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Windows CE on x86-based Embedded Platforms

The Windows CE embedded operating system (OS) has been designed by Microsoft to be the cornerstone of a complete, standards-based operating environment that enables OEMs, hardware manufacturers and software developers to easily create standards-based communication, entertainment and mobile-computing devices. As such, it is destined to unify the currently fragmented embedded OS market and provide a compact, highly scalable OS solution. When coupled with other widely accepted standards, such as the x86 platform and the PC architecture, Windows CE enables developers to focus on adding value to the application rather than on core functionality issues. This article will examine the benefits of adopting Windows CE for x86-based embedded designs, and provides a case study of a Pentium processor based system with Windows CE in Flash memory.

THE WINDOWS CE SOLUTION FOR EMBEDDED SYSTEMS

Prior to Windows CE, there was no single-source, scalable, highly integrated Windows operating system-compatible software solution that filled the needs of the embedded systems marketplace. Instead, developers were forced to integrate pieces of operating systems from multiple vendors in an attempt to patch together a comprehensive solution. This integration was typically divided along functional layers and usually involved a minimum of three distinct components: the BIOS or loader, the OS kernel, and the Graphical User Interface (GUI).

Developers wrote a BIOS or loader from scratch, or bought one from a vendor and customized it to complement the specific embedded hardware features included in the design. Then they wrote a custom OS, or bought one from yet another vendor and ported it to the underlying hardware. Finally, either an off-the-shelf GUI library was purchased from a third vendor, or a custom-built GUI was integrated into the embedded application. In terms of speed of deployment, this procurement and design process was less than optimal.

In response to the problems described above, the Windows CE operating system provides a 32-bit, multitasking, multithreaded operating system that seamlessly integrates all the functions the embedded system developer needs. It's compact, providing high performance in limited memory configurations. It's scalable, allowing it to support a wide range of embedded, mobile, or multimedia designs. It supports standard communications protocols, enabling access to the Internet and e-mail functions. Its graphical user interface incorporates many elements of other Windows operating systems, offering a familiar, easy-to-use interface. And it enables seamless synchronization, communication, and exchange of information with Windows-based PCs.

Building on the experience of thousands of system developers, the Windows CE development environment supports a comprehensive, expandable subset of Win32 APIs and uses familiar off-the-shelf components and development and debug tools such as Microsoft Foundation Classes, Microsoft Developer Studio and WinDBG. These tools, especially when used with an x86 platform and the PC architecture, help OEMs and designers speed the process of product development.

EMBEDDED WINDOWS CE AND X86-BASED COMPUTERS

The x86 processor is rapidly becoming the platform of choice in the embedded systems market, and the acceptance of Windows CE will accelerate that trend. The x86 processor's familiar, well-understood PC architecture can be used as building blocks for embedded systems, freeing the developer from engineering tasks such as custom designing the central controller. Additionally, the PC architecture supports a wide range of software and tools not available for full-custom designs. And component crossover from the high volume desktop PC market benefits embedded system developers by providing multiple source alternatives and lower cost components. For these reasons, utilizing the x86 platform and PC architecture in embedded designs can lead to faster development cycles and a shorter time to market.

There is a growing class of embedded applications that lie between the dedicated controller with no user interface (UI) and the system controller with full GUI and storage capability. These applications often require a specialized UI that is optimized for an application-specific environment and minimal resources, yet is compatible with current desktop OSes.

For these applications, Windows CE provides a well-defined, standard graphical user interface and Win32 support. Windows CE also supports a set of I/O, such as touch screen interface, mouse/track ball and flat panel displays necessary for these applications, which by nature are not desktop bound and often must be compact, rugged and unique to the embedded market.

Combining Win32-based OSes with x86 processors for the embedded market offers the advantage of consistency in the solution spectrum. This applies to OEM x86-based product lines, where a flexible, general-purpose solution uses Windows NT, and application-specific products use Windows CE. In addition to the clear benefit of software portability and consistent look and feel, the OEM benefits from a hardware architecture that is well-understood, has a clear, long-life road map for embedded applications, and is consistent across general and application-specific product lines. The consistency benefit also applies to large integrated systems, for example, a factory floor, where these computers need to coexist, communicate, and often run the same software.

