Virtex-5 Powers Reconfigurable, Rugged PC

RMT's SwitchBack uses Xilinx Virtex-5 FPGA in a PC that users can customize in the field and upgrade on the fly.

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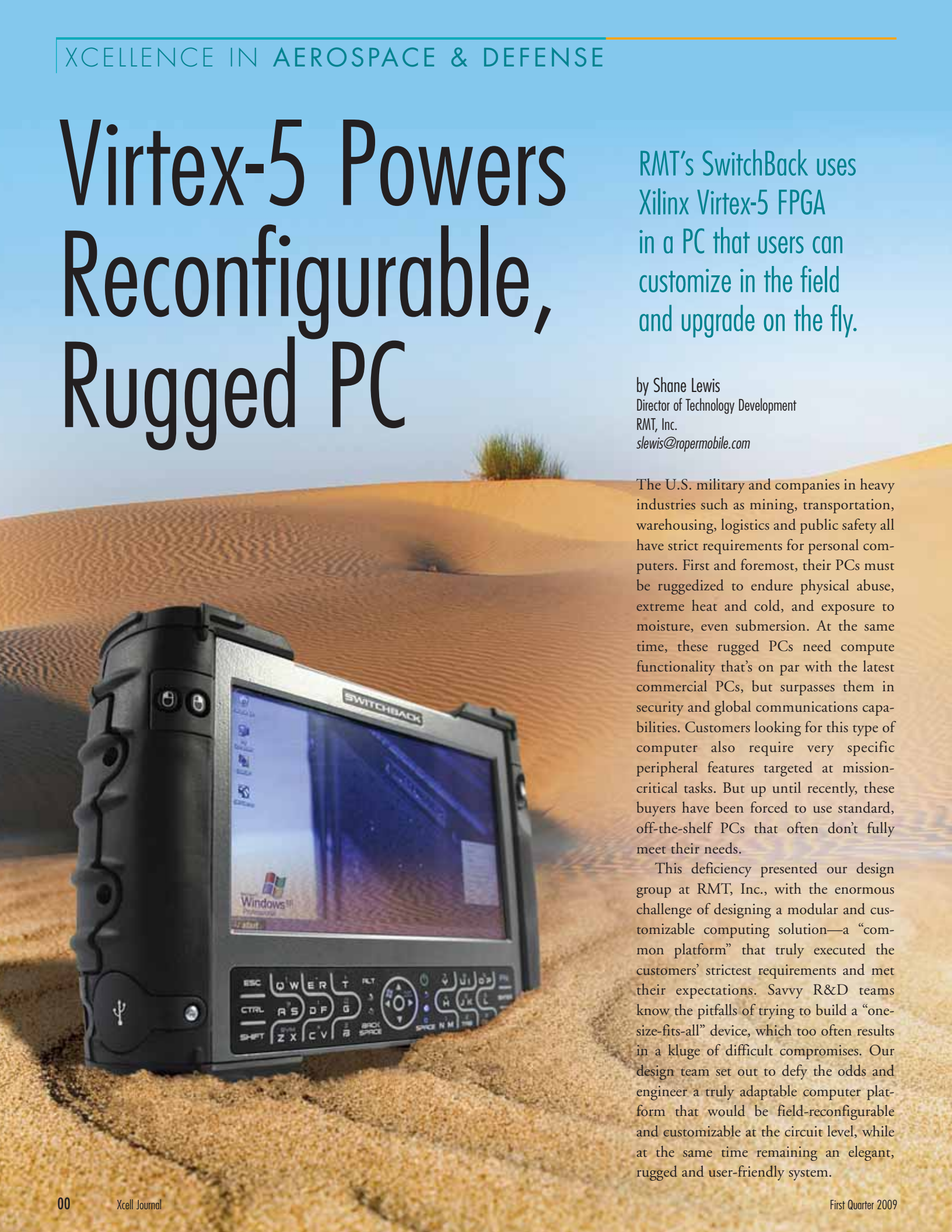

