Virtualization Experts in Real-time Technology
Using virtual machine technology, TenAsys eliminates redundant computer and communication hardware by combining multiple hardware platforms into one. Our RTOS virtualization technology enables a single hardware platform to simultaneously support a standard Windows kernel and a real-time kernel, sharing the CPU, memory, and I/O resources.

Hosting Windows and an RTOS on a single hardware platform reduces system costs and minimizes engineering development time and effort.

Multi-core Enhancements
Multi-core processors further enhance TenAsys’ RTOS virtualization technology by minimizing competition for key resources. TenAsys virtualization technology can dedicate one processor core to the RTOS; the instruction cycles of the dedicated core are available 100% of the time to the RTOS and its processes. All remaining processor cores can be dedicated to the Windows virtual machine.

Contention for key CPU resources such as pipelines, cache, and the FPU are eliminated on multi-core platforms. Coordination between virtual machines is enhanced by using the built-in interprocessor communication mechanisms, eliminating context switch times.

The Best Solution for Adding Hard Real-time Performance to Windows
The INtime® RTOS for Microsoft® Windows® is the only fully-protected, virtual-machine solution available for building hard real-time applications that run concurrently with the Windows operating system, on a single hardware platform.

Combining robust industrial-grade control with enterprise-rich Windows functionality lets applications take full advantage of every Windows feature and thousands of off-the-shelf applications, without having to sacrifice real-time responsiveness. INtime applications can be deployed on Windows Vista, Windows XP, and Windows XP Embedded systems.

Field-proven Real-time Technology
Based on over 25 years of reliable field-proven technology, TenAsys real-time operating systems have been utilized in thousands of applications worldwide, running millions of flawless execution hours. The INtime real-time solution includes a full complement of interprocess communication and synchronization mechanisms to satisfy the needs of the most demanding applications.

Familiar Development Environment
Edit, compile, and source-level debug your INtime real-time applications using Microsoft Visual Studio, the same tools you currently use to build standard Windows applications. There are no new development tools to learn to use.

Key INtime Features:
- Support for all standard multiprocessor systems
- Fully integrated with Microsoft Visual Studio
- Real-time TCP/IP and USB stacks
- EtherCAT, DeviceNet, PROFIBUS, CANopen, ControlNet, GPIB, motion control, and other real-time drivers available

Key Technical Specifications:
- Full memory protection and address isolation
- Precise 50 µs system timer granularity
- Direct I/O and memory-mapped access to hardware
- EC++ libraries conform to ANSI standards
The modern manufacturing process reflects the demands of the customers who use its products. They are more intelligent, more discerning, more cost sensitive and more aware of their special needs and requirements. As a result, the connected digital factory must be flexible, scalable, cost- and energy-efficient and able to quickly keep pace with changing customer demands.

Intel is responding to these demands with a new generation of technology that builds on its traditional PC-base to address the specific needs of automation in industry. These include a whole generation of new multi-core processors, which enables higher performance with less power consumption and heat generation. Multi-core also enables virtualization that allows more compact and efficient combination of real-time control with supervisory applications. Intel® Active Management Technology provides for more reliability in terms of maintenance and upgrades and system monitoring. And pulling it all together, PCI Express offers a proven high-speed connectivity with a roadmap that promises yet higher speeds in the future while including existing systems to preserve investment.

Intel has the components, the experience and the technology to meet the challenge of modern industrial automation with a range of advanced modules in various form factors. Intel products based on the latest multi-core architecture offers energy savings, scalability and flexibility allowing dynamic adaptation of processes as well as ease of management to meet changing demands. This is backed by an extensive eco-system of expertise and standards-based technologies that also offer extended life cycles that protect today’s investment while keeping the path open to future advances.

The modern factory lives by efficiency—in cost, performance adaptability and connectivity. That means that the automated processes and machines not only work under highly precise real-time constraints, but they also produce and consume data that must be made available to other machines and processes as well as to human operators and upper management. The modern factory must work seamlessly with product development, inventory management, suppliers, distributors and customers.

To survive in this environment means optimizing cost and performance such that the operation not only meets the production demands but that the resources are fully used before additional ones are added to meet the performance demands. Too often processors or modules are added to a system with the result that

---

**Table of Contents**

Intel at Every Level: Automation, Control and Management in the New Digital Factory  
*Page Three*

Lower Development Costs of Industrial Control Systems with Resource Partitioning  
*Page Twelve*

Best Practices: Managed Control of Networked Embedded Systems  
*Page Sixteen*

Multi-Core Programming with LabVIEW for High-End Control  
*Page Twenty*

The Power of Two Cores  
*Page Twenty-Four*

Reduce Size and Cost of Embedded Industrial Systems with Multi-Core Processors  
*Page Twenty-Eight*
This new XTXexpress module available from Ampro features the new Intel® Core™2 Duo Processors L7500 and the Intel® 965 Express Chipset. At 1.60 GHz, with a front-side bus speed of 800MHz, the processor dissipates just 17 Watts.

Figure 1

The performance is increased but under the hood, each element in the system is underutilized. This results in unnecessary costs. It also results in needless use of energy, both in terms of heat dissipation and its associated cooling costs as well as the expense of power consumption. The Intel® Core™2 Duo and Core™2 Quad processors with integrated Intel® Virtualization Technology and Intel® Active Management Technology (Intel® AMT) are a major advance in addressing both of these vital needs.

Manageability and configurability are also vital to the dynamic connected digital factory. To meet changing customer demands, machines and processes must be added and reconfigured rapidly and easily. Intel®-based modules with ever-increasing multi-core power and efficiency are ideal for keeping up with customer and production demands. Advanced graphics chips integrated on powerful embedded controllers are able to display real-time data for human operators in a distributed networked factory floor setting.

And then there are concerns about maximizing the investment in these powerful resources. Intel provides long life cycle roadmaps for its embedded processors and chipsets that keep parts available for at least five years. And the Intel® Architecture (IA) code base is compatible with processor architectures available now and into the distant future. All of these demands are addressed by the industrial technologies available from Intel.

Intel® Technology Fuels the Factory

Perhaps the most far-reaching technology advancement that affects industrial automation is the development of multi-core processor technology in the form of the Intel Core 2 Duo and Core 2 Quad processors. The ability to put multiple processor cores on the same die with shared cache memory and interprocessor communication support has enabled quantum increases in cost/performance and reductions in power consumption that translate to direct savings on the factory floor. It has also enabled the integration of multiple applications—both real-time and non real-time—on the same module, which contributes to increased modularity, flexibility and efficiency.

Getting more speed out of a single CPU by continuing to increase the clock frequency had reached a point of steeply diminishing returns, especially in terms of power and heat dissipation. But with two cores, or four cores, tasks can be assigned to different cores, increasing the overall throughput of the CPU without having to expend more power and generate more heat. That translates into savings at the system level because now more real-time control can be put into packages for fanless operation, resulting in smaller size and lower cost.

Assigning different tasks to different cores also allows dynamic load balancing as well as more utilization of CPU resources because fewer tasks of equal priority need to wait to execute than is the case on a single core. This enables the use of more complex applications before you have to consider adding more processor resources. But partitioning tasks is only one advantage.

Intel’s multi-core processors include hardware support for Intel Virtualization Technology, which enables multiple operating systems to operate on the same CPU. Intel Virtualization Technology supported by Virtual Machine Management software can, on an Intel Core 2 Duo processor, run an operating system such as Windows XP Embedded on one core while running a real-time operating system like VxWorks on the other core. The two operating systems can exchange messages by posting to and reading from shared memory, but neither ever intrudes on the CPU registers or partitioned memory of the other.

Thus VxWorks can be controlling a hard real-time process such as a robot arm for assembly operations while Windows XP embedded into a real-time operating system like VxWorks on the other core, which could then do its own task partitioning among them, while another RTOS works on a separate core in a secure partition and a third runs on a core that includes the user interface and Internet connection. Security is assured because any outside interaction via the Internet can be confined to that core and its operating system environment and will be unable to affect the other cores and their secure applications.
Intel Active Management Technology (Intel AMT) can ease manageability tasks such as software upgrades or fault detection. Intel AMT can, for example, provide an inventory of hardware assets on a node, indicate malfunctioning peripherals and allows secure access over a subnet-work even when the node is turned off. Thus maintenance personnel can gather data on nodes over the network, perform routine maintenance and diagnostics. This comes in handy when systems must be reconfigured for a change in manufacturing processes as well as for minimizing downtime.

Working in tandem with the multi-core processors is the fourth generation of the Intel® Graphics Media Accelerator X3000 (Intel® GMA X3000). The Intel GMA X3000 shares memory with the processor to speed graphics updates and offload the display processing burden from the CPU. The result is that even small form-factor modules can be equipped with sophisticated display capabilities that improve management and the human machine interface (HMI) at local factory stations or even in handheld devices.

Intel® based industrial grade computing platforms come together in a wide variety of board-level form factors from small ITX modules for localized high-speed control to blade servers for efficiently moving data on industrial networks throughout the factory operation and making access to needed information easily accessible to other parts of the operation, including inventory, purchasing and all the way up to the executive suite. All are united through the IA-32 code base for the ultimate in flexibility and scalability.

The glue that ties together processors, boards and subsystems is PCI Express. PCI Express has its origins in the PC, which has contributed so much to the industrial world in terms of industrial PC-based system. PCI Express is easily configurable, has extensive software support and current speed of 2.5 Gbit/s per line with lanes normally configurable from x1 to x16 lines. Lanes can be set up using silicon supplied by Intel or a number of other silicon vendors. The configurations are transparent to the user and the software and the only noticeable difference is, of course, the speed.

