WaitForSingleObject or RtWaitForSingleObject	RtWaitForSingleObjects

Mutexes

A mutex is an object for getting exclusive access to a resource used by more than one thread, possibly in different processes.

When a thread attempts to get ownership of a mutex and that mutex is free, ownership is given to that thread; until the thread releases ownership, no other thread can own the same mutex. A thread can own the same mutex more than once, in which case it must release the mutex the same number of times. When a thread with INtime priority Pw wishes to own a mutex and that mutex is already owned by another thread with priority Po, then if Pw < Po, the priority of the owning thread is changed to Pw until it releases all mutexes it owns. This avoids the infamous priority inversion, as described in *Priority inversions* on page 37.

Termination of a thread that owns one or more mutexes causes all threads waiting for such mutexes to be woken up with a WAIT_ABANDONED exception. Deleting a mutex causes all threads waiting for that mutex to be woken up with an ERROR_INVALID_HANDLE error code.

Mutex manipulation functions are:

iwin32 calls	iwin32x calls
CreateMutex or RtCreateMutex	RtCreateMutex
OpenMutex or RtOpenMutex	RtOpenMutex
ReleaseMutex or RtReleaseMutex	RtReleaseMutex
WaitForMultipleObjects or RtWaitForMultipleObjects	RtWaitForMultipleObjects
WaitForSingleObject or RtWaitForSingleObject	RtWaitForSingleObjects

Critical section

A critical section is a mutex that has no name; it can therefore only be used in the process that creates it. A critical section is identified by a CRITICAL_SECTION structure, which in turn contains the handle of the mutex. For more details see mutexes.

Functions for critical sections include:

iwin32 calls	iwin32x calls
DeleteCriticalSection	Part of Win32
EnterCriticalSection	Part of Win32
InitializeCriticalSection	Part of Win32
LeaveCriticalSection	Part of Win32
TryEnterCriticalSection	Part of Win32

Semaphores

A semaphore is a counter that takes positive integer values called units. Threads release units to and wait for units from the semaphore. A semaphore can synchronize a thread's actions with other threads and can also be used to provide mutual exclusion for data or a resource (although a mutex may be better in that case).

A thread can release one or more units to a semaphore. Waiting can be done for a single unit only. A semaphore does not protect against priority inversion (described in *Priority inversions* on page 37). Deleting a semaphore causes all threads waiting for that semaphore to be woken up with an ERROR_INVALID_HANDLE error code.

Semaphore functions include:

iwin32 calls	iwin32x calls
CreateSemaphore or RtCreateSemaphore	RtCreateSemaphore
OpenSemaphore or RtOpenSemaphore	RtOpenSemaphore
ReleaseSemaphore or RtReleaseSemaphore	RtReleaseSemaphore
WaitForMultipleObjects or RtWaitForMultipleObjects	RtWaitForMultipleObjects
WaitForSingleObject or RtWaitForSingleObject	RtWaitForSingleObjects

Events

An event is a flag that can be set (signaled) or reset; it can be reset manually (once set, it remains set until explicitly reset by a ResetEvent call, independent of how many threads are woken up) or automatically (after waking up one thread, the event is reset).

Deleting an event causes all threads waiting for that event to be woken up with an ERROR_INVALID_HANDLE error code.

Event functions include:

iwin32 calls	iwin32x calls
CreateEvent or RtCreateEvent	RtCreateEvent
OpenEvent or RtOpenEvent	RtOpenEvent
PulseEvent or RtPulseEvent	RtPulseEvent
ResetEvent or RtResetEvent	RtResetEvent
SetEvent or RtSetEvent	RtSetEvent
WaitForMultipleObjects or RtWaitForMultipleObjects	RtWaitForMultipleObjects
WaitForSingleObject or RtWaitForSingleObject	RtWaitForSingleObjects

Shared memory

Mutexes and semaphores allow threads to synchronize, but what if you want to exchange data? You can use INtime objects such as mailboxes, but in iwin32 you also find shared memory. Shared memory is memory that has been allocated by one process and that can be accessed by other processes as well. To access shared memory created by another process you need to know its name.

Since every process has its own virtual address space, a shared memory object must be mapped into a process' address space. Different processes may use different local addresses to access the same shared memory! The shared memory is only deleted when all its handles are closed.

Space for shared memory objects comes from an iwin32 virtual memory pool; the maximum size of that pool is configurable.

It is up to the communicating threads to agree on a method of queuing data in the shared memory as necessary.

Shared memory functions include:

iwin32 calls	iwin32x calls
RtCreateSharedMemory	RtCreateSharedMemory
RtOpenSharedMemory	RtOpenSharedMemory
RtGetPhysicalAddress	RtGetPhysicalAddress
RtMapMemory	RtMapMemory

Timers

Any thread can be made to wait for a given time by using Sleep or RtSleepFt. A timer is simply a thread that gets woken up when its time passes. Creating a timer means that a thread is created that calls a user-provided function after a given time. This thread is a special one: it can not be suspended or resumed and its priority can not be changed. It should not call ExitThread and can not be terminated by TerminateThread.

Timer functions include:

iwin32 calls	iwin32x calls
RtCancelTimer	–
RtCreateTimer	–
RtDeleteTimer	–
RtGetClockResolution	RtGetClockResolution
RtGetClockTime	RtGetClockTime
RtGetClockTimerPeriod	RtGetClockTimerPeriod
RtGetTimer	–

iwin32 calls	iwin32x calls
RtSetClockTime	–
RtSetTimer	–
RtSetTimerRelative	–

I/O handling

In iwin32 a few general file handling functions are present. For many functions, the C-library offers alternatives. Device dependent functions (as provided by DeviceIoControl in Win32) can either be programmed using port I/O, or can be delegated to INtime device drivers.

In contrast to Win32, port I/O (accessing hardware ports directly) is allowed in all INtime threads.

I/O functions in iwin32 include::

iwin32 calls	iwin32x calls
CreateFile	Part of Win32
DeleteFile	Part of Win32
RtDisablePortIo	Part of Win32
RtEnablePortIo	–
RtGetBusDataByOffset	RtGetBusDataByOffset
ReadFile	Part of Win32
RtReadPort...	–
RemoveDirectory	Part of Win32
RtSetBusDataByOffset	RtSetBusDataByOffset
RtTranslateBussAddress	RtTranslateBussAddress
SetFilePointer	Part of Win32
WriteFile	Part of Win32
RtWritePort...	–

Interrupt handling

Win32 does not provide interrupt handling functions, as this always takes place in the Windows kernel environment. Since interrupts are critical in INtime, we have extended iwin32 with interrupt handling. There are two choices for handling an interrupt:

Using RtAttachInterruptVector: A thread is created that is woken up when an interrupt occurs. The thread may use all INtime functions, which makes this a simple- to-understand approach. There is a penalty in processing time, as each interrupt requires two thread switches for switching to and from the interrupt thread.