The benefit of a x86-based target system also extends to application development, which is streamlined because of Windows CE and Windows NT's homogeneity. Applications can be developed and simulated on a standard PC running Windows NT, and, when debugged, can be ported easily to CE on the target system.

WINDOWS CE ON A PENTIUM PROCESSOR-BASED SYSTEM

The RadiSys EPC-43 is a Pentium processor-based, PC-compatible computer that provides a modular, upgradable platform for embedded designs. It was chosen as the target platform for a Windows CE system because its hardware supports an appropriately comprehensive set of I/O functions. Fully configured and programmed, the EPC-43 serves as a full function PC capable of supporting a BIOS and any off-the-shelf operating system - or, when programmed appropriately, as a Windows CE reference platform or target system.

The EPC-43 system is comprised of two boards: the Embedded Processor Module (EPM-1) and the baseboard. The EPM-1 is a compact, integrated, 4.2" x 5.3" Pentium processor-based module. It includes the 430HX and PIIX3chipset, a 512KB Flash Boot Device (FBD), SODIMM sockets that can accommodate up to 256MB of DRAM, an 82C42PE keyboard/mouse controller, a processor power supply, 512KB of L2 cache memory, a real-time clock (RTC), battery-backed CMOS RAM and a clock synthesizer. The EPM-1 is designed to interface with the EPC-43 via four connectors that link the PCI, ISA and IDE buses. The connectors also provide an interface for power, two USB ports, keyboard and mouse signals. EPM-1 modules are available in speeds ranging from 100MHz STD to 200MHz with MMX technology.

The EPC-43 baseboard contains the system peripherals and associated interfaces. It supports a 10/100 BaseT Ethernet controller, high performance CRT and flat panel video controller, 2 port (four device) enhanced IDE controller, two USB ports, a CardBus controller (2 slot), a PCI expansion slot, 8MB Resident Flash Array (RFA) and a Zoomed Video Port all on the PCIbus. The ISAbus supports a 16-bit Sound Blaster Pro compatible audio controller, PC/104 expansion bus, four serial ports (three RS232/RS485, and one RS-232/fast infrared), a bi-directional parallel port, a JTAG port, a PS/2 keyboard, and a PS/2 mouse interface.

The Windows CE implementation for this platform includes the drivers for the PCIBus, a Cirrus CL-

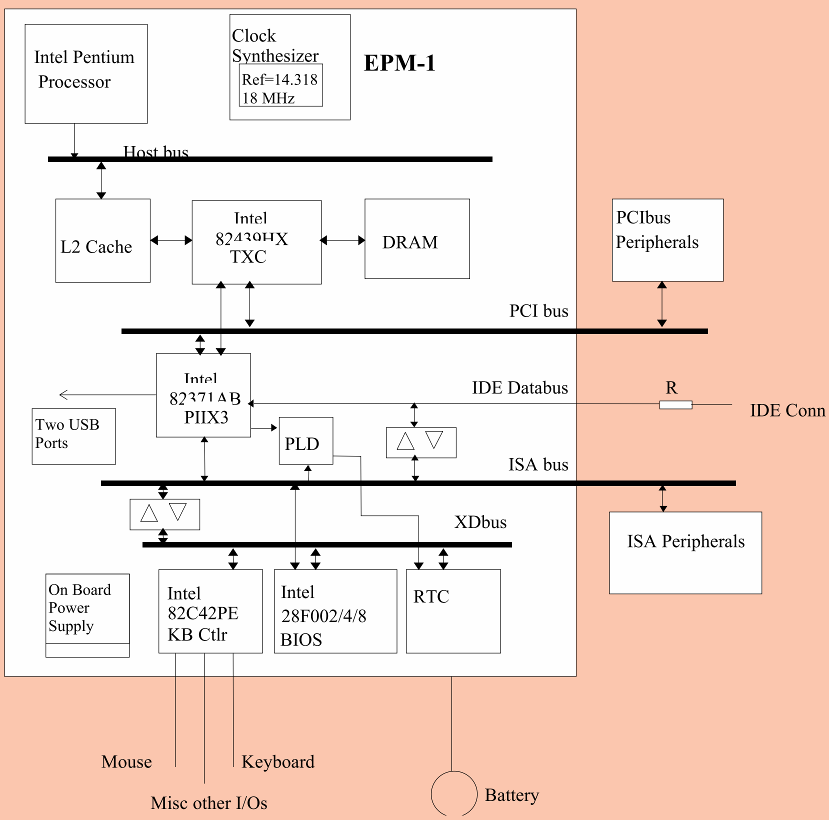

Figure 1. RadiSys EPM-1 Embedded Processor Module.

