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LP-VxWin VxWorks Together with Windows on the same PC

This article deals with how LP Elektronik added Real-Time features to Windows and Windows NT. Three solutions are covered, combining WindRiver OS (VxWorks) and Microsoft OSes. The first solution could be qualified as a soft real-time solution, whereas the two last ones could be considered as hard real-time. To reach this level of predictability these two solutions need extra hardware.

MS-WINDOWS

MS-Windows is a widespread graphical user interface for IBM compatible PCs. Due to the absence of real time ability it was hardly suitable for industrial applications. The advantages of MS-Windows however, are to be found in its widespread applications and the acceptance of the users. Finally, a lot of low-priced user programs for MS-Windows are available. To make MS-Windows useful also for industrial real time applications, a way has been developed, which eliminates the disadvantages of MS-Windows, without giving up its advantages.

VXWORKS

VxWorks is a widespread real time operating system, produced by the american company Wind River Systems. Several versions of VxWorks are available for different processor-architectures (Motorola 68k, Intel 80x86, Sparc, AMD 29k and others). VxWorks normally runs stand alone on one processor and controls the resources (RAM, ROM, I/O hardware, and so on).

LP-VXWIN: VXWORKS AND MS-WINDOWS TOGETHER ON ONE PC

The LP-VxWin product family combines both operating systems, so they can run concurrently on the same PC and the user can get the best of both worlds. There are three different products, which are compatible to each other:

For LP-VxWin Lite and LP-VxWin RTAcc the basic version of VxWorks for Intel processor has been adapted, in order to run VxWorks and MS-Windows simultaneously on the same Intel processor. Of course, VxWorks has a higher priority as MS-Windows. As long as at least one VxWorks task is active, the processor's execution time is available exclusively for VxWorks. In other words, only if all VxWorks tasks have given up their execution time, MS-Windows will be reactivated. This is done when VxWorks falls into the so called idle loop of the VxWorks kernel. From this point of view, one can say, Windows runs as the idle task of VxWorks.

1. The simplest member of the family, LP-VxWin Lite doesn't require any additional hardware at all. It runs on each Intel processor (80386 and higher) with MS-Windows 95 or NT 4.0. VxWorks will be activated by the ISA-Bus interrupts, which can be disabled by MS-Windows drivers. Because of this, a 100% realtime ability cannot be guaranteed.
2. The second product, LP-VxWin RTAcc requires a cheap, passive additional hardware, the so called LP-Realtime Accelerator (RTAcc). Using this version, the 100% real time ability can be guaranteed. The main function of the RTAcc is to accept normal interrupts from the ISA-Bus and to generate a Non Maskable Interrupt (NMI) instead. The NMI cannot be disabled by MS-Windows, so the 100% real time ability can be guaranteed. VxWorks will be activated by the NMI within a few microseconds depending on the PC processor speed.
3. The third one, LP-VxWin LC20 uses an additional, active PC-board with Motorola's 68020 processor. VxWorks runs on this additional processor, so the PC processor is completely relieved from the real time tasks.

COMMUNICATION BETWEEN VXWORKS AND MS-WINDOWS

All three levels can use the TCP/IP-protocol for commu-

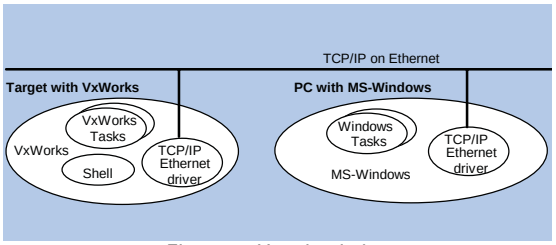

Figure 1. Usual solution

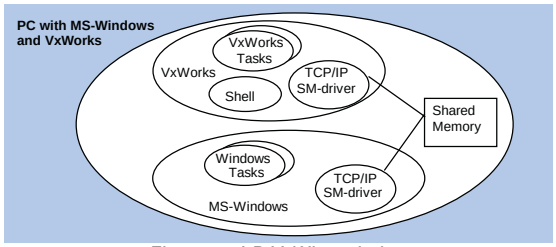

Figure 2. LP-VxWin solution

nication between VxWorks and MS-Windows through shared memory areas. For this purpose two corresponding network drivers has been developed for both sides, MS-Windows and VxWorks. Over the commonly accessible shared memory area, both systems can exchange data as they would do via an ethernet line. Using the MS-Windows NT built in routing feature, VxWorks can access other systems, which are connected to the MS-Windows TCP/IP network.