Using RtAttachInterruptVectorEx: As with the previous function, a thread is created. But in addition a function may be specified that gets called from the hardware interrupt handler, which then determines the need to wake up the thread. In this way many thread switches can be avoided, such as in the case of a terminal: the interrupt function can cause thread wake up for a carriage return character and do internal buffering (and maybe editing) for all other characters. Such an interrupt function can only use the I/O functions RtReadPortXxx and RtWritePortXxx.

When an interrupt comes from a PCI source, the actual interrupt line can be determined using RtGetBusDataByOffset. Access to I/O ports on the device for determining interrupt details is provided by the RtReadPortXxx and RtWritePortXxx functions.

The thread created for interrupt handling is a special one: it can not be suspended or resumed and its priority can not be changed. It should not call ExitThread and cannot be terminated by TerminateThread.

Interrupt handling functions include:

iwin32 calls	iwin32x calls
RtAttachInterruptVector	–
RtAttachInterruptVectorEx	–
RtDisableInterrupts	–
RtEnableInterrupts	–
RtReleaseInterruptVector	–

Registry handling

This lists common operations on registry keys and the registry system calls that do the operations.

To...	iwin32 call	iwin32x call
Create a key	RegCreateKeyEx	Part of Win32
Create a subkey and store registration information into that subkey	RegLoadKey	Part of Win32
Delete a subkey from the registry	RegDeleteKey	Part of Win32
Delete a value from a registry key	RegDeleteValue	Part of Win32
Enumerate subkeys of an open registry key	RegEnumKeyEx	Part of Win32
Enumerate a value for an open registry key	RegEnumValue	Part of Win32
Establish a connection to a registry handle on another computer	RegConnectRegistry	Part of Win32
Open a key	RegOpenKeyEx	Part of Win32
Read registry information in a file and copy it over a key	RegRestoreKey	Part of Win32
Release a handle to a key	RegCloseKey	Part of Win32

To...	iwin32 call	iwin32x call
Replace the file backing a key and all its subkeys with another file	RegReplaceKey	Part of Win32
Retrieve information about a registry key	RegQueryInfoKey	Part of Win32
Retrieve type and data for a value name associated with an open registry key	RegQueryValueEx	Part of Win32
Save a key and all its subkeys and values to a new file	RegSaveKey	Part of Win32
Set the data and type of a value under a registry key	RegSetValueEx	Part of Win32
Unload a key and its subkeys from the registry	RegUnLoadKey	Part of Win32
Write attributes of an open key into the registry	RegFlushKey	Part of Win32

Miscellaneous

In iwin32 (these all have a counterpart in Win32):

FreeLibrary
GetModuleHandle
GetProcAddress
LoadLibrary

Miscellaneous functions include:

iwin32 calls	iwin32x calls
FreeLibrary	Part of Win32
GetModuleHandle	Part of Win32
GetProcAddress	Part of Win32
LoadLibrary	Part of Win32

C INtime software components

This appendix describes product components. The descriptions assume that the installation path is c:\Program Files\INntime\...:

Blue.exe (Windows crash program)

A Windows program that causes the Windows system to have a 'blue screen crash'. Use this program to validate the operation of the INtime software after Windows experiences a "blue screen crash".

Item	Description
Pathname	c:\Program Files\INtime\bin\blue.exe
Invocation	Invoke from the DOS box as follows: `blue -really`

Clk0Jitr.rta

An RT application started by Jitter.exe. This application measures the minimum, maximum, and average times between low-level ticks via an Alarm Event Handler. For more information, see INtime Graphical Jitter.

Item	Description
Pathname	c:\Program Files\INtime\projects\jitterrt\clk0jitr.rta
Invocation	Jitter.exe loads this RT application as it starts.

EventMsg.dll

A resource DLL that associates an event ID with a message. You can add your own messages and event IDs to this DLL by using Microsoft Visual Studio on the project c:\Program Files\INtime\projects\eventmsg.

Item	Description
Pathname	c:\Program Files\INtime\system32\eventmsg.dll
Invocation	The INtime Event Log service loads this DLL at runtime.

INconfCpl.cpl

A Windows program that configures INtime software.

Item	Description
Pathname	c:\Program Files\INtime\bin\INconfCpl.cpl
Invocation	Double-click the icon associated with the file in the INtime program folder (Start>All Programs>INtime>INtime Configuration).

INtime.hlp

INtime software contains the following Help files:

- Main Help files
- Utility Help files
- Embedded C++ Help files

Main Help files

A Windows Help file that describes INtime software.

Note
The Help file uses the file, c:\Program Files\INtime\help\intime.cnt, to display INtime software information.

Item	Description
Pathname	c:\Program Files\INtime\help\intime.hlp
Invocation	Double-click the icon associated with the help file in the INtime program folder (Start>All Programs>INtime>INtime Help).

Utility Help files

Windows Help files that describe INtime software's utilities. Utilities include:

Utility	Help files
Configuration utility	INConfig.cnt INConfig.hlp
RT Process wizard	RtProcW5.cnt RtProcW5.hlp
RT Process Add-in wizard	RtProcAddin5.cnt RtProcAddin5.hlp
RT Device Driver wizard	RtDrvrW5.cnt RtDrvrW5.hlp
RT Application Loader	LdRta.hlp
RT Service Wrapper	ITWrpSrv.hlp

Embedded C++ Help files

HTML and GIF files that describe Embedded C++ calls and syntax. Files include:

Pathname	Files			
c:\Program Files\ INtime\help\ecpp\	_index.html	cstdlib.html	iosfwd.html	setjmp.html
	assert.html	cstring.html	iostrea2.html	signal.html
	cassert.html	ctime.html	iostream.html	sstream.html
	cctype.html	ctype.gif	istream.html	stdarg.html
	cerrno.html	ctype.html	lib_cpp.html	stddef.html
	cfloat.html	errno.html	lib_file.html	stdexcep.html
	charset.html	escape.gif	lib_over.html	stdio.html
	climits.html	exceptio.html	lib_prin.html	stdlib.html
	clocale.html	express.html	lib_scan.html	stream.gif
	cmath.html	float.html	limits.html	streambu.html
	complex.html	format.gif	locale.html	string.html
	crit_pb.html	fstream.html	math.html	string2.html
	crit_pjp.html	fstream2.html	new.html	strstrea.html
	csetjmp.html	function.html	new2.html	strtod.gif
	csignal.html	index.html	ostream.html	strtol.gif
	cstdarg.html	iomanip.html	preproc.html	time.gif
	cstddef.html	iomanip2.html	print.gif	time html
	cstdio.html	ios.html	scan.gif	

Item	Description
Pathname	c:\Program Files\INtime\help\ecpp_index.html
Invocation	Do one of these: • Access INtime software Help, then select Using INtime software>Other system calls>EC++ calls. • Double-click the _index.html file in the EC++ help folder.