Although PCI Express is currently one of the fastest bus structures on the market, it is now poised to enter its second generation (Gen2) with silicon on the near horizon that will increase the basic speed to 5.0 Gbit/s by the end of 2007. Since most boards utilize x4 or x8 lane connections, that translates to 20 and 40 Gbit/s data transfers among very small form factor modules. There is additionally a specification for PCI Express over cable, which will enable high-speed peripheral connections and connections between multi-board chassis at Gen 2 speeds. And further out on the horizon, looking toward 2010, Gen 3 PCI Express is expected to double the transfer rate yet again, resulting in a basic speed of 10 Gbit/s. PCI is definitely the interconnect of the future for industrial applications. It is fast with a roadmap for more speed and also backward compatible in both hardware and software.

The Industrial PC

The attraction of PC technology for automation and control has existed since the first commercial PC was connected to control a machine. Since then, the PC has been repackaged for industrial use in several forms. One is the industrial PC contained in a small, rugged housing and based on a motherboard form factor such as ATX, ETX or PC/104 that is both compact yet allows for configuration through the addition of specific I/O modules and/or solid state or rotating storage.

The industrial PC had been able to take over many of the tasks once carried out by programmable logic controllers (PLCs), which were traditionally programmed in ladder logic, which emulates the wiring of physical relays and switches. An industrial PC is able to use software written to perform like ladder logic, but can also be programmed with more advanced control software to be able to handle more tasks and some real-time control functions. Furthermore it can include much more sophisticated control functions such as proportional-integral-derivative (PID) control loops, which
incorporate feedback from the device under control to adjust the control process in things like servo applications.

Recently, popular operating systems for Industrial PCs have been Windows XP Embedded and Windows CE. Both of these include a rich user interface and XP Embedded is able to address soft real-time applications and also handle user interface, networking and other compute tasks such as data logging. Windows CE has evolved to be capable of very deterministic operation while also maintaining a graphical user interface. This trend is bound to continue with the advent of Intel’s multi-core processors that are starting to appear on the very same form factor boards that are the foundation of the industrial PC. Now, thanks to Intel Virtualization Technology, a hard real-time RTOS such as VxWorks or QNX can run on one core while Windows XP Embedded or Windows CE runs on the other, making the enhancement of its functionality a smooth transition while preserving existing software investment.

New Looks for HMI

Such a trend in the industrial PC becomes very compelling when one looks at the human machine interface (HMI) as industrial PCs become more closely integrated with equipment. The graphical user interface is moving from workstations directly into industrial equipment along with the controller, making the usability of industrial devices more straightforward and bringing sophisticated graphics-based control to more points on the factory floor. A wide variety of Intel®-based panel PCs are available.

For example, the Panel PC V from Kontron incorporates an ETX Express board with an Intel Core Duo processor along with a 12.1-inch to 17-inch analog resistive touch screen in a rugged enclosure (Figure 2). It also includes five USB ports, high-speed networking, fanless operation and two open PCI slots. With this kind of capability, it can be used for any kind of interface from a relatively simple machine-specific GUI to a full-blown SCADA system.

The advantage of an Intel Core Duo processor in such a system is that one core can be devoted to running a “soft” real-time operating system like Windows XP Embedded for all the most common tasks such as the HMI software, networking communications, data logging, etc., while the other core can be completely dedicated to a real-time operating system performing the most time-critical operations. Data exchanged between the two OSs via the mechanisms using shared memory will not interfere with the RTOS operations. Such a panel PC puts it all in one rugged box: real-time control, graphical operator interface and any other needed computer operations thanks to Core Duo technology.

Intel’s graphic chipsets, such as the Mobile Intel® GME965 Express chipset are designed for low-power and incorporate the Intel® Graphics Media Accelerator X3000 which, with its massively threaded architecture, can simultaneously process multiple threads of graphic or video data simultaneously. This can be of great use in something like a manufacturing process that includes inspection where an operator may need to view some part being manufactured and also access
PACs, in contrast to their PLC ancestors, can source serial I/O signals from multiple sources. It monitors and controls digital, analog, and multifunctional signals; it can simultaneously handle multiple I/O signals. Add to this the built-in support for a wide range of display technologies and the choice of a single graphics solution can be applied to a wide selection of system implementations both large and small.

Intel’s low-power solutions, both in terms of Intel® ultra mobile chipsets as well as the Intel® ultra mobile processors, can extend the same powerful functionality into handheld and mobile devices for a high-end HMI on a small device to connect over a wireless link to a machine or process, which lets the operator use the same HMI on a smaller display. The ultra mobile chipset allows for a 7 watt solution in a fanless, embedded form factor while offering application scalability to higher-end Intel architecture-based devices. Intel’s low-power roadmap extends beyond Intel Ultra mobile and will continue to push the performance/power/cost envelope through advancements in process technology and architectural innovations.

**From PLC to PAC**

Renowned for their robustness and reliability, the programmable logic controllers that have traditionally been used in factory automation have been evolving with the development of microprocessor control systems. Originally oriented around ladder logic that imitated the wiring of physical relays and timers, PLCs that have incorporated computer control also need a way of handling more complex control tasks that cannot be defined in ladder logic. Tasks involving floating point arithmetic and PID control loops, for example, require higher levels of programming and processing.

As more computing power has been added to the PLC, it has evolved into the programmable automation controller, a computer-based system, which is multifunctional and can simultaneously monitor and control digital, analog and serial I/O signals from multiple sources. PACs, in contrast to their PLC ancestors, handle multiple domains like logic, motion, drives and process control on a single platform, which means they also use a single development environment with richer programming resources, a single database and the ability to use open architectures for interfaces, languages, and networking. The source of strength for a PAC is its processing power and its multiplicity of I/O capabilities. Most PAC manufacturers offer a huge variety of I/O modules for all kinds of special requirements. The I/O signals are then translated by the software. These capabilities are integrated in a rugged, industrial package.

All this, of course, makes increasing demands on processors. Intel offers a scalable range of processors, chips and networking silicon, including the Intel Celeron M and the low-power Intel Core 2 Duo processors that integrate processor cores, PCI Express, UARTs, USB 2.0, SATA and Gigabit Ethernet. This enables the development of controller systems with a scalable range of capabilities and price points but which share industry standards in terms of hardware compatibility, ease of development and modularity.

**Motion Control**

From small, high-speed “pick-and-place” operations to moving multi-axis robot arms and heavy equipment, motion control is an area where high-performance computing, real-time control and the need for high-speed communications converge. Sophisticated PID control loops must work from reference positions computed by the motion profiler portion of the motion control software. Then they must issue commands to motors, sense the resulting positions in relation to the reference points, compute the difference and issue new position commands in a steady real-time stream of incoming data and commands. In the case of multi-axis control, they must communicate their individual control and position status to each other to coordinate the motion for a common goal.

Intel® multi-core processors offer the computing performance of their individual cores coupled with the high-speed on-die communications that can bring the servo loops down into the 10 mS range. The developer has the option, depending on the demands of the application, to place the entire control operation on one core, reserving the other for a user interface, or to dedicate a core to the control of each axis. The use of a quad core processor extends these options and the amount of processing power that can be applied to them even further. Intel Virtualization Technology makes it straightforward not only to balance the loads that may be required for different axes, but also to move an application from, for example, an Intel Core Duo solution to a quad core solution with minimal effort. As Intel’s roadmap extends into the future, these basic technology foundations will continue to guide the transition to more powerful solutions.

**Machine Vision**

Computer vision systems are becoming increasingly important in an expanding range of industrial applications. These include pick-and-place, automated assembly, silicon fabrication, inspection, plant safety systems and even automated multi-robot manufacture of complex assemblies. A typical machine vision system consists of one or more cameras, and image capture/processing element, and some means of triggering processing along with the software for the needed tasks.

Machine vision depends on some of the basic DSP functions addressed by the Intel Performance Primitives IPP library, but that same library also contains functions specific to machine vision. These include feature detection, such as corner and edge detection, pattern recognition, distance transforms, optical flow calculation and camera calibration. The advent of the Intel Core 2 Duo has made it possible to include such sophisticated functions in a much smaller space and consuming much less power, resulting in the self-contained smart camera.

The smart camera incorporates the image sensor and lens (the camera) along with the embedded image processor,
network connectivity and a user interface. The embedded processor eliminates the need for a separate frame grabber board.

Once again, the use of the Intel Core 2 Duo architecture means that the dedicated computer vision functions can take place on one core while the networking and user interface operations take place on the other. The result is a compact, programmable vision systems that can easily be reconfigured and integrated into a wide range of possible equipment and applications.

Beyond the smart camera, quad core architectures open the way to the design of hybrid vision systems with a multiple cameras, each dedicated to a single core that can share data and coordinate operations, such as an assembly process. In addition, multiple smart cameras can be shared within an industrial PC-based control system.

Siemens has already implemented a robust industrial machine vision system based on the Intel Core 2 Duo in its SIMATIC PCs. One example, the Rack PC 847B, includes three PCI Express x4 slots, one x16 slots and 2 Gigabit Ethernet ports. Using such processing...
and data transmission power along with its Windows XP-based Visionscape software, developers can create rugged high-end industrial vision systems that can readily be reprogrammed for whatever tasks are at hand.

Test and Measurement
The idea of test and measurement usually brings to mind the use of individual instruments like oscilloscopes and frequency meters, but it is an integral part of the manufacturing process. Monitoring processes, such as the temperature and levels of liquids in vessels, the flow of materials into a mixer must be able to present the results to automatic control processes as well as to human operators. Technologies like PCI Express rapidly get data from I/O modules and sensors to the processors that integrate it into control loops and simultaneously send it to HMI displays.