The U.S. military and companies in heavy industries such as mining, transportation, warehousing, logistics and public safety all have strict requirements for personal computers. First and foremost, their PCs must be ruggedized to endure physical abuse, extreme heat and cold, and exposure to moisture, even submersion. At the same time, these rugged PCs need compute functionality that's on par with the latest commercial PCs, but surpasses them in security and global communications capabilities. Customers looking for this type of computer also require very specific peripheral features targeted at mission-critical tasks. But up until recently, these buyers have been forced to use standard, off-the-shelf PCs that often don't fully meet their needs.

This deficiency presented our design group at RMT, Inc., with the enormous challenge of designing a modular and customizable computing solution—a "common platform" that truly executed the customers' strictest requirements and met their expectations. Savvy R&D teams know the pitfalls of trying to build a "one-size-fits-all" device, which too often results in a kluge of difficult compromises. Our design team set out to defy the odds and engineer a truly adaptable computer platform that would be field-reconfigurable and customizable at the circuit level, while at the same time remaining an elegant, rugged and user-friendly system.

The result of this effort is the SwitchBack. This computer is truly different at every level, and redefines PC architecture through its innovative use of the Xilinx® Virtex®-5 FPGA. The difference between the traditional PC and the SwitchBack architecture is quite extraordinary.

Traditional Open PC Architecture

The base of any modern legacy PC is an x86 processor and associated chip set for either Linux or Windows, namely Windows XP or Vista. It's the legacy support behind this code set that has enabled it to dominate the PC world and subsequently, to constrain the embedded computer space, where operating systems and processor technologies tend to be more fragmented. If you open any desktop, laptop or tablet PC designed to run Windows XP or Vista, you will find a chip set/CPU circuit topology.

This architecture, which has been the de facto standard for all PCs, both rugged and commercial, for many years, has one fundamental limitation. Task execution must either be written for a specific processor or must be plugged into one of the many available expansion ports as external hardware. The boundaries of what can be done are closely defined around the wiring of the dedicated ASICs that make up the chip set itself.

Figure 1 – The difference between a traditional PC architecture (left) and the revolutionary SwitchBack is that in the latter, the FPGA is the primary controller. This improves processing time and makes the SwitchBack reconfigurable and customizable.

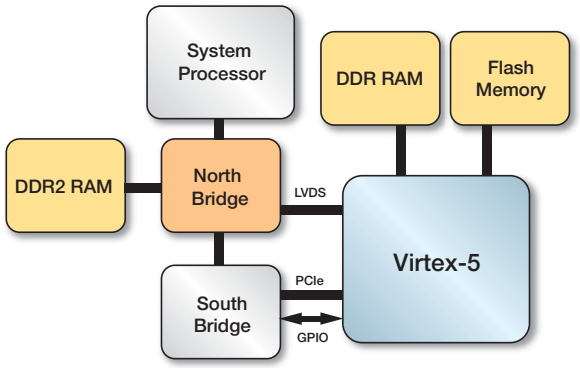

Figure 2 – In the SwitchBack architecture, primary system control is a function of the Virtex-5 FPGA, not the main x86 CPU processor.

SwitchBack Architecture

To get a different outcome, the RMT team knew that we had to rethink this design. We crafted SwitchBack's patent-pending architecture to be both field-reconfigurable as well as compatible with Windows-based applications. The concept of field reconfiguration is widely utilized today in embedded computing, a trend that FPGAs have enabled.

While programmable logic may play various supporting roles on some x86 PC-based motherboards, the FPGA is the hero in the SwitchBack, directing the computer's functions (Figure 1). The Virtex-5 is the primary controller of all major subsystems. From the moment the user presses the power button, the FPGA controls all peripherals, including the display itself, as well as the flow of most data. This scheme makes it possible to access and view data without booting the Windows operating system—a feat that's virtually impossible with a traditional PC. The SwitchBack takes it a step further by allowing users to access and control custom functions and peripherals without the assistance of the processor or operating system. These are programmed into the BackPack, a modular system that attaches to the rear of the SwitchBack and allows full control of any peripherals without waiting for slow-moving processors or operating systems.