INscope.exe

A Windows program that uses NTX calls to communicate with its self-loaded RT counterpart to trace execution of INtime applications.

Item	Description
Pathname	c:\Program Files\INtime\bin\inscope.exe
Invocation	Double-click the icon associated with the file in the INtime Program folder (Start>All Programs>INtime>INtime Real-time Performance Analyzer).

INtex.exe

A Windows application which allows you to browse the objects in an INtime kernel.

Item	Description
Pathname	c:\Program Files\INtime\bin\intex.exe
Invocation	Double-click the icon associated with the file in the INtime Program folder (Start>All Programs>INtime>INtime Explorer).

INtime local kernel (INtime.bin)

The RT kernel binary image , loaded by LoadRtk.exe (INtime Kernel Loader).

Item	Description
Pathname	c:\Program Files\INtime\intime.bin
Invocation	Launched by LoadRtk.exe (INtime Kernel Loader).

INtime remote kernel (Remote.bin)

The RT kernel binary image for use with RT nodes.

Item	Description
Pathname	c:\Program Files\INtime\Remote\common\remote.bin
Invocation	Booted on remote node.

INtime Visual Studio .Net 2003 project type pacakge

A collection of DLLs and Wizards which implements the INtime project type in Visual Studio .Net 2003.

Item	Description
Pathname	c:\Program Files\INtime\vstudio\...

INtime Performance Monitor (INtmPerf.* files)

The INtime Performance Monitor reports INtime Kernel CPU usage to the Windows Performance Monitor.

INtmPerf.ini is a setup file required as a part of the INtime installation process. It is used by the Windows LOADCTR utility to add the proper registry keys and settings.

Item	Description
Pathname	c:\Program Files\INtime\system\intimperf.dll c:\Program Files\INtime\system\intimperf.ini

INtime RT Client Browser

An ActiveX control that you can add to your INtime applications. For information about adding this browser to INtime applications, see *Adding the INtime RT Client Browser to your INtime application* on page 88.

Item	Description
Pathname	c:\Program Files\INtime\system32\inbrow.ocx

You can also add the INtime RT Client Browser using the NTX API call ntxFindINtimeNode and its associated export library and DLL, See INtime Help for detailed information about this call.

Item	Description
Pathname	c:\Program Files\INtime\nt\lib\ntxbrow.lib c:\Program Files\INtime\bin\ntxb.dll

iWin32 header files

Pathname	Files
c:\Program Files\INtime\rt\include\...	iWin32 header files.

iWin32 interface library

Pathname	Files
c:\Program Files\INtime\rt\lib\iwin32.lib	iWin32 interface library

iWin32x header files

Pathname	Files
c:\Program Files\INtime\nt\lib\iwin32x.h	iWin32x header file

iWin32x interface library

Pathname	Files
c:\Program Files\INtime\rt\lib\iwin32x.lib	iWin32x import library

ItWrpSrv.exe (Service wrapper)

A Windows program that installs and removes a user application (either Windows or INtime software) as a Windows service.

Item	Description
Pathname	c:\Program Files\INtime\bin\itwrpsrv.exe
Invocation	A user runs this program to install a custom service to Windows. Run it with the `-help` switch to display usage parameters. Once installed, run ItWrpSrv.exe using the -remove switch to remove the custom Windows service.

Jitter.exe

A Windows program that automatically starts Clk0Jitr.rta, then processes output and displays a histogram. This application measures the minimum, maximum, and average

times between low-level ticks via an Alarm Event Handler. For more information, see INtime Graphical Jitter.

Item	Description
Pathname	c:\Program Files\INtime\projects\jitternt\jitter.exe
Invocation	Select Start>All Programs>INtime>INtime Graphical Jitter

LdRta.exe (INtime RT Application Loader)

A Windows program that loads and starts the RT portion of INtime applications. The loader has two parts: the program that executes on Windows, and an RT "helper" process that performs the RT portion of a load operation. The "helper" process is part of the RT kernel.

The Windows-resident portion of the RT Application Loader is a 32-bit Windows program that uses NTX library calls to load and start INtime applications under the RT kernel.

The RT Application Loader:

- Supports loading of both 32-bit Microsoft PE code (the output of Visual Studio) and 32-bit OMF386 code.
- Supports both command line and dialog-based operation. Supports specification of the file to load, optional debug arguments, and optional program arguments.
- Recognizes the file extension ".RTA" (for RT application).

The INtime Installation processes set up a file association so that an INtime application loads automatically when a user double-clicks the file name in a supporting Windows application (such as Windows Explorer). If a default node has not been established, such an invocation (double-click of the filename) displays ldrta.exe's user interface so you can establish a default node.

Item	Description
Pathname	c:\Program Files\INtime\bin\ldrta.exe
Invocation	Do one of these: • Double-click the icon associated with LdRta.exe (INtime RT Application Loader) in the INtime program folder (Start\All Programs\Intime\INtime Loader), then select the INtime application you want to load. • Double-click an INtime application executable which has a .RTA extension.

LoadRtk.exe (INtime Kernel Loader)

A 32-bit Windows program that loads the RT kernel after Windows starts. When set to automatically start, the Windows service manager launches the INtime Kernel Loader at system startup. In this case, the loader loads the RT kernel after the Windows kernel

and after other Windows services, but before users log on. Otherwise, the INtime Kernel Loader is started manually using the Services applet (Start>Control Panel>Administrative Tools>Services).

The INtime Kernel Loader cooperates with the RT Interface Driver (RtIf.sys) to load the RT kernel image set up by the INtime Configuration Utility.

First it loads the specified image into the memory allocated by the RT Interface Driver, then it makes a request to the RT Interface Driver to start the RT kernel.