GD7555 CRT/LCD controller, a Read/Write Flash File System (FFS) for the RFA, Ethernet, keyboard, mouse, parallel port, serial communication drivers, CardBus and USB (Q1'98). Additionally, a reflash monitor and Win32 based application level-reflashing program are included. The hardware and software architecture of this system makes it an excellent reference platform, which can be refined with hardware modifications, or a full-featured target system.

HARDWARE-SOFTWARE CONSIDERATIONS

Windows CE was designed for small, diskless embedded systems that require the ability to run from Flash memory. RadiSys worked with Datalight, Inc. to implement the Datalight FlashFX Flash File System (FFS) to support Windows CE on the EPC-43. This read/write file system provides an installable non-volatile storage capability using Windows CE's native file system format. Because the EPC-43 leverages the benefits of standard PC hardware and I/O, RadiSys implemented a loader within the OEM Abstraction Layer (OAL) that performs some of the same functionality as a BIOS in a standard PC-based system. The loader takes advantage of a predictable set of hardware and I/O to perform such tasks as configuring the chipset, the COMA serial port and selected PCI devices.

Although the loader executes outside of the context of Windows CE, its architecture for both portability and cooperation with the Windows CE OAL code is extremely important. When developing the Windows CE port, careful consideration was given to dividing the responsibilities of the loader and the OAL code in order to take into account the architecture, programming model and details of the configurability of the chip sets and their associated idiosyncrasies.

Grey sections are included in the EPC-43 platform unmodified; red and yellow sections are modified by RadiSys for the Pentium processor.

Creating Windows CE Drivers on an x86 Platform

The EPC-43 supports a wide range of standard PC hardware and I/O for which flash-based Windows CE drivers must be developed. The Windows CE OEM Adaptation Kit (OAK) (available from Microsoft) includes sample drivers such as video, keyboard, touch panel, audio, serial and PCMCIA. In order for the EPC-43 to act as a Windows CE target system, RadiSys modified the generic drivers provided in the OAK to match the controllers found on the EPC-43. For a target system that uses different controllers, some modification will be needed to support specific initialization and mapping functions. In addition, drivers not located in the x86 sample tree must be converted to work in the x86 architecture model.

A Seamless Development Environment

The x86 is the only common platform across all of the Microsoft Windows operating systems: Windows CE, Windows 95 and Windows NT. This offers developers an ideal development environment for an x86 and

