New PCI Express Solution Simplifies Video Security Applications

How to implement a video security system using PCI Express.

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An ideal video security device would be able to collect live compressed or uncompressed video, monitor each stream for motion, record all of the streams, and save the video to a hard disk (or write it out to a shuttle DVD system). However, these systems would end up costing more than what an average security consumer would be willing to pay, especially when the per-stream cost expands after four to eight streams.

This ideal security device would also be able to monitor motion and only record those streams that had motion, saving both disk space and bandwidth. One way to do this is to capture the video streams on a low-cost PCI card and store the input streams to a hard drive after performing some CPU processing. This reduces the cost of a built-from-scratch dedicated system by using off-the-shelf hardware.

However, there's a problem with the densities and processing power. If you want to store uncompressed streams, you quickly run out of bus bandwidth on a shared PCI bus, as well as processing power on its CPU. For instance, the maximum bus bandwidth in both directions on an off-the-shelf, low-cost ($800) PC would be between 2-4 Gbps. Spreading the video-capture capabilities among multiple PCI cards does not help the bus bandwidth issue because 4 Gbps is the top limit of the entire PCI bus – not just of any single slot. And once shared with other cards on the PCI bus, you would be lucky to get about 1 Gbps of throughput in both directions.

You could use compression chips to reduce the bandwidth on the bus, but this would increase your cost and limit you to existing MPEG chipsets, without an easy way to perform additional processing or special motion-detection functions that are key for the security market.

Uncompressed video (once stripped of blanking) is around 165 Mbps of data. Thus, with 1 Gbps of total bandwidth, you are limited to at most a mix of six capture or playback devices of uncompressed video on one PCI bus PC.

PCI Express to the Rescue

PCI Express (PCIe) technology provides a significant jump in throughput to PC users. PCI Express is broken down into lanes. Each lane comprises a differential pair in each direction. Each differential pair provides a 2.5 Gbps stream with an 8b/10b encoding scheme, with 2 Gbps of data throughput per pair in that direction. But even more impressive, each PCIe slot on a motherboard has its own lanes that are not shared with any other slot. Each slot comes in configurations of 16 lanes (also called a x16 or "by 16"), 8 lanes (x8), 4 lanes (x4), or 1 lane (x1).

Today you can purchase an off-the-shelf low-cost PC motherboard with one x16 PCIe graphics slot and two x1 PCIe card slots, as well as two or more regular PCI slots. Server models come with x4 or x8 PCIe slots. You can even use the x16 graphics slot for another function if you do not need a graphics function, or if it is already integrated into the motherboard.

Thus, PCIe allows each card to provide data from 2 Gbps in a x1 lane to as much as 32 Gbps in a x16 lane.

You can immediately see the advantages. Most low-cost motherboards are now capable of supporting more than 36 Gbps of video data in both directions (this is very dependent on the speed of the peripherals). Bandwidth-wise, this means that each PC motherboard could technically support more than 200 uncompressed video captures or playbacks in each direction (although you will run into limitations on the peripherals before you get to this point).

Using low-cost Xilinx® FPGAs, you can go one step further and provide motion detection as well as some hardware assist in the FPGA. A high-speed DDR DRAM will allow the CPU to perform the easier portions of the compression and store data only when there is motion, thus reducing the storage requirements. Of course, you will have to make some compromises, depending on if the streams will be played back on standard DVD players.

The Tentmaker PCIe Prototyping Solution

The Tentmaker PX Wave PCIe Design Kit shown in Figure 1 (the block diagram is shown in Figure 2) is one possible video security solution, comprising four video capture devices from Philips, a Xilinx Spartan™-3 FPGA, and a Philips PCI Express x1 PHY. It is designed as a low-cost ($1800) evaluation system for companies