Note
You can configure the RT kernel to start automatically at boot time by using the Windows Services Manager.

Item	Description
Pathname	c:\Program Files\INtime\bin\loadrtk.exe
Invocation	Start INtime software's RT kernel either in Manual or Automatic mode, using the Windows Services Manager (Start>Control Panel>Administrative Tools>Services>INtime Kernel Loader).

mDNSINtime.exe

A Windows application which configures remote NTX connections automatically.

MFC*.dll files

Microsoft DLLs required by MFC programs; included in the event they were not installed with Windows.

Item	Description
Pathname	c:\Program Files\INtime\system32\mfc30.dll c:\Program Files\INtime\system32\mfc30d.dll c:\Program Files\INtime\system32\mfc42.dll

netstat.rta

An RT application that displays statistics about the INtime TCP/IP stack.

Item	Description
Pathname	c:\Program Files\INtime\bin\netstat.rta
Invocation	netstat [-ains] [-p protocol] [interval]

NTX header files

Pathname	Files
c:\Program Files\ INtime\nt\include\...	ntx.h.....C NTX header file

NTX import libraries

Pathname	Files
c:\Program Files \INtime\nt\lib\...	ntx.lib..... NTX import library ntxext.lib.....Extended NTX import library.

NTX DLLs

DLLs provided with INtime software used by Windows applications to communicate with INtime applications using NTX system calls.

Item	Description
Pathname	c:\windows\system32\ntx.dll c:\windows\system2\ntxext.dll
Invocation	Windows loads these DLLs when a Windows application attempts the first NTX call.

NtxRemote2.exe (INtime Remote Connection Manager)

Manages connections with remote INtime nodes. Runs as the INtime Remote Connection Manager.

Item	Description
Pathname	c:\Program Files\INtime\bin\ntxremote2.exe
Invocation	Start INtime software's ntxremote2.exe either in Manual or Automatic mode using the Windows Services Manager (Start>Control Panel>Administrative Tools>Services>INtime Remote Connection Manager).

OvwGuide.pdf

The INtime Software User's Guide in PDF format. This file requires Acrobat32.exe.

Item	Description
Pathname	c:\Program Files\INtime\help\OvwGuide.pdf
Invocation	Double-click the file in the Windows Explorer. This launches Acrobat32.exe which, in turn, opens the OvwGuide.pdf file for viewing.

Ping.rta

An RT application that you use to test the network connection between two machines. If connected, the remote system responds with a series of packet echoes.

Item	Description
Pathname	c:\Program Files\intime\bin
Invocation	Start the program using the RT Application Loader. Use this syntax: `ping TargetSystemIPAddress`

Project files

INtime software has a number of sample applications that you can use as samples for your own INtime applications.

The source code for these applications is provided in both Microsoft Visual Studio 6.0 and .Net 2003 generation format, and reside in separate directories. For example, the INtime API test program source files reside in the My Documents\INtime\Projects\RTTest directory.

Click on the desired project's name (Start>All Programs/INtime/Sample Code and Projects) to open the Microsoft Visual Studio and find out more about each of these projects:

- INtime API Sample
- INtime Serial Driver Sample
- INtime Graphical Jitter
- Real-time Interrupt Sample
- C and C++ Samples for Debugger
- TCPIP>TCIP-IP Client Sample
- TCPIP>TCP-IP Server Sample
- Fault Handling (ntrobust)
- Floating Point Exception Handling
- RSL Example
- NTX Sample (MsgBoxDemo)
- INtime Windows STOP Detection sample (STOPmgr)
- INtime USB Client sample

Item	Description
Pathname	My Documents\INtime\Projects\<Sample Directory>\for source code My Documents\INtime\Projects\<Sample Directory>\ debug for executables
Invocation	Use Microsoft Visual Studio to edit/compile these sample applications. Use the INtime RT Application Loader to load the resulting sample application executables.

Quick Start Guide

The INtime Quick Start Guide in PDF format. This file requires the Adobe Acrobat reader.

Pathname: c:\Program Files\INtime\help\QuickStartGuide.pdf

Invocation: Double-click the file in Windows Explorer. This launches the Acrobat Reader which in turn opens the QuickStartGuide.pdf file for viewing.

RT node files

Contains the files required to build an RT node. For more information about building RT nodes, see *Chapter 8, Preparing an RT node*.

Pathname	Files
c:\Program Files\INtime\remote\common	

RT header files

Pathname	Files
c:\Program Files\INtime\rt\include\...	C RT and C library header files.
c:\Program Files\INtime\rt\include\sys\...	Additional C RT and C library header files.
c:\Program Files\INtime\rt\include\arpa\...	Internet C header files.
c:\Program Files\INtime\rt\include\netinet\...	Additional internet C header files.
c:\Program Files\INtime\rt\include\services\...	C RT Services header files.

RT interface libraries

Pathname	Files
c:\Program Files\ INtime\rt\lib\...	ciff3m.lib ..... CLIB function interface library ecpp.lib ..... Embedded C++ library net3m.lib ..... Sockets utility flat library pcibus.lib ..... PCI library rmxiff3m.lib ..... Flat RMX library rt.lib ..... INtime API interface library rtpplib ..... Embedded C++ library rtppd.lib ..... Embedded C++ debug library rtserv.lib ..... INtime port interface library usbss.lib ..... INtime USB subsystem interface library

RT Stack Services

INtime RT components that make up the RT TCP/IP Stack. These components include NIC drivers and TCP/IP Stack Layers.

Pathname	Files
c:\Program Files\ INtime\remote\common\...	3c59x.rta ..... INtime 3COM Driver eepro100.rta ..... INtime EEpro 100 Driver ip.rta ..... INtime IP loopback.rta ..... INtime Loopback Driver ne.rta ..... INtime NE Driver rip.rta ..... INtime Raw IP rtl8139.rta ..... Realtek Driver tcp.rta ..... INtime TCP udp.rta ..... INtime UDP

RT USB Interface Drivers

INtime RT components that make up the RT USB Subsystem. These components include Host Controller drivers for UHCI, OHCI, and EHCI (USB 2.0) interfaces.

Pathname	Files
c:\Program Files\INtime\bin	usbss.rsl ..... INtime USB Subsystem Shared Library uhci.rta ..... INtime USB Universal Host Controller Interface Driver ohci.rta ..... INtime USB Open Host Controller Interface Driver ehci.rta ..... INtime USB Enhanced Host Controller Interface (USB 2.0) Driver

RtClkSrv.exe (INtime Clock Synchronization Service)

A Windows program that provides time-of-day and time interval services used to synchronize the RT time-of-day clock to the Windows time-of-day clock.