For a more direct TCP/IP connection to systems outside of the PC an additional Ethernet hardware can be used. For LP-VxWin Lite and LP-VxWin RTAcc an Ethernet board, which is supported by a standard VxWorks driver can be plugged in into the PC. Usually, this will be an additional Ethernet board beside the first one, which is used by MS-Windows. LP-VxWin can control this Ethernet board directly.

For LP-VxWin LC20 a mezzanine board is available, called M-Module M9, which can be plugged onto the LC20. This M-Module has got an Ethernet interface, which is controlled directly by VxWorks running on the LC20.

Using the standard TCP/IP protocol, any additional VxWorks products can be used together with the LP-VxWin product family, e. g. the development system Tornado on the PC or the VxWorks development system for UNIX. Source level debugging is possible as well as the use of WindView or others. For the Run Time System, TCP/IP sockets or Remote Procedure Calls (RPC) can be used for communication between MS-Windows and VxWorks programs.

From the point of view of the VxWorks or the MS-Windows applications there is no difference between running under LP-VxWin on the same PC or as usual running on two different systems.

LP-VXWIN LITE

This version doesn't require any additional hardware but runs on each Intel processor (80386 and higher) with MS-Windows. Figure 3 shows the cooperation between VxWorks and MS-Windows using LP-VxWin Lite.

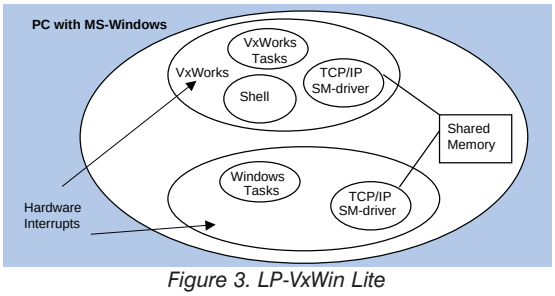

Figure 3. LP-VxWin Lite

In this version all hardware interrupts are received directly from the Programmable Interrupt Controller (PIC) of the PC. If MS-Windows programs or drivers are disabling the interrupt mask of the Intel processor for a certain time, the processor does not react immediately on a VxWorks-interrupt. Therefore the corresponding VxWorks Interrupt Service Routine (ISR) will be called with a certain delay. Since under MS-Windows it is not defined, how long an interrupt may be disabled, the 100% realtimeability cannot be guaranteed.

Under Windows NT 4.0, there was measured interrupt latency times up to two milliseconds. However, even this time can not be guaranteed.

LP-VxWin Lite can be used for simulation, for slower control applications or at least for demonstration purposes.

Loading and starting of LP-VxWin Lite and LP-VxWin RTAcc

After MS-Windows is up and running, LP-VxWin can be started by uploading the VxWorks.st file with a little loader tool called UpVxWin.EXE. This application communicates with the LP-VxWin-interface-driver which was loaded during the boot sequence of MS-Windows. At first, the loader calls the driver to allocate memory which VxWorks can use for code and data. The allocated memory is guaranteed to be fixed (not swapped to disk) and the code running in this me-mory has the highest privilege level (Ring 0). The next step of the loader is to read the VxWorks image from disk, and copy it to the allocated memory via the driver. After the code and data are relocated to the loading address, VxWorks is started by calling the init function of VxWorks. As soon as all initialization tasks are idle, the init function returns and the loader terminates. From now on, VxWorks only will be activated by interrupts.

LP-VXWIN RTACC

The second product, LP-VxWin RTAcc, is based on another LP product, named the LP-RTWin Toolkit.