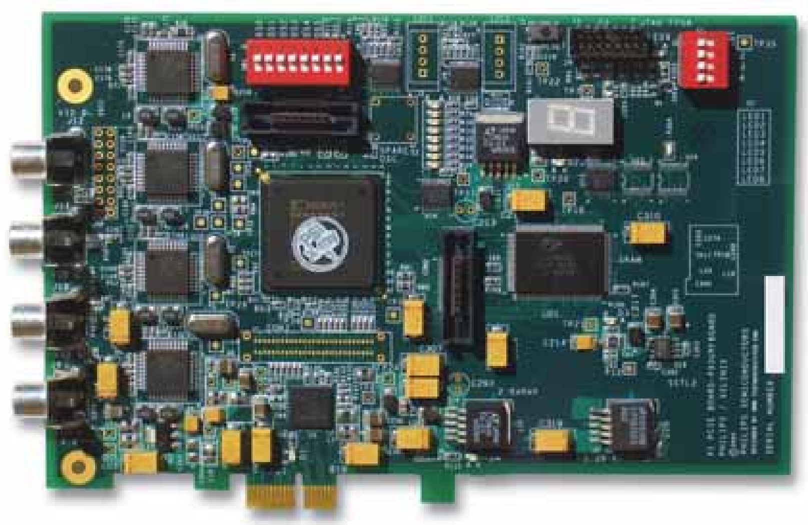

Figure 1 – PX Wave PCIe Design Kit board

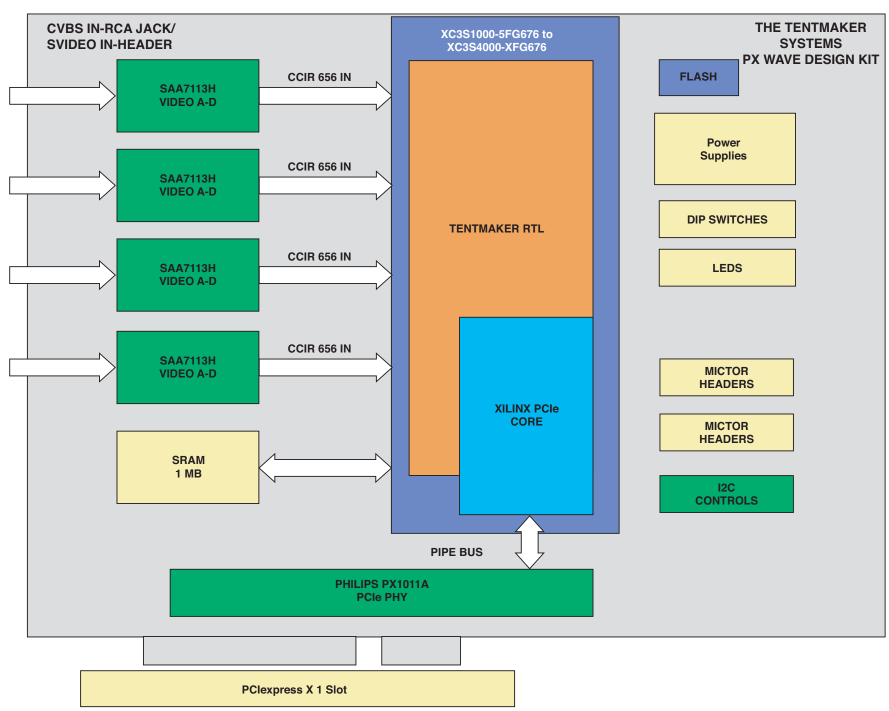

Figure 2 – PX Wave PCIe Design Kit block diagram

PCI Express is becoming more pervasive. As more applications like video continue to grow and require more bandwidth, PCI Express is well-suited to meet the related demands.

that want to get a jumpstart on designing boards to address this market. It contains all of the components except the high-speed DDR DRAM (an SRAM is used in this version). The PX Wave Design Kit allows companies to eliminate much of the learning curve associated with PCIe designs.

It would be easy to expand this design to use 16 video captures, the Xilinx PCIe x4 core, and an associated x4 PHY (Figure 3). Naturally, a cable harness would need to be created for the 16 video inputs because of rear-plate surface-area limitations. The hardware assist could include a simple FPGA motion detector that provides an alarm and directs the PC to only record those streams that have motion, or you could dynamically allocate bandwidth so that cameras with the most motion get more bandwidth. Other hardware assists could include complex motion estimation, VLC (variable length code) generation, and other such preprocessing.