Note

You can have the INtime Clock Synchronization Service start automatically at boot time by using the Windows Services Manager to set up the INtime Clock Synchronization Service for Automatic Startup. If the INtime Node Detection Service has not yet started, it is automatically started by the INtime Clock Synchronization Service.

Item	Description
Pathname	c:\Program Files\INtime\bin\rtclksrv.exe
Invocation	This program is run as a Windows service (Start>Control Panel>Administrative Tools>Services> INtime Clock Synchronization Service).

RtDrvrW5.awx (RT Device Driver wizard)

An MSVC 6.0 Application Wizard that you use to develop device drivers for INtime applications.

Item	Description
Pathname	c:\Program Files\INtime\msdev\template\rtdrvrw5.awx
Invocation	Invoked by the MSVC 6.0 IDE.

RtELServ.exe (INtime Event Log Service)

A 32-bit Windows program that supports Windows event log manipulation by RT threads. The RT Event Log Service receives, processes, and responds to requests from the RT application library's event log entry points. When the RT Event Log Service receives a request, it blocks the calling thread, executes the appropriate Win32 event log function, and replies to the original request (unblocking the calling thread). If the Windows host and/or the RT Event Log Service terminates execution, it terminates all pending requests with an E_EXIST error.

The RT Event Log Service supports a single request: to write an entry from the RT client event source at the end of the local PC's Application event log.

Neither the RT application library nor the RT Event Log Service support event logging to the system or security event logs, event logging by a source other than RT client, event logging to a remote PC, or backing up an event log file.

Note
You can have the INtime Event Log Service start automatically at boot time by using the Windows Services Manager to set up the INtime Event Log Service for Automatic Startup. If the INtime Node Detection Service has not yet started, it is automatically started by the INtime Event Log Service

Item	Description
Pathname	c:\Program Files\INtime\bin\rtelserv.exe
Invocation	Start the INtime Event Log Service using the Windows Services Manager (Start>Control Panel>Administrative Tools>Services).

RtIf.sys (RT Interface Driver)

A Windows kernel mode device driver that co-manages the OSEM used by the INtime product to add RT capabilities to Windows. This driver:

- Establishes the initial RT kernel environment.
- Co-manages switching between the Windows and INtime runtime environments.
- Supports communication and synchronization mechanisms between Windows threads and RT threads by relaying NTX library requests.

Note: For detailed information, see Help.

Item	Description
Pathname	c:\windows\system32\drivers\rtif.sys
Invocation	Windows loads this driver at system initialization time.

RtIOCons.exe (INtime I/O console)

The RT I/O Console is a 32-bit Windows program that provides support for Windows console I/O for RT threads. It creates and manages a single console window and executes keyboard data (input) requests and display (output) requests from the RT thread.

Item	Description
Pathname	c:\Program Files\INtime\bin\rtiocons.exe
Invocation	Invoked by RtIOSrv.exe (INtime I/O Service)

RtIOSrv.exe (INtime I/O Service)

A 32-bit Windows program that provides Windows file system and console I/O support for RT threads. This program acts as a server to RT "C" library to obtain a console window for display (via printf) of application data and to receive (via scanf) user input from the system keyboard.

When the RT "C" library receives an stdio request from a real-time thread, it checks to see if a console exists. If a console exists, it relays the request to the appropriate RT I/O console If no console exists, it blocks the thread making the request, creates an RT I/O console window for the thread via the INtime I/O Service, and relays the request to the RT I/O console. When a request completes, the INtime I/O Service unblocks the corresponding thread and relays the reply. If Windows terminates execution, the RT I/O Console terminates all pending requests with an E_EXIST error.

When the RT "C" library receives a file I/O request from an RT thread, it blocks the thread making the request and forwards the request to the INtime I/O Service for completion. When a request completes, the RT "C" library unblocks the thread making the request and relays the reply to the thread.

Use of the INtime I/O Service is restricted to the RT "C" library.

Note

You can have the INtime I/O Service start automatically at boot time by using the Windows Services Manager to set up the INtime I/O Service for Automatic Startup. If the INtimeNodeDetection Server has not yet started, the INtimeIO Server starts it automatically.

Item	Description
Pathname	c:\Program Files\INtime\bin\rtioserv.exe
Invocation	Start the INtimeIO Server using the Windows Services Manager (Start>Control Panel>Administrative Tools>Services).

RtNdSrv.exe (INtime Node Detection Service)

A 32-bit Windows program that detects RT clients, both local and remote. This program checks for and registers RT clients that exist in both of these locations:

- RT clients configured in INtime Configuration utility.
- RT clients available to the system.

Item	Description
Pathname	c:\Program Files\INtime\bin\rtndsrv.exe
Invocation	Start the INtime Node Detection Service using the Windows Services Manager (Start>Control Panel>>Administrative Tools>Services).

RtProcW5.awx (RT Process wizard)

An MSVC 6.0 Application Wizard that you use to develop the RT portion of INtime applications.

Item	Description
Pathname	c:\Program Files\INtime\msdev\template\rtprocw5.awx
Invocation	Invoked by the MSVC 6.0 IDE.

RtProcAddinW5.awx (RT Process Add-in wizard)

An Application wizard for Microsoft Visual Studio, version 6.0, that you use to add supplemental files to the already-generated RT portion of INtime applications.

Item	Description
Pathname	c:\Program Files\INtime\msdev\addins\rtprocaddinw5.awx
Invocation	Invoked by the MSVC 6.0 IDE.

RtRegSrv.exe (INtime Registry Service)

A Windows program that provides RT Registry Clients access to the Windows registry.

Item	Description
Pathname	c:\Program Files\INtime\bin\rtregsrv.exe
Invocation	Start the INtime Registry Service using the Windows Services Manager (Start>Control Panel>Administrative Tools>Services).

RtRslWiz.awx (RT Shared Library wizard)

An MSVC 6.0 Application Wizard that you use to develop a Realtime Shared Library (RSL) for an INtime application.

Item	Description
Pathname	c:\Program Files\INtime\msdev\template\rtrslwiz.awx
Invocation	Invoked by the MSVC 6.0 IDE.

Spider.exe (INtime standalone debugger)

A Windows program to provide standalone debug capabilities for any INtime application generated with MSVC 6.0 or with Visual Studio .Net 2003.