Working with high-end control and programming systems such as National Instruments’ LabView, connected modules based on Intel processors can be monitored and configured with a straightforward graphical tool. LabView is now available in Version 8.5, which supports multi-core development and includes modules for high-end control design, including Model Predictive Control (MPC) and advanced filtering algorithms. Using a tool like LabView with connected Intel-based modules, and an operation can be set up that implements control and instrumentation in the same application and which connects multiple applications into an overall plant operation. Intel partners like National Instruments are constantly working with Intel as its technology develops to produce tools that can help developers quickly take advantage of the advances in their day to day operations.

Building the Digital Factory
Outwardly, a factory is traditionally built with bricks held together by mortar. Inwardly, today’s modern factory is built of intelligent modules held together by networks and software. Intel and its partners offer a vast selection of board-level modules, all of which are rapidly becoming available supported by the very latest multi-core processor and high-speed graphics technology from Intel. Increasingly, the emphasis is on performance per watt per square centimeter and this is leading to exciting new developments in modules and form factors.

Intel® SoCs
Intel has announced plans to also bring to market in 2008 a range of highly integrated system-on-chip (SoC) processors that will combine multiple system components into a single chip design. Instead of three chips on a board, the...
new SOC products will allow developers to use just one device that integrates an Intel® Architecture processor, an MCH Northbridge and an ICH Southbridge. Additional capabilities will be integrated on different models including Gigabit Ethernet, PCI Express, SATA, USB 2.0 and others to offer a range of pre-integrated selections.

The benefits of the new SoC include lower system and development costs, easier design, smaller form factors, and even greater power-performance efficiency. These devices will be extremely attractive for use in applications such as industrial control, where the integration of IEEE 1588 hardware-based control, Gigabit Ethernet MACs, and security accelerators on to a single-chip will be expected to reduce chip sizes by up to 45 percent and power consumption by approximately 20 percent compared to a standard three-chip design, while improving throughput performance and processor efficiency.

Replacing DSPs

In many industrial applications that require the use of digital signal processing, such as machine inspection or filtering and transforming input signals from real-world events, it has been necessary to either use a dedicated digital signal processor (DSP), which then had to communicate with other elements in the control systems, such as the main CPU or a data network. This involved separate memory systems, some high-speed communication link between processors and separate areas of software development expertise. Alternatively, there has been an option to offload dedicated DSP functions to an FPGA. While both approaches can achieve the needed performance, the also involve overhead in terms of data transfer, silicon cost, board real estate, power consumption and development costs.

With the ever-increasing computational power and speed of today’s processors, Intel has been able to close the gap between the needs of a large segment of DSP tasks and the ability of software using the Intel architecture to perform at the required speed. Intel has developed a software library called the Intel® Integrated Performance Primitives (Intel® IPP), which is now optimized for use on multicore. Included in the Intel IPP are a set of DSP functions that includes filtering and convolution operations such as finite impulse response (FIR) and cyclic convolution. It supports transforms such as FFT and discrete cosine transforms (DCT) along with array/signal initialization and manipulation, array signal statistics and array arithmetic and logic operations.

Implementing such DSP function-
RadiSys Corporation
Endura TP945GM Long-life Mini-ITX Express Motherboard

The Endura TP945GM is optimized for use with the Intel® Core™ 2 Duo T7400, Intel® Core™ Duo T2500 and Intel Celeron M 440 processors for high performance, low power applications with operating temperatures up to 60C. For ultra low power applications, the Endura TP945GM is also available with the Ultra Low Voltage Intel® Celeron® M BGA processor, which has a thermal design power of just 5.5W. This processor enables the board to be passively cooled in extended temperatures up to 70C. The Endura TP945GM is therefore ideal for use in rugged, space constrained applications with demanding thermal performance characteristics.
Lower Development Costs of Industrial Control Systems with Resource Partitioning

A modern industrial control system may contain dozens or even hundreds of software tasks, all competing for a finite amount of memory and CPU time. To speed development of such complex systems, companies will often divide the work among multiple development teams, assigning each team the job of creating a separate software subsystem. Given the parallel development paths, performance issues often arise at the integration phase, when, for the first time, the various subsystems begin vying with one another for system resources. Subsystems that worked well in isolation now respond slowly or simply fail to operate.

Diagnosing and solving such problems is intrinsically difficult. Designers must juggle task priorities, possibly change thread behavior across the system, then retest and refine their modifications. The entire process can easily take several calendar weeks, resulting in increased costs and delayed product.

Resource partitioning offers a way to manage these complex integration issues. Using this approach, the system designer can isolate software subsystems into separate containers, or partitions, and allocate a guaranteed portion of memory or CPU time to each partition. For example, the designer can place a set of threads that have a common purpose (such as motion control) into a partition and allocate the partition 50% of the entire CPU capacity. The partitioning scheduler will then guarantee that this partition always receives its allocated CPU budget.

In effect, each partition provides a stable, known runtime environment that development teams can build and verify individually. If the software processes within a partition perform well during unit testing, they will, with a high degree of confidence, exhibit the same performance at integration time. Unforeseen resource contention among subsystems can be eliminated.

Avoiding Thread Starvation

In most cases, a typical control system schedules threads using a priority-based preemptive scheduler, which always gives CPU time to the highest-priority thread that has work to do. This type of scheduler is widely used and well-understood, and it helps ensure that time-critical threads always meet their deadlines. It does pose a problem, however: If a given thread is even one priority level higher than another thread, it can potentially starve the less-critical thread of CPU time.

Imagine you have two threads, A and B, where A has a slightly higher priority than B. If A becomes swamped with work, it will lock out B (as well as any other lower-priority thread) from accessing the CPU. In an industrial control system, A could be the robot arm control loop and B the human machine interface (HMI). If the control loop consumes too many CPU cycles, it will prevent the HMI from displaying updates or make the HMI unresponsive to operator input.

As control systems become more complex and design teams grow, assigning and maintaining priorities for a large number of threads becomes increasingly difficult. Realizing that unconstrained priority assignment yields to chaos (or a nonoperational system), system design-
Simplifying Development and Testing

With time partitioning, the system designer can define an OS-enforced CPU budget for each software subsystem. Moreover, each team can easily test their subsystem to ensure that it works within those defined budgets. At integration time, the RTOS will enforce the resource budgets, preventing any subsystem from consuming resources needed by other subsystems. Each system will work as expected — and as previously tested.

In effect, partitioning makes it much easier for development teams to work in parallel. As a developer, you no longer have to worry about the priorities of threads outside of your subsystem: those threads won’t impact your performance, even if they run at a higher priority than yours.

Within a partition, threads are scheduled according to the traditional rules of a preemptive, priority-based scheduler. In effect, each partition becomes a separate virtual processor, allowing each design team to define a subsystem-level priority scheme appropriate to their subsystem’s requirements. The need to enforce global priority schemes is eliminated.

To appreciate these benefits, consider a simple system designed without the use of time partitioning. The system illustrated in Figure 1, contains the following processes:

- A high-priority process for motor control
- A low-priority process for motor control
- A medium-priority process that handles the local human machine interface (HMI)
- A medium-priority process that performs periodic sensor scanning

When the system is brought together at integration time, all processes will receive their share of CPU time as determined by their priorities.

If any of the processes have the same priority, the ready queue can become very long. A ready thread must consequently wait until it reaches the head of a long queue before it can run.

As a result, the HMI issues commands that result in a high level of motor control, the remote monitoring agent doesn’t receive any CPU time, and the HMI becomes starved when the system operates at full CPU load.

Trying to solve the problem, the system designer assigns the local HMI a lower priority than the remote monitoring agent. However, this approach leads to an unacceptable level of performance for the HMI. Setting the remote monitoring agent, sensor scanner, and HMI to medium priority doesn’t work either, as it compromises the performance of all three processes. Because priority reassignment doesn’t resolve the issue, the development team must take the next step and attempt to change thread behavior — a costly solution at the integration stage.

Partitioning provides a way to avoid these integration headaches. For instance, the system designer could set a CPU budget for each of the four partitions: 10% for the HMI partition, 10% for the remote monitoring partition, 30% for the sensor scanner partition, and 50% for the motor control partition.

With this approach, each partition can be verified according to its CPU budget. When the system is brought together at integration time, all processes will receive their share of CPU time as determined by their budget. As a result, the remote monitoring agent will no longer starve when the system becomes fully loaded. Furthermore, by simply changing the partition budgets, the developers can trade off local HMI response time with remote update time to tune the system to the desired performance level.

Properly implemented, a partitioning scheduler will allow developers to perform this tuning at runtime, without forcing them to rebuild their applications or the system image. Figure 2 shows a tool for dynamically tuning partition budgets.
Figure 3 In the symmetric and bound multiprocessing models, partitions can flexibly span across multiple cores.

Although one could argue that appropriate system design and careful priority assignment can fix the problems in this relatively simple system, the many subtle interactions in a more complex system can result in task starvation issues that are much more difficult to troubleshoot and correct. It is in these types of systems where partitioning shows the largest benefits.

Quantifying Development Savings

Often, task starvation results in intermittent, unexplained system behavior rather than in hard failures. Consequently, it is difficult to collect the appropriate data for follow-up troubleshooting. In most cases, the troubleshooting activities demand both a breadth and depth of system knowledge and therefore require a team to find and repair the problem. These activities can include those listed in Table 1 along with the conservative estimate of cost per incident.