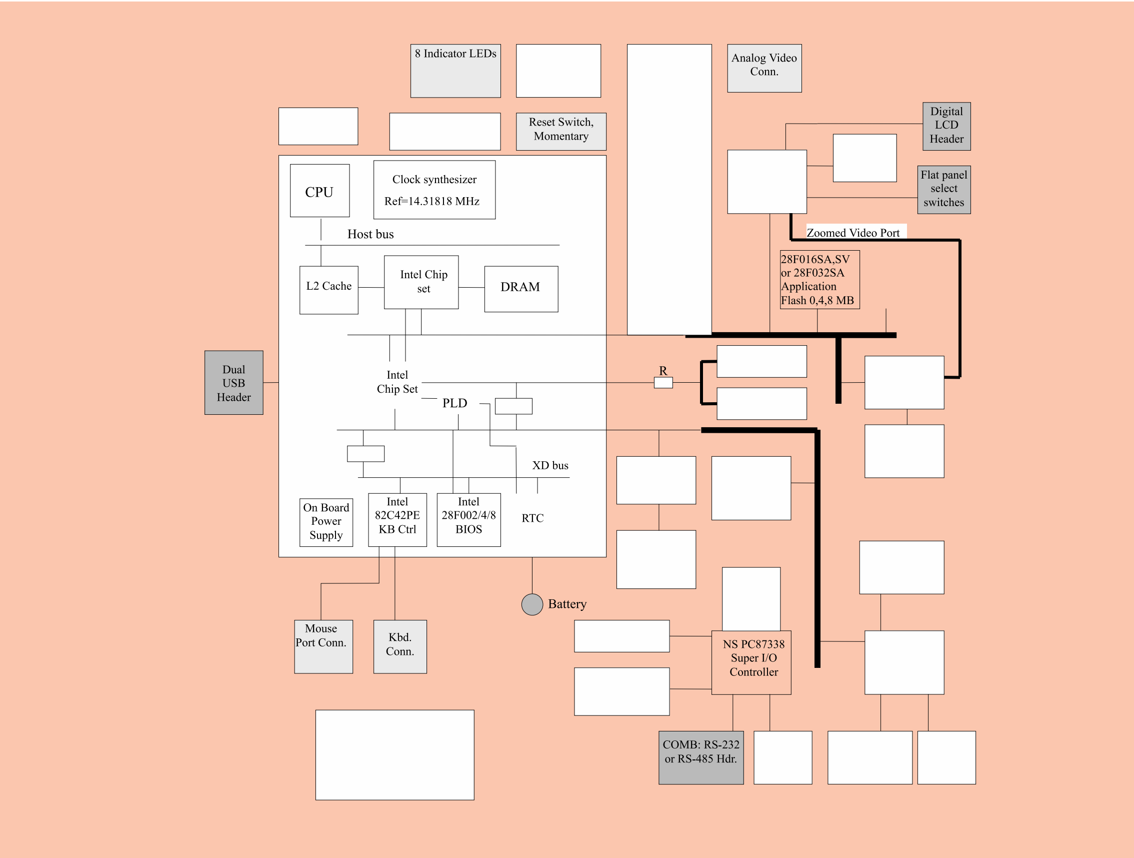

Figure 2. RadiSys EPC-43 Pentium processor-based platform for Microsoft Windows CE.

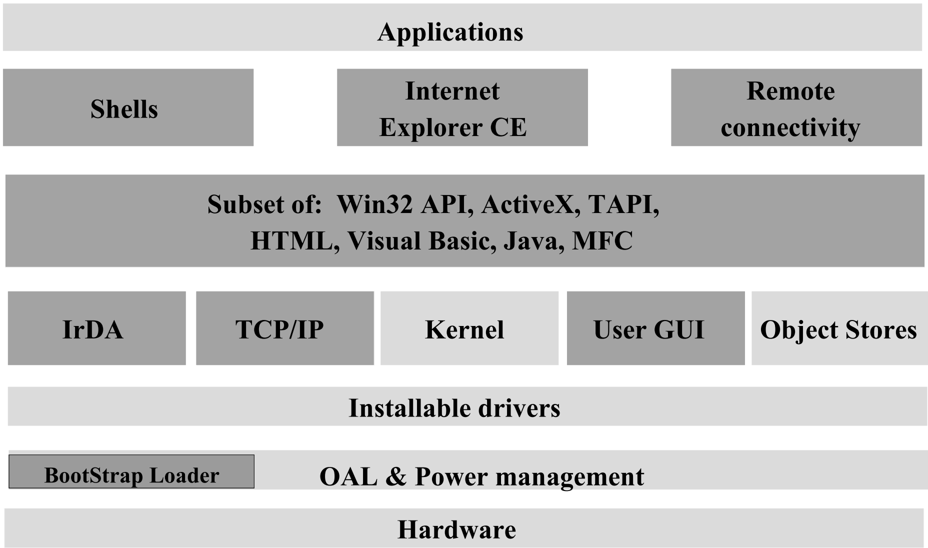

Figure 3. Windows CE operating system architecture.

Windows CE-based system: the developer can create the application on an off-the-shelf PC with Windows NT, then debug the application from the PC using the remote debugger. Once the application is ported to the target system, the developer can modify the familiar Win 32 APIs to work under Windows CE.

CONCLUSION

This paper presents several examples of leveraging the tools and technologies of the PC to create and deploy a x86-based platform for a Windows CE target system. The RadiSys EPC-43 provides a case study that illustrates the advantages of extending the use of PC standards such as buses, components, peripherals and development tools to compact Windows CE-based embedded systems.

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Prior to working at RadiSys he spent 5 years at AST computer writing data communication software. Prior to AST, he held software positions at Eagle Computer, Beckman Instruments and TRW. He earned a BS in Computer Science from California Polytechnic University.
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