D Visual Studio .NET debugging for older INtime projects

This appendix describes how existing INtime projects may be upgraded to use the Visual Studio .NET product and its debugger. INtime software continues to support the Microsoft Visual Studio 6.0 product, but the use of Visual Studio .NET allows you to take advantage of the new advanced debugging features of the product.

Upgrading to Visual Studio .NET

The Visual Studio .NET product is also known as Visual Studio 2003 (there is a 2002 version, but that is not supported by INtime software). We will refer to this version as VS2003 from here on. These instructions will also apply to upgrading to the Visual Studio 2005 product.

When you open an existing project (.dsp or .dsw file) in VS2003, you are asked whether you want to upgrade; if you refuse, the workspace is not opened. If you agree, VS2003 modifies your file set and you now have these files:

Filename	Contents
proj.c	Main source files
proj.sin	Solution properties
proj.suo	User options file
proj.vcproj	Project properties

The solution file, proj.sln, is the modern version of the workspace: it contains solution properties (a solution is the new word, but it means the same: a solution or workspace is a container for one or more projects). There can be different types of projects, but for INtime we are interested only in the C/C++ project type, which is referred to as a VC project and identified by the file extension .vcproj; a VC project file contains compiler and linker settings.

After upgrading, you now have access to all VS2003 features, but you cannot use the integrated INtime debugger yet.

Converting to a .intp project

To get access to the integrated INtime debugger, we need to tell VS2003 that we have an INtime project. This is accomplished by converting the VC project into an INtime project (represented by a file with an .intp extension) which encapsulates the VC project. When VS2003 reads an INtime project, it provides access to features specific to INtime projects, which includes the integrated INtime debugger. Before leading you there, let us see how you convert a project.

You have already upgraded your VS6 workspace to a VS2003 solution. Start by opening that solution in VS2003. Load the macros provided by INtime 3.0 into VS2003 as follows (loading the macro project needs to be done only once):

1. Select Tools>Macros>Loade macro project.
2. Navigate to the vstudio directory in INtime's installation directory.
3. Open the tointp.vsmacros file.
4. Locate ToIntp in the Macro Explorer window:
   A. Click the plus icon to expand ToIntp.
   B. Click the plus icon to expan Module1.
5. Double-click ToIntp, or click it once and press Enter.

   Progress messages display in the Output window, located at the bottom of VS71. You are then prompted to save files.
6. Click Yes to save files.

You now have a solution with one or more INtime projects identified by an INtime icon; each INtime project contains a VC project. Your set of files now looks like this:

Filename	Contents
proj.c	Main source files
proj.sin	Solution properties
proj.suo	Same, but in binary
proj.intp	INtime project properties
proj.vcproj	VC project properties

Setting project properties

An INtime project has an additional set of options: when you reght-click the VC project and select properties, you see the compiler and linker settings, just like before. Right clicking the INtime project and selecting properties shows two pages (there are also menu items to achieve the same results):

- Launch settings, that determine on which INtime noe the application will run and what command line arguments are passed to it, and
- INtime settings, which control resources in the INtime system.

The pool maximum parameter on the INtime settings page is the same as the Heap reserve size on the Linker/System page of the VC project properties.

Getting to work with the debugger

All of these steps had to be done only once. From now on you can use the integrated INtime debugger, just like you are used to doing so with Windows applications:

- Press F9 to set a breakpoint on a source line.
- Press F5 (run), Control-F5 (run without debugging), or F10 (single step) to start debugging.
- When at a breakpoint, view threads, variables, registers, call stack, modules, etc.

Note that the integrated debugger will refuse to debug an INtime RSL—you must select a project that represents a .RTA file.

What if conversion did not work?

The ToIntp macro makes some assumptions about projects that can be converted to INtime projects:

- Such a project is identified by the Version=21076.20052 option in the Linker/General properties page. Projects that do not have this option are skipped by the convertion macro.
- There are two configurations, named Debug and Release.
- compiler and linker options are set to default values applicable for INtime.

There is a second macro ToIntpSelected that only converts the selected project.

If for any reason you choose not to use the conversion macro but still want to use the integrated debugger, you can proceed as follows in VS2003:

1. Create a new solution if you wish.
2. In the solution, create a new project; use the INtime projects>Application wizard for this, and select an empty project.
3. When the wizard is finished, modify the VC project to suit your needs (add configurations, change compiler and linker settings). Note that you will not be able to modify the platform in the configuration manager; it will always ge “INtime”.
4. Add project items such as .c and .cpp source files, .h and .hpp include files, and so on.

E Adding INtime software to an XP Embedded configuration

You can add INtime components to your XP Embedded configuration using the standard mechanism provided in the XP Embedded Developer's Kit.

The INtime.sld file (c:\Program Files\INtime\Xpembedded\intime.sld) defines the INTime components and should be imported into the component database using the Component Database Manager. After creating new target XPE images, you can view and add INtime components from the Database.

INtime components are found in the component hierarchy under this key:

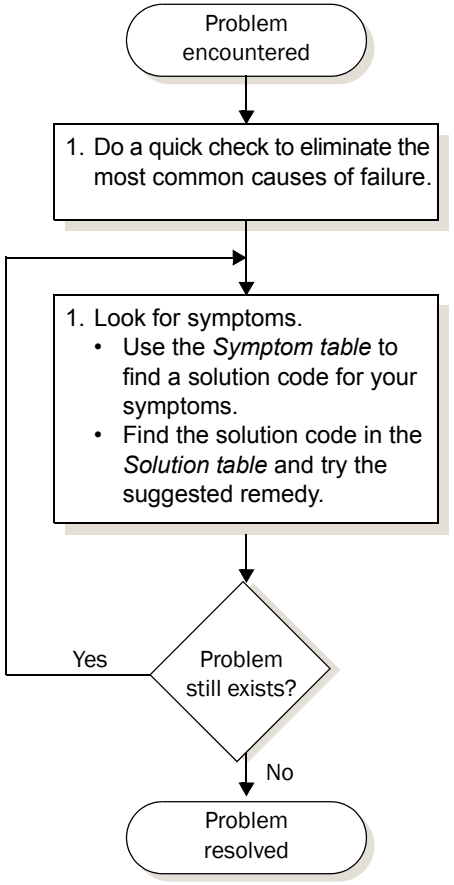
```
Software\System\OEM System Extensions\Infrastructure\
```

F Troubleshooting

This appendix lists problems you may encounter while running INtime software, and explains how to avoid or resolve those problems.