From this example, it is easy to see how task starvation can easily cause development delays; in this case, two to three calendar weeks. Even then, this example considers only four threads — many industrial control systems have dozens of threads that interact in hundreds of ways as they compete for CPU time. As a result, it is common for several cases of task starvation to occur in even a moderately sized system. By preventing one subsystem from robbing another subsystem of CPU time, partitioning provides an efficient

Ardence, a Citrix Company

RTX

RTX is the only software solution designed as a high-performance extension to control Microsoft Windows. RTX is proven in thousands of demanding applications to provide enhanced performance, control, and scalability combined with unmatched dependability for industrial automation, military/aerospace, test and measurement equipment, robotics, and many other industries, all while reducing system costs and speeding time to market.

Overview

RTX is specifically designed as a real-time extension to the Windows operating system and is not an RTOS ported to Windows. RTX provides precise control of IRQs, I/O, and memory to ensure that specified tasks execute with proper priority and 100% reliability. By operating in Ring 0, RTX ensures the highest performance and requires minimal configuration, supporting sustained interrupt rates of 30 KHz with an average IST latency of less than one microsecond.

Software engineers using RTX benefit from optimized tools that simplify development by providing the information to quickly and accurately troubleshoot and resolve development issues.

- RTX is based on the Windows Win32 API, and because of this, code can be built as windows executables (EXE) that run in Ring 3 to utilize memory protection. They can also be recomplied as a real-time subsystem (RTSS) executable that runs in Ring 0, where performance can be optimized with RTSS applications taking precedent over all Windows applications.

Key Features

- Robust, High-performance Windows RTOS Extension in Ring 0: sustained interrupt rates of 30 KHz
- Smallest operational footprint - 250KB
- Support for all standard Microsoft HALs: including ACPI compliant PIC, uni-processor and multi-processor ACPI
- Win32 API compliant: no need to use code wrappers for API mapping

- Complete x86 CPU support: including multi-processor and multi-core in either shared or dedicated mode
- Priority Inversion Avoidance with Promotion: ensures that lower priority threads do not impact application performance
- Priority-driven or preemptive scheduling: assignable on a per thread basis
- WinSock compliant TCP/IP stack: independent of Windows
- High-speed Inter-Process Communication (IPC) mechanism
way of dealing with these task starvation issues.

Partitioning schedulers vary. Some strictly enforce CPU budgets at all times, so that each partition will consume its full budget even when it has no work to do. Other implementations can dynamically allocate these unused CPU cycles to other partitions, thereby maximizing overall CPU utilization and allowing the system to handle peak demands.

Bringing Resource Partitioning to Multi-Core

The idea of resource partitioning takes on an entirely new dimension when you add partitioned hardware resources in the form of multi-core processors. To date, partitioning has been used almost exclusively in single-processor systems. But with the growing proliferation of multi-core chips such as the Intel Core2 Duo and Intel Core2 Quad processors, developers now need a way to implement partitions across two, four, or more processing cores.

Therein lies the challenge. In a single-processor system, the RTOS allocates CPU capacity to each partition. To extend this concept across every core in a multi-core system, the RTOS must have the ability to control multiple cores simultaneously.

An RTOS can support asymmetric multiprocessing (AMP), symmetric multiprocessing (SMP), bound multiprocessing (BMP), or any combination of the three. In AMP, a separate instance of the RTOS runs on each core. This approach treats each core as a discrete CPU and, as a consequence, prevents partitions from spanning multiple cores. In SMP and BMP, on the other hand, a single instance of the RTOS can manage all of the chip's cores. This approach gives the RTOS an overall system view, allowing it to use all of the available cores for partitioning.

With SMP and BMP, the system designer can flexibly map partitions onto multiple cores according to system requirements — and independently of processor boundaries. For instance, in Figure 3, Secure Partition 1 spans across two cores while the other partitions run on single core.

This flexibility accommodates platform evolution. For instance, introducing new software features to a partition may stress it to the point where a single core can no longer handle the load. If so, the partition can easily be expanded to encompass two cores. Moving to a different multi-core processor may also require changes to partition budgets, again creating the need for partitions that span multiple cores.

QNX Software Systems
Ottawa, Ontario.
(613) 591-0931.
www.qnx.com

ADLINK Technology
NuPRO-965

The NuPRO-965 is an SHB Express (PICMG 1.3) system host board supporting the powerful combination of the Intel® Core™2 Quad / Core™2 Duo family of processor families and the Intel® Q965 chipset for improved system manageability, graphics, and stability. The NuPRO-965 also supports the Intel® Pentium® D, Intel® Pentium® 4, and Intel® Celeron® D processors on a front side bus up to 1066 MHz to support a wide range of performance requirements. This performance is further enhanced by backplanes, which allow 10 Gb/s bandwidth from/to the system host board to eliminate data bottlenecks between the I/O cards and memory. The four DIMM slots support up to 8 GB of dual channel DDR2-800 RAM with a peak transfer rate at 12.8 GB/s.

The NuPRO-965 integrates a 3D graphics engine based on the Intel® Graphic Media Accelerator 3000 (Intel® GMA 3000) architecture with Microsoft® DirectX® 9.0 to provide the high-end graphics performance. The PCI Express® x16 lane offers the possibility for additional high-end graphics options. There are four PCI Express® x1 lanes for a variety of high-bandwidth I/O applications, two Ethernet connectors for redundancy, support for four 3.0 Gb/s Serial ATA storage devices, four USB 2.0 ports, and an UltraATA/133 IDE interface.

This unique combination of the support for the latest high-performance processors, memory, and bus technologies makes the NuPRO-965 ideal for industrial automation, process control, medical instruments, surveillance systems, and network security applications.
Best Practices: Managed Control of Networked Embedded Systems

Giving management access to industrial control systems requires an operating system strategy that can allow the needed access—with security—and still guarantee the high performance and real-time determinism required.

by Steve Woodard, Ardence, a Citrix Company

As the performance and manageability requirements for embedded and enterprise computing environments continue to converge, embedded IT executives face formidable new challenges in attaining the levels of managed control that enable them to create and maintain optimized systems. Fortunately, by taking advantage of innovative embedded and enterprise technologies, IT and the business can achieve the desired performance, manageability, security, reliability, and supportability for an industrial controller.

From an embedded computing perspective there are some key criteria for meeting IT’s desired managed control needs as well as the business goals for managed control and from these can be derived as set of best practices that can be brought to bear to assure success. The key criteria include:

- Performance optimization for embedded systems includes precision accuracy, high availability, direct access to hardware, and real-time processing.
- Manageability includes centrally managed system delivery and upgradeability, as well as re-configurability
- Security for embedded systems entails protection from data theft and elimination of the possibility that malware installs via networked access.
- Reliability involves failover protection, and reducing or eliminating downtime from corruption.
- Supportability is attained by using standards-based hardware/software platforms, and ensuring compatibility by using tools that simplify and streamline system development, maintenance, and diagnostics.

Clearly, three of these criteria – performance optimization, reliability, and security – have long been strong points for traditional embedded industrial systems. And while the trend toward networked deployments provides the opportunity for increased manageability and supportability, there is a risk that embedded system strong points can become vulnerabilities.

For example, networked industrial controllers that run time-critical motion-control applications can suffer from unacceptable performance degradation caused by malware being installed, or from over-reliance on a server’s processor. Additionally, networked devices offer access points for data theft and security
“The QNX Neutrino microkernel OS has the perfect DNA for multi-core processors”

Dan Dodge. QNX CEO & CTO. Pioneer in distributed and multiprocessor computing.

Introducing the QNX® Momentics® development suite Multi-Core Edition, the industry’s most comprehensive software platform for multi-core systems. Powered by the massively scalable QNX Neutrino® RTOS, this fully integrated solution supports AMP, SMP, and BMP, a groundbreaking technology that simplifies code migration and future-proofs your designs for quad-core and beyond. It’s the latest innovation from QNX Software Systems, the undisputed leader in multiprocessing technology.

Maximum Choice for Multi-Core

Only QNX gives you the power to choose the best multiprocessing model for your multi-core design:

<table>
<thead>
<tr>
<th></th>
<th>SMP</th>
<th>BMP</th>
<th>AMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seamless resource sharing</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Scalable beyond dual-core</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed OS environment</td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Dedicated processor by function</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Inter-core messaging</td>
<td>Fast (OS primitives)</td>
<td>Fast (OS primitives)</td>
<td>Slower (application)</td>
</tr>
<tr>
<td>Thread synchronization between cores</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Dynamic load balancing</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>System-wide debug &amp; optimization</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

QNX Unlocks the Power of Multi-Core

Maximize performance. Eliminate complexity. Accelerate migration. Only QNX offers:

- **Asymmetric Multiprocessing (AMP)** for full developer control and fault tolerance
- **Symmetric Multiprocessing (SMP)** for maximum concurrency and scalability
- **Bound Multiprocessing (BMP)** for the fastest code migration and minimum design complexity
- **System tracing tools** for fast debugging and optimization of multi-core applications
- **Off-the-shelf BSPs** for multi-core platforms based on MIPS®, PowerPC®, and x86 architectures

Discover how Dan and the QNX team deliver the shortest migration path to multi-core. Call 1 800 676 0566 or visit [www.qnx.com/innovate](http://www.qnx.com/innovate).

QNX, Momentics, and Neutrino are trademarks or registered trademarks of QNX Software Systems GmbH & Co. KG and are used under license by QNX Software Systems International Corporation. All other trademarks belong to their respective owners.
breaches. How then can managed control be attained in the new networked world of embedded devices?