The Heart of the SwitchBack

The amazing flexibility and control of the SwitchBack is made possible through an architectural design based on the Xilinx Virtex-5 LX30T. The RMT team selected the Virtex-5 for its vast array of internal resources as well as its RocketI/O™ and PCI Express® Endpoint Block. We then set the PCI Express interface as the major connection point between the embedded system and the Intel x86 system. Although there are other interface bridges between the components, this one is the major data pipeline for processing and control.

Hardware Design

The fundamental layout of SwitchBack's hardware design is essentially two systems that can operate independently. The Virtex-5 FPGA, not the x86 CPU processor, is the primary control system (Figure 2). It actually configures immediately upon system boot-up, before allowing the secondary system to begin booting.

Additionally, the FPGA has its own RAM and flash memory for both configuration and program storage, should users need to program secondary operations into the FPGA. This revolutionary architecture and its FPGA-defined algorithms provide several key capabilities that ordinary PCs cannot accomplish. They include control of all system resources allowed by the main processor or its base chip set, and independent and autonomous control of peripherals, including those programmed into the SwitchBack's BackPacks. The FPGA also includes processor-independent functions to assist the main processor.

Control of system resources and peripherals is straightforward and well-understood in the embedded world. But the use of processor-independent functions raises new possibilities for realizing the SwitchBack's full potential. The options include reconfigurable hardware, open FPGA for open architecture, additional customization via BackPacks and a BackPack modular development kit.

Reconfigurable Hardware

The Virtex-5's internal resource array—including the ExpressFabric Architecture, block RAM, 1.25-Gbit/second Select I/O and DSP48E slices—offers a multitude of possibilities when creating functions and processes that would normally be done in software on the main processor. With these chip features, we were able to implement many capabilities into the FPGA to offload a portion of the main processor's duties, or create from scratch entirely new subsystems that behave like physical expansion cards in a regular PC.

By using the PCI Express bus between the two systems, we can connect the new hardware expressed in the FPGA to the main processor as though it were physical hardware plugged into an expansion port (Figure 3). This allows the construction of new types of devices that operate independently of the main x86 processor. These devices or functions may include data format conversion, custom logic interfaces, hardware emulation, independent microprocessors, communications devices, arithmetic cores and autonomous BackPack control.

In fact, we call these functions "virtual devices" because they appear to the operating system as separate hardware, yet there is no physical circuit card to implement them. One or more devices can be implemented at the same time, expanding the platform far beyond the features expressed by the onboard chip set.

Open FPGA for Open Architecture

Part of our vision was to preserve the PC's open architecture platform and extend that flexibility further to include the FPGA itself. The capacity of the Virtex-5 FPGA is greater than the SwitchBack requires for its main control functions. Our team purposely chose a larger FPGA to allow customers to add their own programming and functionality to SwitchBack, enabling them to develop a truly custom, precision tool that can accomplish the same results as multiple independent subsystems attempting to work in parallel.

Figure 3 – Any reconfigurable hardware expressed in the FPGA can connect to the main processor, which can access it as though it were physical hardware plugged into an expansion port.

Thanks to the innovative use of the Virtex-5 in the SwitchBack, customers need no longer settle for a suboptimal computer and an assortment of dissimilar peripherals connected by a mess of cables.

We also intentionally underutilized the Virtex-5 FPGA as the system master in SwitchBack. For example, of the Virtex-5 LX30T FPGA's 32 DSP48E slices, the SwitchBack uses only one, leaving the remaining 31 available for the end user. Depending on the buyer's resource needs and the configuration of the SwitchBack at purchase, available resources such as registers, LUTS, BRAM, DCM and PLLs may be available for customer-specific use. In general, the SwitchBack uses less than half of the FPGA for system management and general housekeeping, leaving the majority of the remaining resources for the user to define.