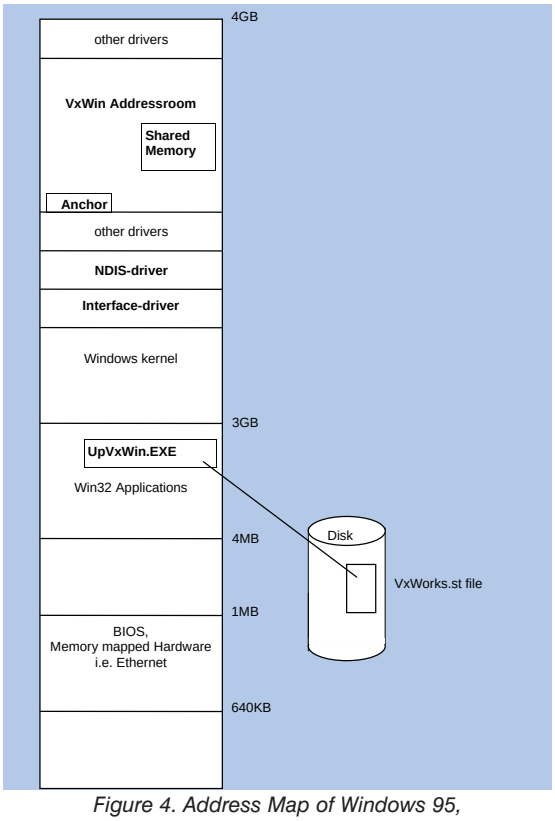

Figure 4. Address Map of Windows 95, logical addresses

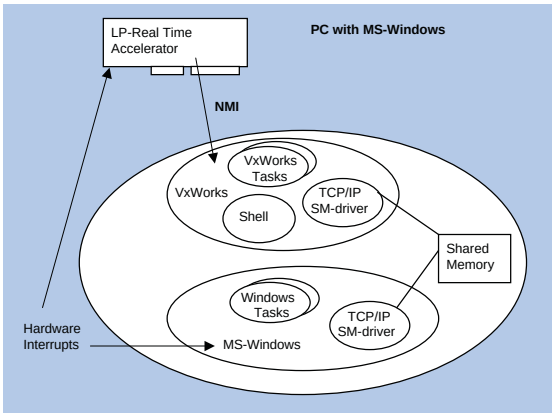

Figure 5. LP-VxWin RTAcc

With the help of this tool, simple realtime-able Interrupt Service Routines (ISR) can be written. These are called within a few microseconds by guarantee due to ISA-Bus interrupts.

The core of the LP-RTWin Toolkit is a small hardware, the so called LP-Realtime Accelerator. Using this variant, the realtime ability within microseconds can be guaranteed.

LP-Realtime Accelerator

The LP-Realtime Accelerator mainly consists of a simple passive logic chip (44 Pin EPLD). This device supports the functionality of a Programmable Interrupt Controller (PIC) for the Non Maskable Interrupt (NMI) and a 12 Bit Timer on one chip. It can receive up to seven “normal” interrupts, i.e. from other ISA-Bus hardware over its seven hardware input pins. Some or all of them can be enabled by software over eight addresses in the I/O address-room of the PC. If an interrupt is enabled and received by the LP-RTAcc chip, a NMI will be generated.

Additionally the LP-RTAcc chip contains a 12 Bit Timer, which is clocked by about 6.7 micro-seconds on the evaluation board. With that feature, periodically realtime interrupts can be programmed with cyclic times between 6,7 microseconds and 27,4 milliseconds. This timer is used by the VxWorks system ticker.

The LP-RTAcc chip is available not only on the evaluation board. It also can be ordered stand alone with a data sheet. The user can design this chip into a new developed PC plug in board. A third way to use the LP-RTAcc chip is to employ PC motherboards, where this technology is already on board.

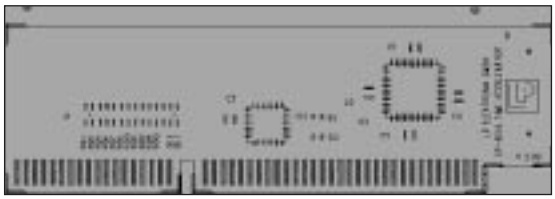

Figure 6. The LP-Realtime Accelerator evaluation board

The NMIs, generated by the LP-RTAcc chip will interrupt MS-Windows or VxWin tasks within a few microseconds and call the corresponding VxWorks interrupt service routine. After returning from the ISR, but before returning to MS-Windows, the system checks, if there are any tasks ready to run. If this is the case (one or more tasks has been activated within the ISR), the system will not return to MS-Windows, but it will activate the corresponding VxWorks task, first. Those tasks keep on running until all of them will be suspended again. The system then enters the kernel idle loop of VxWorks, which will lead to a return to MS-Windows. Since MS-Windows only will be activated, if all VxWorks tasks are idle, one can say that MS-Windows runs as the idle task of VxWorks.