Ardence, a Citrix Company, has developed best practices for delivering managed control through software solutions that enable Dynamic Devices™. A dynamic device comprises standards-based hardware and software; the OS and applications are delivered on-demand – not deployed. By streaming the device’s required OS and software on demand – including hard real-time control capabilities for Windows – Ardence can provide all of the desired managed control advantages while eliminating vulnerabilities.

Take the example of networked factory-floor controllers, using a combination of on-demand OS/application-streaming technology developed by Ardence and Ardence® RTX®, the high-performing deterministic control solution for Microsoft® Windows.

The controllers are performance optimized, secure, centrally managed, reliable and supportable. Security, manageability and supportability are achieved by on-demand streaming of the OS/application image. And with RTX included in the device image, optimized performance and reliability are assured.

Developers are creating and optimizing a variety of dynamic devices by utilizing Ardence software in a variety of combinations to address the required criteria for a fully controlled, networked system.

Ardence RTX for MP and Intel® multi-core Processors-based Systems

RTX was the first real-time extension to support Intel® multi-core architectures, and has done so since 2005. Ardence also supports Intel® vPro™ Processor technology as well as all of Intel’s new multi-core architectures. Before 1999, RTX ran on single processor systems only. But for more than 8 years, RTX releases run on multiprocessor systems and on Multi-Core systems as soon as they were introduced.

Intel Multiprocessor Specifications provide for interrupts to be controlled by an advanced programmable interrupt controller (APIC), suitable for a multiprocessor system. Through the APIC, different interrupts can be steered to different sets of processors.

On a multiprocessor system (MP), RTX can be configured in one of the following ways as shown in Figure 1:

• Shared Mode - One processor handles both RTX and Windows processing; all other processors are dedicated to Windows processing.
• Dedicated Mode – The real-time subsystem (RTSS) of RTX dedicates one processor of the system to running RTSS threads, while the remaining

---

DIGITAL-LOGIC

MSM945 PCI/104-Express CPU Board

The new MSM945 in PC/104 format is based on the COM Express compliant SMX945-L7400 module with Low Voltage Intel® Core™ 2 Duo Processor with clock rates of 2x1.5GHz, 4’096kB L2 cache, 667MHz FSB and up to 2GB DRAM. It is supported by the Intel 945 GME Express Chipset. The PCI/104-Express represents a forward-looking standard which will make it possible, even within the next 10 to 20 years, to develop computer boards on the PC/104 form factor and to employ the new serial bus standards.

The new MSM945 CPU board features a vast variety of interfaces with 6xUSB V2.0, 2xPS2, 2xCOM, LPT and LAN. It has one Video/SDVO and one AC97/HDA-compatible 7.1-sound interface, one floppy disk, one P-ATA and two S-ATA150 interfaces. Stackable extension is provided with the 32-bit PCI port and the PCI Express port with 4 automatic shifted PCI Express lanes, PEG (PCIe 16 lanes), 2xSDVO, 2xUSB V2.0, SMB and ATX signals. For displays, the MSM945 board uses the graphic controller of the Intel 945 GME Express Chipset with up to 224MB video memory. The video controller offers two 18-bit LCD interfaces. It supports resolutions with up to 2048x1536 pixels.

The MSM945 can run fan-less with passive cooling or with active cooling-fan at extended temperature of -25°C to +70°C. Designed for low current consumption with high video performance, it is the ideal solution for video processing, video streaming and data processing. The MSM945 module is perfectly suited for embedded computing with high CPU and graphics performance, in transportation, telecommunication, medical, or aerospace applications.
processors run Microsoft Windows XP threads. This dramatically lessens the latency of real-time threads while preventing the processor starvation of Windows XP threads possible on a single processor system.

- Symmetrical Multi-processing – RTSS will assign threads and tasks to pre-determined cores

The Ardence Product Suite

Ardence® RTX® is the highest-performing deterministic control solution for Microsoft® Windows – saving developers time, reducing system costs and getting products to market faster. It is the only complete solution that supports standards-based multi-processor and multicore platforms. RTX enhances Windows’ universally adopted look/feel with features that give developers real-time determinism, better control, and unmatched dependability.

The Ardence® Software-Streaming Platform™ enables cost reductions and productivity gains by centralizing the delivery and control of the operating system and applications. Streaming the OS and applications from the network provides devices with unmatched manageability and reliability, while reducing operating costs. PCs and devices can be operated without a hard-disk drive and be managed remotely via a local or remote server. The OS and application are processed locally on the client devices, without the need for increased RAM, and the clients maintain direct access to peripheral devices.

Ardence® Select™ is a next-generation product (the direct result of customer feedback) that provides single OS systems with the ability to boot to multiple configurations, or “personalities.” OEMs can easily re-configure and update products remotely, and even provide multiple configurations based on boot-sequence options. This device-configuration manager enhances the user experience and provides a separate utility configuration that helps in system diagnostics and enables rapid recovery.

Ardence® ReadyOn® enables OEMs to integrate instant availability with enhanced reliability and corruption protection into their Windows-based designs. Additional benefits include reducing manufacturing costs and speeding time to market. The enhanced end-user experience of instant-on/off functionality and secure, corruption proof reliability in devices using the Windows operating system provides OEMs with clear competitive advantages and the required functionality to compete in tomorrow’s markets.

Ardence
Waltham, MA, (781) 647-3000.
www.ardence.com

MEN Micro Inc.
F18 CompactPCI SBC

The new single-slot, 3U CompactPCI Express F18 incorporates the latest Intel® multi-core technology, employing the Intel® Core™ 2 Duo T7500 processor operating at 2.2 GHz and offering full 64-bit support with 4 GB of addressable memory. The versatile SBC offers a 32-bit/33 MHz CPCI bus interface and can function without a bus as well. In addition, various side cards easily extend the board’s functionality. For example, a specific side card enables the F18 to perform system-slot functionality in a CompactPCI Express system.

Designed for embedded systems requiring high computing performance coupled with low power consumption, the F18 is used in a wide range of industrial applications such as monitoring, vision and control systems, and test and measurement throughout the automation, transportation, aerospace, robotics and medical engineering industries.

The board features six PCIe lanes for high-speed communication (Gigabit Ethernet, graphics, etc.) and two x1 PCIe links used for the two onboard Ethernet interfaces. Standard I/O available via the front panel includes graphics on the VGA connector, two PCIe-driven Gigabit Ethernet interfaces and two USB 2.0 ports. Additional functions include two digital video inputs for flat panel connection via DVI (multimedia), a variety of different UARTS, SATA for hard disk or RAID connection as well as HD audio. Four additional USB 2/0 ports can also be added using a side card connector.

The F18’s 2 GB soldered DDR2 DRAM withstands significant shock and vibration. A robust CompactFlash interface through onboard IDE offers virtually unlimited space for user applications.
To bring out the full advantages of multi-core processors requires a software development tool that is also inherently capable of expressing parallelism.

by Jeff Meisel, National Instruments

To take advantage of multi-core processors for high-end control applications, engineers can gain real advantages by leveraging parallel software to maximize key system requirements. These include control loop rates, number of data channels, and algorithm performance. One way to do this, is to use a high-level language that takes care of a lot of work involved with parallel programming.

National Instruments LabVIEW is a programming language which is inherently multithreaded to allow for optimal execution of control applications on parallel hardware. For example, a block diagram with a filter operation and a spectral measurement operation will execute in parallel and utilize both cores in a dual-core based system simply because the diagram is drawn in parallel (Figure 1).

LabVIEW also supports programming models that allow engineers to abstract the complexity of the application at hand – all of which leverage the same LabVIEW multithreading technology under the hood. Programming models supported in LabVIEW include configuration-based, textual math, simulation models, and state charts. State charts are the latest addition to the LabVIEW family, and are a visual representation of reactive, or event-driven, systems which evolved from the classical state diagram used to represent finite state machines. Figure 2 shows an example of a state chart used to represent a control and logging application. Notice how the distinct states and transitions provide a clear high-level view of what’s happening in the system.

Choosing the right language to express parallelism is critical in a multi-core design; however, that alone does not ensure a successful project. Examining the complete software stack helps to evaluate key problem areas in developing multi-core-ready software.

The real-time software stack consists of development tools, libraries, device drivers, and a real-time operating system. Many real-time control applications from previous generation systems were built on a software stack intended for single-processor designs. Companies migrating software to a multi-core processor experience varying levels of scalability, and should look at each layer of the stack for readiness. Table 1 lists a few key consider-
What It Means to Be Multi-core Ready

Development Tool
Support is provided on RTOS, tool allows for threading correctness and optimization. Debugging and tracing capabilities are provided to analyze real-time multi-core systems.

Libraries
Libraries are thread-safe and can be made re-entrant so they may be executed in parallel. Algorithms are in place so as to not cause memory allocation and induce jitter into system.

Device Drivers
Drivers are designed for optimal multithreaded performance.

Real-Time Operating System
RTOS supports multithreading and multitasking, and can load balance tasks on multi-core processors with SMP.

Table 1 Real-time software stack considerations for control applications.