A custom update interface tool allows users to easily update the flash memory inside the SwitchBack. This simple software update requires no JTAG or specialized equipment to modify the FPGA's configuration file. Installing new hardware is quick and easy. Users simply reboot the SwitchBack system and watch the new hardware appear in the Hardware Manager, ready for immediate use.

We also packaged the SwitchBack's requirements for the FPGA into an easy-to-implement core, which allows the end customer to quickly add logic, registers and data buses to the remaining FPGA space available.

Our Firmware Development Kit (FDK) allows customers to modify and reconfigure the SwitchBack to meet their own specific needs, as the mission changes. The SwitchBack can quickly adapt to the in-field situation with a unique module upgrade, custom logic changes to the FPGA or both. This scheme effectively redesigns the system in the field. By providing this capability in an FDK, customers with FPGA experience and the proper place-and-route tools can create and shape the SwitchBack to fit their exact needs.

Additional Customization via BackPacks

The SwitchBack is capable of further customization through its BackPack technology. BackPacks are customer-specific modules that users can securely attach to the back of the SwitchBack. RMT initially created the BackPack to eliminate the need for external peripherals and to add multiple ports. BackPacks can take on an infinite array of sizes, shapes and complexity—handling additional processing capabilities, for example—endowing this personal computer with the computational clout of a supercomputer. In this way, the BackPack is a field-customizable system that can morph SwitchBack into a highly integrated, precision tool.

The RMT team routed the GPIO from the FPGA directly to the BackPack port so that logic in the FPGA could gain access to the attached BackPack, making it possible to control any type of device without ever involving the main system processor. The SwitchBack's promise can now be fully realized when combining the reprogrammable FPGA with the unlimited potential of external adaptability.

Modular Development Kit

Building upon the success of the BackPack, we found that FPGA-savvy customers could develop and program their own BackPacks if we provided them with the right tool kit. The SwitchBack's Modular Development Kit (MDK) allows them to design custom BackPacks that will make use of SwitchBack's unique architecture. In many cases, customers have electronic devices or circuit cards they wish to integrate for rapid testing and deployment. The MDK makes doing so a snap. It provides a functional circuit board, cables, schematics and mechanical CAD data, allowing a customer to build a BackPack in a matter of days.

By using SwitchBack's onboard FPGA and BackPack technology, users can build entire subsystems of specialized functions and tie them to the computer rapidly. Although a BackPack is part of the computer itself, it can operate completely autonomously, sharing only processed data rather than bogging down the main processor with extra duties, as can happen when attaching devices through traditional methods (such as USB). Thus, customers can implement BackPacks with equal or greater processing responsibility without burdening the main processor.

The Xilinx Virtex-5 with DSP48E slices can be put into service to provide additional signal processing at an enhanced and improved efficiency level. A few examples of possible adaptations include image processing, software radios, cryptography, network security and analog modems.

Users can increase the performance of particular functions when they build the analog topology of these functions into a BackPack while letting SwitchBack handle the processing duties onboard.

Thanks to our design group's innovative use of the Virtex-5 in the SwitchBack, customers no longer have to settle for a suboptimal computer and an assortment of dissimilar peripherals connected by a mess of cables. In this way, the SwitchBack enables rapid system design and deployment for mission-critical applications.

SwitchBack is the next evolutionary step in computer technology. Essentially, it's a reconfigurable PC platform that customers can customize in the field and upgrade on the fly. Since it can run mission-critical applications without interruption, it is especially suited for operations in key markets such as the U.S. military, mining, transportation, warehousing and logistics, public safety and many others.

To learn more about the SwitchBack and its revolutionary architecture, visit *www.ropermobile.com* or e-mail or phone the author at RMT, Inc., at *slewis@ropermobile.com* or (480) 705-4200, ext. 306.