Complete these steps to resolve INtime software problems:

Figure F-1. Troubleshooting INtime software problems



Do a quick check

Many problems are solved by correcting these:

- **Is the RT kernel running?** You must start the RT kernel prior to starting most INtime development tools and all INtime applications.
- **Did you use the INtime RT Application wizard to set up the project?** Using this wizard automatically starts an INtime project and ensures that the project includes proper settings.

Look for symptoms

Scan the *Symptom table* until you find a symptom that your system exhibits. The Symptom table lists solution codes in the order most likely to occur.

Locate the corresponding solution codes in the *Solution table* and take the recommended action. You may need to try several solutions before you successfully resolve the problem.

Table F-1. Symptom table

Symptom	Solution codes
INtime software does not install.	1, 2, 3, 4, 5, 6
Tools in the INtime development environment do not run.	11
The INtime application reports build errors.	9, 10
A serial mouse does not respond after you start the RT kernel.	12
The INtime application does not load.	11, 13
The file is not recognized as a valid INtime application.	14
The INtime application terminates unexpectedly.	15
The INtime application displays this message: `Running out of Virtual Address Space (error code 0xf0)`	15
The INtime application reports an unsupported C library function.	10
The INtime application performs terminal I/O, and no terminal window appears.	17
Only a blue screen displays.	20
Windows window events and applications respond slowly.	19, 16
The system doesn't respond to attempts to move the cursor or make entries from the keyboard.	18, 20, 19, 16, 8
You're running SDM and neither the system console nor the SDM terminal respond to attempts to move the cursor or make entries from the keyboard.	7

Table F-2. Solution table

Category	Solution	
Installing INtime software	1	Adjust your system configuration. Your system has an incompatible system configuration.
	2	ICheck the System Event Log for error messages from source RTIF. Also check the Application Event Log for error messages from LOADRTK.
	3	Ensure that your PC has: • Sufficient RAM to allow for your configure memory size for INtime. • A minimum 45MB disk space • Windows 2000, Service pack3, or later version of Windows.
	4	Ensure that you exit all programs before you install INtime software.
	5	Ensure that your system does not contain a previous version of INtime. If a previous version exists, uninstall it by selecting Start>Control Panel>Add/Remove programs.
	6	Ensure that you are logged on with Administrator privileges.
Developing INtime applications	7	Use the SDM PDP <logical address> command to get the physical address of memory in question, followed by S c80:physical address (returned by PDP). Do not use the SDM D command to display Ring 3 code/data in a Virtual Segment at an address not populated with memory. Do not use the SDM S command to modify memory using a Ring 3 code segment (read-only).
	8	If you're running SDM, no action is required. When you run SDM, you access the INtime software via the SDM terminal and the Windows system console no longer responds.
	9	Verify project build settings and ensure that you: • Select Not Using MFC to disable use of MFC classes. • Include the <INtime install path>\rt\include directory as a preprocessor directive. • Ignore all default libraries as a link option.
	10	Remove C library calls not supported by INtime. For a list of C library calls that INtime supports, run INtime Help and select Programmer's reference>C library reference.

Table F-2. Solution table

Category	Solution	
Loading INtime applications	11	Start the RT kernel before starting an INtime application. For information about starting the RT kernel, see *Chapter 9, Operation*.
	12	Do one of these: • If your mouse is on COM2, switch it to COM1. • Switch the RT kernel debug port to COM1 or disable RT kernel debug.
	13	Run the RT Application Loader and select the Advanced option to increase the amount of virtual address space in 4 MByte increments. Not enough memory exists to load the application. The program size and its heap and stack requirements specified when it was built may exceed the amount of memory available for INtime applications. For more information about changing memory options for loading INtime applications, see Help in the RT Application Loader.
	14	Rebuild the project. You may have tried to run a corrupted executable. This can occur, as an example, when a project is open and Windows halts.

Table F-2. Solution table

Category	Solution	
Running INtime applications	15	Run the INtime Explorer to obtain debug information. For information about running the INtime Explorer, see *After you start INtime software* in *Chapter 9, Operation*.
	16	Set the RT kernel tick interval above 200usec. When the kernel tick drops below this rate, Windows slows down because the CPU devotes too much time to switching between the Windows and INtime kernels.
	17	Ensure that the INtime I/O Service is running. INtime applications that perform terminal I/O require that the INtime I/O Service runs. For information about starting this service, see *Starting the RT kernel and related components* in *Chapter 9, Operation*.
	18	End the INtime application: 1. Invoke the INtime Explorer (Start>All Programs>INtime>INtime Explorer). 2. Highlight the INtime application you want to terminate. 3. Right click the mouse. A pulldown menu displays. 4. Select Delete. INtex prompts you to confim the deletion process. 5. Select Yes. If you cannot display the INtime Explorer (i.e., the Windows screen seems frozen and the mouse does not respond), the INtime application may have halted or may be monopolizing system resources. If you suspect the latter, see solution 19. **Note**: To verify whether Windows has halted, try to access the file system from another system. If you can, Windows is still running but cannot respond.
	19	Adjust your INtime application so that the RT portion of your INtime applications do not dominate CPU time. Your INtime application may be designed to monopolize too many system resources. For more information about designing applications to balance RT and Windows activity, see *Methodology* in *Chapter 5, Designing RT applications*. **Note**: To aid in diagnosing system resource misuse, try to access the file system from another system. If you can, Windows is still running but cannot respond.
Running INtime applications (continued)	20	Exit INtime applications, if possible, then reboot your system: One of these situations may have occured: • Windows halted. • A Windows application halted. • An INtime application monopolized system resources. **Note**: Try other solutions before trying this one.

Other resources

If the information in this chapter doesn't solve the problem, you may want to contact TenAsys as described in *Where to get more information* on page v.