<table>
<thead>
<tr>
<th>Processor</th>
<th>Channel Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single CPU 2.4 GHz Intel® Pentium® 4 Processor</td>
<td>22 Channels</td>
</tr>
<tr>
<td>Single CPU 3.0 GHz Intel® Pentium® 4 processor</td>
<td>29 Channels</td>
</tr>
<tr>
<td>Dual-Core 3.0 GHz Intel® Pentium® D processor</td>
<td>50 Channels</td>
</tr>
<tr>
<td>Quad CPU 2 Dual-Core Intel® Xeon® Processor 5103</td>
<td>80+ (never reaches the limit)</td>
</tr>
</tbody>
</table>

Table 2 Channel limits for transmission testing application on single- and multi-core processors.

application was a control loop that executed deterministically while simultaneously acquiring many channels of data. A short time ago, Eaton's transmission testing application was running on single-core processor desktops limited to 16 channels of data. To get to the point where they could test all data in a single dynamometer, Eaton would have needed 15 desktops. Such a configuration would have been unwieldy for many reasons. The ability to measure transmission performance while a vehicle is operating on open roads would make for more ideal test conditions and provide better feedback to Eaton's engineers. Therefore, Eaton's goals for improving their transmission testing platforms were identified as follows:

- Increase platform performance to allow for the processing of more data channels without affecting determinism or real-time analysis.
- Shorten the test and product development cycle to help speed time to market for new solutions.
- Stay within the current system footprint so that power consumption and thermal output do not increase.
- Continue to use standard, off-the-shelf PC technology to maintain compatibility with customers' systems and keep costs down.
- Harness the multithreaded architecture of LabVIEW software to improve test efficiency.
- Move the Eaton test application to the vehicle to allow portable testing.

Eaton performed tests to evaluate the LabVIEW-designed application using different desktop configurations, all with Intel® processors. Eaton's internal benchmark tests were run using the company's three-loop application performing real-time data acquisition, analysis, statistical trending, and sequence control. The channel limits reached on each platform are noted in Table 2.

"With the multi-core architecture of Intel's newest chips, we can finally take advantage of the automatic multithreaded design of the LabVIEW software to get to real-time data acquisition, analysis and feedback that meets the requirements of our application" said Scott Sirrine, Lead Design Engineer in Eaton's Truck Division. "Not to mention the fact that LabVIEW as a programming language presented our engineering team with two
key advantages over other programming languages – development productivity and execution performance. Engineers looking for faster control loop rates, a high number of data channels, and improved algorithm performance, need to consider how they can implement parallel applications. With LabVIEW, you can take advantage of a software environment that is ideal for parallel programming because of the dataflow nature of the language. LabVIEW also includes programming models such as statecharts to allow different levels of abstractions to solve applications. In addition, applications can take advantage of a top-to-bottom “multi-core ready” software stack, as the example from Eaton Corporation illustrated.

National Instruments
Austin, TX.
(512) 338-9119.
www.ni.com

Advantech Corporation
Multi Core Industrial ATX Motherboard

Advantech’s industrial motherboard AIMB-764 offers rich performance and expandability. With an ATX form factor measuring roughly 12.01” x 9.61” and the capacity to support up to seven expansion slots, AIMB-764 is built for servers and other high-end applications. Its standard size ensures easy compatibility with readily available enclosures, simplifying the installation process and enabling quick upgrades. Most connectors and interfaces are directly implemented on the standard-size ATX board, and since the connectors are identically arranged, external interfaces are easy, especially during system updates. It is equipped to support the most demanding applications with an Intel® Core™2 Duo processor and up to 8 GB of DDR2 SDRAM. Multi-core processors are driving traditional processors off the market because they can control separate functions simultaneously while boosting performance. The power consumption of multi-cores remains the same as traditional CPUs; however, data output per watt rises dramatically. A multi-core processor can run Windows and control the human-machine interface on one core, and run a RTOS for the machine control system on the other core. In addition to multi-core technology, AIMB-764 comes with five SATA II ports with a 300 MB transfer rate, PCIe x16 slot for a graphic card, one PCIe x4 slot and five PCI connectors to enable extensive expansion. AIMB-764 supports dual 10/100/1000Base-T Ethernet via a dedicated PCIe x1 bus. RAID 0, 1, 5 & 10 is also supported.
NI LabVIEW. Limited Only by Your Imagination.

- Build and program robots with LEGO® MINDSTORMS® NXT using software powered by NI LabVIEW
- Develop your human machine interface (HMI) display
- Independently control multiple servo motors
- Communicate via multiple protocols including Bluetooth
- Graphically program concurrent, real-time applications
- Target 32-bit microprocessors and FPGAs

PRODUCT PLATFORM
- LabVIEW Real-Time Module
- LabVIEW FPGA Module
- LabVIEW Microprocessor SDK
- NI CompactRIO Embedded Hardware Platform

When the LEGO Group needed parallel programming and motor control tools intuitive enough for children, it selected graphical software powered by NI LabVIEW. With LabVIEW graphical system design, domain experts can quickly develop complex, embedded real-time systems with FPGAs, DSPs, and microprocessors.

>> Expand your imagination with technical resources at ni.com/multicore
The Power of Two Cores

Maximizing the power of industrial PCs by increasing clock frequency reached its limits because the processors could no longer be sufficiently cooled. The new industrial PCs by Siemens with Intel® Core™2 Duo processor technology achieve a higher computing power without increasing power consumption.

by Thomas Steinhorst and Dr. Lutz Heinrich, Siemens

Particularly high-performance applications require powerful industrial PCs like those now offered by the new Siemens IPC product range with Intel Core 2 Duo processors. These computers are equipped with a chipset that integrates powerful graphics and memory technology of the latest generation and, together with the current PCI-Express bus technology, feature the computing power required for demanding automation solutions.

The innovative capacity of the Intel Core 2 Duo processor must not be underestimated as a processor which was originally developed for notebooks has been successfully transferred to the industrial environment. Thus, the Intel Core 2 Duo processors offer, on the one hand, the power of the two processor cores with substantially improved microarchitecture and, on the other hand, the low power consumption of a Intel® Pentium® M processor.

Like the previous Simatic PCs, the new industrial PCs are available as system solution in three designs for diverse requirements in industrial applications: as Rack PC, Box PC or Panel PC. All designs are equipped with the same motherboard, which offers advantages in terms of spare parts management (uniform memories, processors, power supply units) and operating system installation. Whether a Rack, Box or Panel PC is employed, the BIOS structure is identical thanks to the uniform motherboard. Additionally, also the drivers are standardized, which provides benefits particularly for non-Windows-users as regards system generation.

Last but not least, the integration and test expenditures accruing in connection with the integration of the customer’s application in diverse PC designs is substantially reduced.

Rack PC for maximum expandability

With its standardized dimensions, the 19-inch Simatic Rack PC 847B with a depth of only 450 mm is designed for installation in control cabinets but can also be used as stand-alone device (Figure 1). The development of this industrial PC mainly targeted the aspect of expandability: eight or optionally eleven free PCI-/PCI-Express slots also allow for the use of long expansion cards. If the integrated onboard graphics card is not sufficient, a powerful PCI-Express x16 graphics card can be installed. Furthermore, a variety of integrated interfaces for communication on the field or control level is available: Two Gigabit-Ethernet interfaces can be optionally integrated as can a Profibus/MPI interface for the cost-effective connection of distributed field devices or to Simatic S7 programmable logic controllers. In addition to six high-speed USB ports, the computer also has so-called legacy interfaces such as LPT and COM 1 and 2. It can therefore be easily integrated also in older plant architectures.

For faster data transmission and improved drive reliability, hard disks with native command queuing (NCQ) technology are employed. The hot-swap removable frame and the RAID1 mirror disk configuration, which allow for hard disk replacement during operation, guarantee a high system availability and data protection. The RAID controller is already onboard and does not occupy an additional PCI slot.

Tailored to applications in industrial...
environments, the Rack PC offers a high electromagnetic compatibility (EMC) as well as shock and vibration resistance. Even at ambient temperatures of up to 50 degrees Celsius, the computing power does not decrease as throttling is not necessary. The enclosure is very dirt-resistant and protected against dust through the positive pressure ventilation with temperature-controlled fans and replaceable filters.

Box and Panel PCs for Machine-Level Applications

As a space-saving industrial PC, the Simatic Box PC 627B (Figure 2) is particularly designed for machine-level applications. Occupying minimum space – with a volume of only 6 liters – it is as powerful as the Rack PC. Chipset and motherboard are identical. As storage media, up to two SATA hard disks can be installed, which are currently available at up to 80 GBytes. The system offers flexible installation options and is also suitable for space-saving portrait assembly.

Two CompactFlashDrive slots, one of which can be easily accessed from outside, allow for the assembly of low-maintenance systems without hard disks and high availability. The RAM can be upgraded up to 4 GByte so that the industrial PCs also support applications with a high data volume. Despite its small size, the Box PC comes with numerous interfaces such as two Gigabit-Ethernet interfaces, four USB-2.0 or one COM1 interface.

Simatic Panel PCs, also shown in Figure 2, are a combination of a Box PC and a rugged operation and display unit. The panel is available in four sizes 12, 15, 17 or 19 inch with touch screen. With the Simatic Panel PC, machines can be operated and monitored directly on site. The front of the Panel PC complies with degree of protection IP65 and is also protected against chemical influences.

![Figure 2](image_url)

**Figure 2** The Panel PC (left) comes in various screen sizes and the Box PC 627B (right) offers a small footprint without compromising functionality. Both are suitable for on-site machine applications.

An essential feature of the IPC product range with Intel® Core™2 Duo processors is the scalable system availability concept. Although the industrial

---

**Microsoft**

**Windows® XP Embedded**

Windows® XP Embedded is the operating system and development platform that delivers the power of Windows XP Professional in a componentized form. Windows XP Embedded helps you to rapidly assemble an operating system image that meets footprint requirements and helps ensure the operating system’s dependencies and full functionality are maintained.