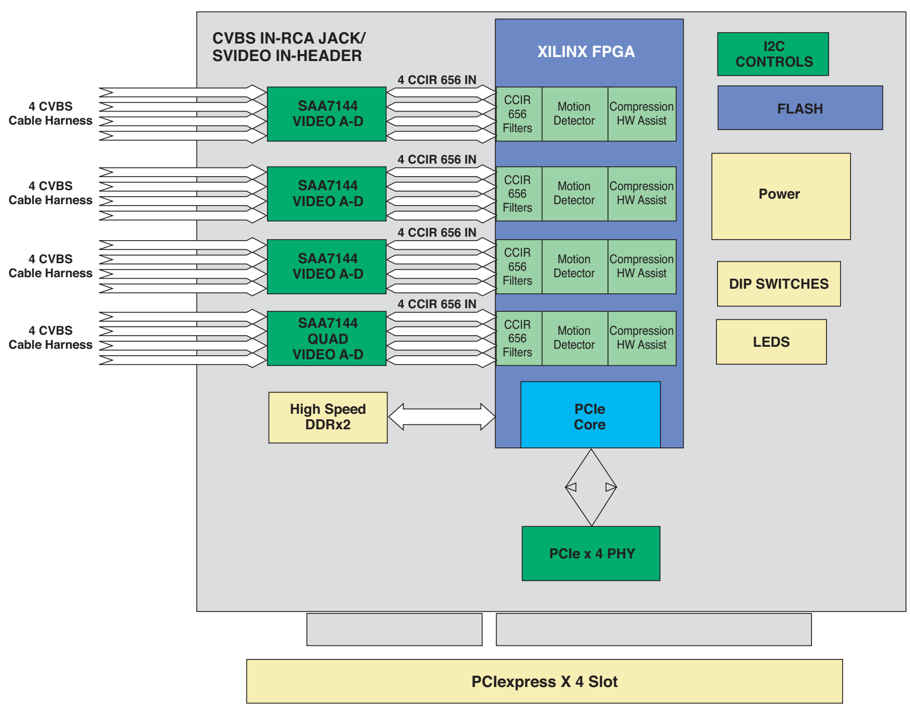

Figure 3 – Block diagram of a 16-input security solution with hardware assist

Other applications could use a high-speed, high-resolution camera that requires the extra bandwidth of PCIe for a single stream. You could also add hardware processing by using a preprocessing FPGA, as I've described.

For storage, it is also useful to be able to automatically add a graphic overlay showing the capture time and camera number. You can do all of this very easily in software or hardware, assuming that the system has access to the compression algorithm. You can also insert text into the closed-caption fields at this point.

In the PX Wave PCIe Design Kit, four Philips SAA7113 chips are used to capture four input analog CVBS (composite video, blank, and sync) or Y/C (luma and chroma) streams. The video analog-to-digital converters produce four independent digital CCIR656 streams, which are then fed into a low-cost Spartan-3 device for preprocessing. In the FPGA, the video data is stripped of blanks and syncs, packetized appropriately for PCIe, and fed to the Xilinx PCIe core. Software can then take the input video and display it, process it, or store it to disk.

PCI Express is straightforward if you follow some simple design principles. The high speed 2.5 Gbps lines are differential and thus simple to lay out, as long as the traces are length-matched and you adhere to some standard layout methodologies. More complicated is the PIPE bus that goes between the FPGA and the PHY. This bus must support signals at 250 MHz and each direction must be length-matched.

Conclusion

PCI Express is becoming more pervasive. As more applications like video continue to grow and require more bandwidth, PCI Express is well-suited to meet the related demands.

With connectors that allow you to add daughter boards and easily debug, the PX Wave PCIe Design Kit provides an easy way for companies to prototype generic PCI Express cards for security, video, and any generic application. In fact, the Xilinx PCIe core and the Philips PCIe PHY were prototyped and passed PCI-SIG PlugFest in the Summer of 2005 using the PX Wave Design Kit.

For more information, visit *www.tentmakersystems.com.*

Tentmaker Systems Consulting Group is part of a group of companies working on a PIPE-C specification. This is a connector specification that provides a standard connection between PHYs and PCIe cores, allowing various cores to be easily tested and used with various PHYs. The PIPE-C connector is available on various Tentmaker Systems boards.