Glossary

application loader	The layer of an INtime application that loads programs into memory for execution, such as when a user enters a command at the console.
asynchronous	Events that occur at random times.
BIOS	(Basic I/O System) On a PC system, the code that resides in ROM to supply OS-independent access to the computer's I/O system.
BSOD	(Blue Screen of Death) An acronym used to describe total Windows failure.
client	On a network, a client is a computer which makes requests of a remote system that acts as a server. For example, a client could request a remote server to supply it with data from one of the server's disk files.
descriptor	An 8-byte data structure taken from a descriptor table in memory. Descriptors provide the CPU with the data it needs to map a logical address into a linear address. The fields of a descriptor include information concerning segment size, base address, access rights, and segment type (such as read/write segment, executable segment, call gate, task gate, trap gate, etc).
determinism	Predictable response time. Enables threads to execute before their deadlines expire.
device controller	The hardware interface between the CPU or system bus and a device unit.
device driver	The software interface between the I/O system and a device controller.
Distributed INtime	A configuration of INtime where an INtime kernel (RT client) runs on a CPU that does not run Windows.
encapsulation	A characteristic of object-based systems. The representation of an object is hidden from the user of that object. Only the object's type manager can manipulate an object. Users of an object can manipulate the object only by invoking type manager functions for the object.
EOI	(End of Interrupt) A command sent to a PIC to indicate that an interrupt handler completed processing an interrupt.
event-driven	Applications can respond to interrupts as they occur; they do not waste time polling for interrupts.
exception handler	A program that receives control when either the operating system or hardware detects an error.
exchange object	Generic name for object types managed by INtime software that allow threads to synchronize and communicate with each other. Exchange objects include: semaphores, mailboxes, and regions.

execution state	Thread state. Thread execution states include: running, ready, asleep, suspended, or asleep-suspended.
FIFO	First in, first out.
GDT	(Global Descriptor Table) A memory segment that contains descriptors for code, data, and descriptor table segments.
handle	An object identifier.
IDT	Interrupt descriptor table.
interrupt	A signal from a device such as a NIC (Network Interface Card) or IDE hard disk controller. You connect interrupt sources to the processor through a PIC (Programmable Interrupt Controller).
interrupt handler	Code executed first in response to a hardware interrupt. This code runs in the context of the thread that was running when the interrupt occurred. Interrupt handlers must save the current context on the stack before using any CPU registers.
interrupt levels	PICs manage interrupts by presenting them to the system processor as discreet levels in priority order. INtime software handles more critical interrupts first, and keeps track of which interrupts occurred, the order in which they occurred, and which ones have not been handled.
interrupt response time	The time between a physical interrupt happening and the system beginning to execute the interrupt handler. By being able to calculate a predictable worst-case response time to interrupt processing, a real-time system can be designed to ensure that incoming data is handled before it becomes invalid.
INtime node	A computer that simultaneously executes both a Windows host and an RT client that are connected via the OSEM.
MAC	(Media Access Control) The 6-byte Ethernet address for a computer node on a network.
mailbox	An RT kernel object type managed by the RT kernel. Mailboxes are used for interthread synchronization and communication. Two types of mailboxes exist: • **Data mailbox**: sends and receives data. Available in both high and low level. • **Object mailbox**: sends and receives object handles. Available only in high level.
memory address	The architectural mechanism used by x86 processors to access an individual byte of system physical memory. In the 32 bit protected mode environment of Windows and INtime, memory addresses are 32 bit linear addresses relative to a 16 bit descriptor that is loaded into a CPU segment register. The INtime kernel manages the 16 bit descriptors (virtual segments - VSEGs) for INtime applications that only use 32 bit linear addresses to access code and data (flat model applications generated with MSVC tools).
memory area	Provides memory for threads to use for many purposes, including communicating and storing data.

memory pool	An amount of memory, with a specified minimum and maximum, allocated to a process. The basis of INtime software's memory management. The initial memory pool is all the memory available to the application (that is, free space memory). It is managed by the OS and allocated to the application on request.
message port	An RT kernel object type managed by the kernel. Used to provide an access point for an INtime application thread to communicate with an INtime service.
multi-programming	Ability of an operating system to simultaneously run several unrelated applications on a single system. Allows more than one application to run at a time.
multithreading	Ability of an operating system to run multiple threads at virtually the same time. When the operating system stops executing one thread, it resumes/starts executing another thread. This transition from one thread to another is called a thread switch.
object	An instance of a data structure that can be accessed only through a set of functions provided by a type manager.
object directory	A storage area within an INtime process where objects can be cataloged, i.e. have a name associated with the objects so that other theads may refer to/access the cataloged object by name.
PIC	(Programmable Interrupt Controller) An integrated circuit that can resolve simultaneous interrupt requests and negotiate a sequence of CPU interrupt requests based on the priorities of the requesting device controllers.
priority-based scheduling	Abiltiy of an operating system to assign execution order importance values (priority) to each thread in the system. In an INtime system, the scheduling policy enforced by the INtime kernel is that the highest priority ready thread is/will immediately become the running thread. Thus, when thread A is running, if thread B becomes ready through some system event, and thread B is higher priority than thread A, then the INtime kernel will immediately preempt thread A, and make thread B the running thread.
priority inversion	A situation in which a high-priority thread is effectively prevented from running by a lower-priority thread. Proper use of the RT kernel's region objects eliminates this problem.
process	An RT kernel object type. Processes have memory pools and contain/own execution threads and other objects.
region	An RT kernel object type managed by the kernel. Regions are binary semaphores with special suspension, deletion, and priority-adjustment features. You can use regions to provide mutual exclusion for resources or data.
round-robin scheduling	A scheduling method where equal priority threads take turns running. Each thread gets a time slice, an equal portion of the processor's time.
RT	Real-time.
RT client	An RT subsystem designated to consume INtime services (booting, configuration, file system proxy, etc.) provided by a Windows host.

RT kernel	(Real-time kernel) An operating system that provides full RT functionality.
RT subsystem	A self-contained collection of software containing an RT kernel, a number of RT support processes, and the RT portion of zero or more INtime applications.
semaphore	An RT kernel object type managed by the kernel. Semaphores are used for interthread synchronization. A counter that takes positive integer values. Threads use semaphores for synchronization by sending units to and receiving units from the semaphores.
server	On a network, a server is any computer which responds to requests from remote systems. For example, file or print servers allow remote systems to access local disks or printers.
system call	A subroutine supplied by INtime software to provide a service, such as I/O processing or memory allocation. A programmatic interface you use to manipulate objects or control the computer's actions.
thread	An RT kernel object type managed by the RT kernel. Threads, or threads of execution, are the active, code-executing objects in a system.
thread switch time	The time required to save the context (data registers, stack and execution pointers) of one thread, and to start another thread by moving its context into the processor registers.
time slice	An equal portion of the processor's time.
Windows host	A Windows subsystem designated to provide INtime services (booting, configuration, file system proxy, etc.) to one or more RT clients. Not all Windows subsystems are Windows hosts.
Windows node	A computer executing a Windows subsystem.
Windows subsystem	A self-contained collection of software containing Windows, a number of Windows support processes, and the Windows portion of zero or more INtime applications.

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