Simply install the product, use the many tools available to you through Microsoft Windows Embedded Studio, and start innovating your device with:

- Over 9,000 Windows Hardware Quality Labs (WHQL) certified drivers for PC-architecture hardware platforms
- Over 3,000 operating system components
- Pre-existing design templates
- Plug and Play interoperability (with a third-party plug-in)
- Win32 API compatibility
- A rich set of integrated technologies including multimedia codecs and formats, Bluetooth, DirectX, and the .NET Framework
- Familiar desktop applications and services, such as Microsoft® Windows® Media Player and Internet Explorer
- Support for all x86-based hardware platforms
- Embedded-enabling features that help optimize Windows XP Embedded for embedded devices
- Professionally tested hardware support providing at least 10 years maintenance support for all operating system components and drivers that are included with Windows XP Embedded

Based on the Win32 programming model, Windows XP Embedded allows you to reduce development time and costs by using familiar development tools such as Visual Studio 2005, working with commodity PC hardware and desktop applications, drivers, and services. The Windows Embedded Studio tools help streamline the end-to-end development process and help enable developers to rapidly configure, build and deploy smart designs with rich applications.

For more information, please visit [http://www.microsoft.com/windows/embedded/](http://www.microsoft.com/windows/embedded/)
Industrial Control Solutions Guide

PCs already feature a rugged design and comprehensive reserves, important data may still get lost as a result of improper processing or the fan may fail due to excessive temperature. In order to eliminate these fault sources, system availability can be improved by efficient expansion options.

**Long-Term Availability Versus State-of-the-Art Technology**

In a broad sense, high system availability implies long-term availability of spare parts, which ensures that machine and plant manufacturers can order identical types of Simatic PCs for their existing machines in the foreseeable future. This is a dilemma particularly as regards the processors: On the one hand, the market calls for state-of-the-art industrial PCs where, on the other hand, old systems are expected to be available without modifications for several years (i.e. installation- and image-compatible). This is a tough balancing act for IPC manufactures.

The Intel Core 2 Duo processor originates from the office PC sector, where the marketing period of motherboards usually ranges between six and twelve months. These short market cycles are not acceptable in the industrial environment. This is why Siemens only uses processors from the Intel’s Embedded product range for industrial applications. Here, Intel guarantees a long-term availability. Moreover, key components such as the motherboard are developed and produced internally. The life cycles of industrial PCs are therefore adaptable to the requirements of industrial customers; availability is not controlled by the (office) market, but by Siemens. The typical marketing period of a new industrial PC is approximately three years. The availability of identical spare parts is guaranteed for another five years.

The long-term availability of industrial PCs is one of the reasons for Siemens to currently offer computers with dual-core technology. Only the second generation of the Intel Core 2 Duo processors produced with 65 nm technology, which are

---

**Wind River**

**Wind River Device Management**

Wind River Device Management products offer OEMs the technological answer to their pressing business questions. Combining groundbreaking Sensorpoint™ technology with a secure, enterprise-class collaboration infrastructure, Device Management links development, QA, and support teams in a powerful information loop that prevents wasted brain power, money, and time. The net effect is a persistent connection to the end customer and an enhanced user experience.

The Device Management line includes two complementary products:

- **Lab Diagnostics** is a distributed software diagnostics system that enables development and test engineers to collaborate effectively to test and repair running software before deployment - an estimated 30-50% faster than is customary today. The ability to automate long-run testing workflows streamlines system integration, verification and validation, making it possible to deliver higher quality products to market faster.

- **Field Diagnostics** is a scalable remote diagnostics system that enables OEMs to securely access, collect, and manage information from deployed devices to diagnose and correct defects in running software. Performance and time of failure data collected from fielded devices enable OEMs to resolve difficult, even intermittent issues based on facts, not symptoms. Persistent Sensorpoints™ enable field support teams to hot patch problematic software hitlessly, increasing device uptime and customer satisfaction.

Wind River Device Management products support Intel® architecture for Wind River Linux and VxWorks 6.6.

also part of the Intel-Embedded product range, can guarantee the required long service life.

When using industrial PCs with Intel Core 2 Duo processors, users not only benefit from the increased performance and the reduced power consumption for reliable operation even at high ambient temperatures. Intel Core 2 Duo processors most notably show its strength when multiple applications are run simultaneously: the integration of control and visualization in a single system will provide a cost-efficient total solution to users.

With these new system solutions, the PLC software (Siemens Simatic WinAC RTX software package) is installed in a way that ensures it is permanently allocated to one core, which is then reserved with this software, while the visualization software (Simatic WinCC flexible) is executed on the second core. The latest comparisons between conventional single-core systems and the Simatic PCs with Intel Core 2 Duo processors proved that cycle times of 10 ms are easily realizable also with complex PLC programs (Figure 3). At the same time the visualization is characterized by short image change and refresh times – despite the large number of images and process connections. Improvements of up to factor 10 and 4 compared to single-core systems were achieved. In addition to this, the processor utilization of the visualization component remains rather low. The user can use this performance reserve for further software applications and adding more hardware resources is a thing of the past, resulting in further cost-savings.

The new Simatic PC product range now includes an IPC system which not only meets the performance requirements of future automation tasks, but can also directly contribute to the rationalization of systems and machines. Despite this up-to-date technology, the computers feature a long-term availability which is matched to the life cycles of machine and plant construction.

Siemens Munich, Germany. +49 89 636-00 www.siemens.com

Arcom Control Systems

Gemini

The GEMINI, Arcom’s 5.25” form-factor SBC, brings the Intel® Core™ 2 Duo technology to the embedded and industrial market. Offering our highest ever performance, coupled with the guaranteed longevity-of-supply the market expects from Arcom. The GEMINI has all the requirements for enterprise and residential network applications as well as the processing power to handle today’s demanding software, such as graphics-intensive applications or serious number-crunching programs.

• Intel® Core™ 2 Duo / Core™ Duo / Core™ Solo / Celeron® M 4xx Processor @ 533 / 667MHz FSB
• Mobile Intel® 945GM Express chipset and integrated Intel® Graphics Media Accelerator 950
• 2 x DDR2 533/667MHz SDRAM up to 3GB
• Integrated RTC with onboard lithium battery
• ACPI 1.0 compliant, supports power saving mode
• 1 x 44-pin Ultra DMA33 IDE interface supports up to 2 x ATAPI devices
• Up to 224MB video memory shared with system memory
• Onboard 18/24-bit single/dual channel LVDS connector
• Dual video, VGA LVDS, DVI and component video output
• 2 x serial ATA interfaces with 150MB/s transfer rate
• 4 x Intel 82573L Gigabit Ethernet controller
• Onboard programmable 8-bit digital I/O interface
• 1 x PCI slot ,1 x Mini-PCI socket
• RoHS-6 compliant
• 3 year Product Warranty
Reduce Size and Cost of Embedded Industrial Systems with Multi-Core Processors

Allocating CPU cores in a multi-core processor can combine real-time tasks in that formerly required an entire hardware compute platform such as an embedded PC or DSP card. The key is using software that exploits the multi-core and virtualization features of the hardware.

Partitioning at the operating system (OS) level is a straightforward technique for shrinking embedded systems that formerly required multiple hardware platforms down to a single hardware platform. You can reduce cost, size, and hardware complexity by assigning each OS to dedicated cores in a multi-core processor platform. This includes embedded systems that incorporate a mix of dedicated subsystems, providing functions such as real-time control, data acquisition, and a human machine interface (HMI). The key to supporting a mix of real-time and general-purpose operating systems, on dedicated cores within a multi-core processor, is to use an underlying element of software that exploits the Virtualization Technology in the latest Intel® multi-core processors.

Traditionally, embedded systems have been built from a collection of independent subsystems, each running its own operating system on independent hardware platforms. This was driven by the need for critical applications to respond quickly and predictably to real-time events, without interference from subsystem elements that deal with non-critical events, such as human interface functions and enterprise network connections. Multiple independent subsystems minimize the potential for conflicts, and allow the use of operating system software that is appropriate to the specific tasks being performed.

Task isolation via independent hardware platform, however, comes at significant expense in the form of communication overhead, physical system size, excess heat, component cost, and manufacturing and test complexity. By eliminating redundant system elements (such as disk, memory, network interfaces, and power supplies) inter-module communication bottlenecks can be avoided, system costs can be reduced, and system manufacturing and maintenance can be simplified.

Example: DSP Elimination

Consider a high-speed electronic circuit board assembly machine that performs precision motion operations. The system includes a DSP subsystem for calculating coordinated real-time multi-axis motion profiles that drive a positioning platform. Another subsystem performs real-time data acquisition from a vision subsystem. And a third subsystem serves as an HMI to monitor and control overall machine operation and to perform setup and assembly tasks from a menu of options (Figure 1).

The assembly machine’s vision subsystem contains a dedicated real-time computer

Figure 1  Independent real-time functions in a control system connected via a non-real-time control computer over networking schemes.
that captures and analyzes images from cameras to determine the placement and orientation of components that are to be placed on the circuit board assembly. The analysis made by the real-time vision system results in multi-axis positioning targets. A complex set of floating point operations must be completed within a time-limited window (typically a few milliseconds) to ensure that the motion subsystem can hit its targets precisely, repeatedly, and on time.

Like the vision system, the multi-axis motion subsystem must complete a complex sequence of floating point calculations in a predetermined amount of time. In one such system the cycle time between position updates is 100 microseconds (10 kHz). The high update rate, coupled with multiple axes of motion, necessitates DSP level performance. Within each 100 microsecond cycle, the DSP performs a set of floating point calculations that represent the coordinated profiles of several axes of motion. In addition to calculating motion profiles, the DSP monitors and controls a collection of digital and analog I/O points connected to system safety switches and status and control points within the equipment.