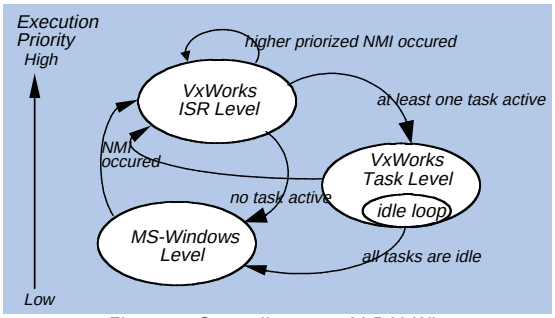

Figure 7. State diagram of LP-VxWin

Exception Handling of VxWorks

Whenever VxWorks is activated via the ISRs a new exception table is loaded by only one assembler instruction. Therefore the exception handling for page faults, debugging, an so on is exactly the same as it is by VxWorks running stand alone on a PC motherboard. Before falling back to MS-Windows, its exception table is reloaded.

Usage of the Arithmetik Co-Processor

The arithmetic Co-Processor can be used within LP-VxWin without any restrictions. Since it is possible, that the interrupted MS-Windows has the Co-Processor currently in use, the state of the arithmetic Co-Processor is saved whenever VxWorks needs it. To save performance, this is not done every time when the ISR is entered. In the ISR only a special monitoring bit of the processor is set. When a later activated VxWorks task uses the Co-Processor, the first Co-Processor instruction forces a call to a trap-handler, where the Co-Processor state is saved. Before falling back to MS-Windows, the Co-Processor state is restored.

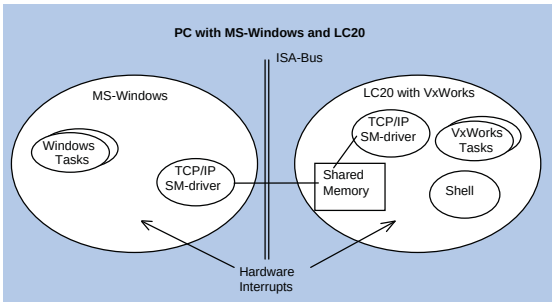

Figure 9. LP-VxWin LC20

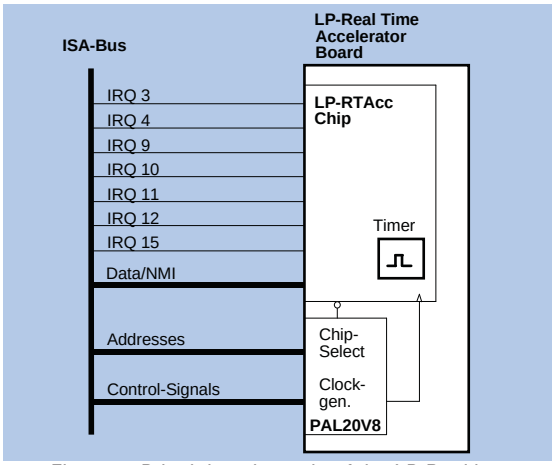

Figure 8. Principle schematic of the LP-Realtime Accelerator

LP-VXWIN LC20

The third product, LP-VxWin LC20, is a short sized PC plug-in board (16Bit ISA-Bus) with a Motorola 68020 CPU (25Mhz) and a local 8MB of RAM. The LC20 can be used as a VxWorks target running within a PC. The communication with MS-Windows is done via a TCP/IP-NDIS shared memory driver over the ISA-Bus. Due to its Bus-Master-DMA ability, VxWorks running on the LC20 can directly access other PC hardware via the I/O or memory channel of the PC. It also can receive interrupts from other boards.

Memory map of MS-Windows and VxWorks with the LC20-version

MS-Windows "sees" the VxWorks-memory through a 64 KB window, which can be placed in segment D000 or E000. This window can be moved over the entire memory of VxWorks. ■

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Immediately after his studies in 1985 he founded together with his partner, Josef Leibinger, an engineering company for software and hardware development for the industrial automation and realtime market. In 1987, the current company LP Elektronik GmbH was founded. LP Elektronik announced in 1996 a revenue of 2,2 Mio of DEM and employs 14 people.

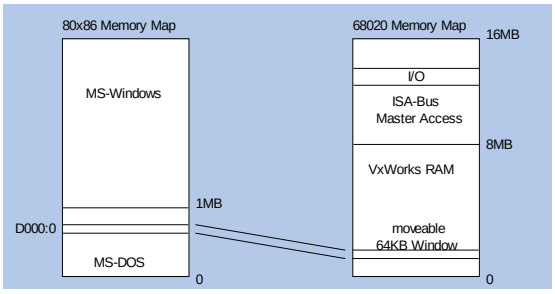

Figure 10. Memory map of MS-Windows and VxWorks with the LC20-version