The high costs that plague builders of high performance machines like these are summarized in Table 1. These cost penalties include those associated with using specialized processing subsystems like DSP cards and the duplication of memory components, power supplies, circuit cards, and enclosures within the machine.

There are development and maintenance expenses that result from having to write and maintain specialized DSP code using expensive and development systems that come with a steep learning curve. There are also expenses associated with an increase in assembly complexity and a decrease in system reliability, due to more parts and interconnects between subsystems of the machine. Component availability issues inevitably force future redesign costs due to the obsolescence of non-mainstream processors by their manufacturers.

The proliferation of multi-core implementations on Intel Architecture processors provides not only a cost-effective solution to these problems, but can also bring new CPU capabilities to embedded systems that previously needed special purpose processors. By adapting DSP and real-time functions to run on dedicated cores of an Intel architecture-based multi-core CPU, where each core is running its own RTOS, machine builders gain the following advantages:

- Expanded resources for more complex algorithms by adding processor cores
- Newer and cheaper standardized I/O subsystems can be incorporated, a benefit of PC market economies of scale (for example: USB, PCI Express, and Ethernet)

Virtual Machine Approach for Real Results

Combining multiple disparate subsystems onto a single multi-core platform requires an operating environment that supports multiple virtual machines. In this environment, each OS must run unmodified on its own virtual machine, using the hardware features of the CPU to keep each virtual machine from impacting the other. And, making multi-OS embedded systems work on a multi-core CPU requires an RTOS that supports virtualization. Virtualization provides the isolation needed between multiple operating environments, and also enables legacy real-time systems to be transformed from multi-platform systems into single-platform systems.

The INtime® RTOS for Windows®, from TenAsys, is an example of such a system. It is capable of hosting Microsoft® Windows® and multiple RTOS environments, with each operating environment dedicated to its own processor core(s). INtime also adds the ability to develop real-time application code on the same platform and with the same tools that are used to develop Windows applications such as Microsoft Visual Studio® (Figure 2).

The latest Intel® multi-core processors include Intel Virtualization Technology to further enhance the isolation of I/O and memory between multiple virtual machines. With hardware-supported virtualization, a distinct boundary is established between real-time processes and threads and non-deterministic tasks that execute on different processor core(s). Intel VT hardware includes a collection of new processor instructions, traps, and a privileged “root” operating mode that enables Virtual Machine Manager (VMM) software to more efficiently host multiple virtual machines on a single hard-
Dedicating CPU cores to operating systems in a multi-OS platform removes contention for key processor resources like registers, instruction pipelines, floating point resources, and interrupts. This approach has a dramatic impact on real-time performance metrics, such as interrupt latency, when compared to platforms that must share a CPU with non-deterministic tasks. In Figure 3, worst case interrupt latencies measuring as high as 20 microseconds have been reduced by a factor of three to a maximum of seven microseconds. In this case a dual-core system was first operated in shared-mode where Windows uses two CPU cores, sharing one with the INtime RTOS, and then in a dedicated-mode where Windows uses only one CPU core and the INtime RTOS uses the other core.

TenAsys has measured even more dramatic improvement in worst case interrupt latency, when comparing the INtime RTOS and Windows running on a dual-core platform compared to an equivalent clock speed single-core platform. With such low guaranteed interrupt latencies, real-time control loops can execute at 50-200 microsecond cycle times with very high precision, while a general-purpose OS such as Windows is simultaneously supported on the same hardware platform.

### Table 1: Intel® architecture-based system virtualization attributes

<table>
<thead>
<tr>
<th>Issue</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of DSP subsystems</td>
<td>Dedicate a CPU core and utilize libraries that exploit SIMD instructions (Single Instruction, Multiple Data) such as SSE on Intel® Architecture processors.</td>
</tr>
<tr>
<td>Development and maintenance expenses and risk associated with specialized subsystems</td>
<td>Use a standard processor architecture. Better availability of talent that understands standard platforms. Development tools for mainstream processors are more powerful and easy to use.</td>
</tr>
<tr>
<td>Hardware duplication (e.g., memory, power supplies, and enclosures)</td>
<td>Merge multiple hardware platforms into a single hardware platform.</td>
</tr>
<tr>
<td>Increased complexity decreases reliability</td>
<td>A single hardware compute platform minimizes interconnects, increasing reliability.</td>
</tr>
<tr>
<td>Redesign costs due to hardware obsolescence</td>
<td>Build software on operating systems designed for forward-moving platforms.</td>
</tr>
</tbody>
</table>

Table 1: Intel® architecture-based system virtualization attributes

### Building Inter-OS Protocols for Multi-Core Systems

To facilitate the reuse of existing application software in new multi-core designs, virtual device drivers can be used as an interface for inter-OS communication and signaling protocols. For example, an inter-OS protocol could be implemented entirely within a virtual PCI hardware interface. The guest operating systems are configured to share an area of physical memory to which common data is posted. After a guest updates its data structure in the shared memory region, it signals the other guests of the update via a register in the virtual PCI interface (Figure 4).

In this example, each virtual PCI device presents two memory ranges to each guest. The first memory range, pointed to by PCI configuration register BAR0, maps the shared memory buffer. The second range, pointed to by BAR1, presents an I/O address to each guest OS. When an application within the guest OS accesses the BAR1 I/O address a trap is made into the virtual device driver hosted by the VMM. The virtual device driver then injects a virtual IRQ into the target guest OS, which responds by accessing the shared memory area for updated data.

The net gains from the application of real-time virtual machine technology on multi-core processor platforms are the elimination of redundant computer and communication hardware, faster communication and coordination between multiple operating environments, improved reliability and robustness, reuse of

### Table 2: Intel® architecture-based system virtualization attributes

<table>
<thead>
<tr>
<th>Virtualization Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® Virtualization IA-32 Intel® architecture</td>
<td>Special CPU root mode to trap system-level instructions.</td>
</tr>
<tr>
<td>VT-d: Chipset Virtualization</td>
<td>Hardware supported DMA and interrupt remapping.</td>
</tr>
<tr>
<td>PCI-SIG: I/O Device Virtualization</td>
<td>Address Translation Services (ATS) to accommodate sharing PCI Express I/O cards between multiple operating systems.</td>
</tr>
</tbody>
</table>

Table 2: Intel® architecture-based system virtualization attributes
proven legacy applications, and simplified development and debugging.

Intel architecture-based multi-core processors are capable of delivering system-level benefits for embedded computing applications. For those systems that require the user-interface and enterprise connectivity of a general-purpose OS, like Windows, but also need deterministic real-time control, it is possible to dedicate CPU cores to processing real-time tasks, while dedicating remaining core(s) to general-purpose processing. This has the benefit of enabling real-time processes to operate unencumbered by unpredictable non-deterministic applications. By isolating real-time processes from general-purpose processes on different cores, interrupt latency and response time is greatly improved, yielding a more reliable and higher-performance real-time system.

The potential software complexity of implementing multi-core systems that incorporate multiple heterogeneous operating environments is eased by basing the processor usage models around a virtual machine approach. By hosting the real-time and general-purpose OS portions of the system on dedicated processor cores and employing integrated development environments that support design and execution on multi-core systems, complexity in design and partitioning of resources can be greatly simplified.

TenAsys, Beaverton, OR. (503) 748-4720. www.tenasys.com

Figure 4 Different operating systems on a quad-core processor each have exclusive use of their core, but can share data by posting it to areas of shared memory on the same die.

MEN Micro Inc.
D7 Blade Server

NEW SERVER BLADE FROM MEN MICRO, INC. FEATURES AN DUAL-CORE INTEL® XEON® PROCESSOR FOR HIGH COMPUTING PERFORMANCE IN INDUSTRIAL APPLICATIONS

MEN Micro, Inc., a world-renown provider of embedded computing and I/O solutions for demanding industrial, mobile and harsh environment applications, has just released a new 6U, CompactPCI single board computer (SBC) equipped with either one or two Dual-Core Intel® Xeon® processors, providing up to four CPU cores with a frequency of 1.66 GHz, and the Intel® E7520 server chipset. The new D7 blade server, which can function as either a system or a peripheral slot board, is ideal for applications where fast and reliable communication is required.

Specific uses of the D7 include networked installations found in the telecommunications industry at base stations, routers, switches, concentrators and other communication-specific computer systems. The D7 is also used in the medical engineering and transportation industries for instrumentation and railway signaling, respectively. The board’s multiple memory variants, such as ECC DDR2 DRAM with a speed of up to four GB and error correction, non-volatile FRAM, SRAM and NAND Flash, make it suitable for safety-critical applications, as well.

The hot-swappable D7 can be used as a peripheral slot board, a 64-bit/66 MHz PCI system or a 64-bit/133 MHz PCI Extended (PCI-X) system on the CompactPCI bus using one or two slots depending on the configuration. The PCI Express (PCIe) link connects to the two Gigabit Ethernet interfaces on the front panel and are used to attach up to two XMC modules.
Intel. Powering an Industrial Revolution.

Intel provides a full range of components and platforms to meet the demands of the digital factory—from Test & Measurement devices and advanced Human-Machine Interfaces to Industrial PCs and Factory Automation & Control systems. Intel’s embedded lifecycle products provide the real-time operation and energy efficient performance of processors based on Intel® Core™ microarchitecture. Create your own revolution with Intel’s advanced platform technologies, development tools, and an ecosystem of leading third-party vendors—including members of the Intel® Communications Alliance. Visit us online today. The industrial revolution is about to begin.

www.intel.com/go/industrial