Military Display Systems Leverage PCI Express Backplane Architectures

Display systems used for today's command and control programs can do amazing tasks. But it's the data processing and data movement behind the scenes that makes it all possible.

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Many factors are at play in both training and live combat situations, but Situational Awareness (SA) continues to be a defining factor in executing successful battlefield missions. The warfighter is tasked with making decisions in the field based on the data at hand, while military command and control centers are designed to attain a far more thorough understanding of the operational landscape by aggregating, analyzing and integrating large volumes of data collected from a wide range of sources. In either case, sophisticated display technology is increasingly being called upon to present a combination of images and raw data in such a way that the decision-making process is significantly improved by having access to more accurate and timely information.

The history of electronic displays in military operations goes back to WWII and the early incarnations of CRT-based radar screens. Revolutionary in its time, radar capability proved pivotal to the Allies winning that war, but the more recent advent of powerful computers and enhanced communications capability, combined with advances in video processing technology and display systems, has spawned the age of visualization and collaboration—a paradigm shift that is promoting situational awareness to an entirely new level by creating a more precise Common Operational Picture (COP) that is dynamically generated and can be shared with anyone in the world possessing a network connection.

Figure 1

With advancements in ruggedization, durability, resolution and performance, displays have fueled a wide variety of military systems including the Panoramic Cockpit Display (PCD) aboard the F-35 Lightning II Joint Strike Fighter (JSF).

Command and Control Centers

Benefiting from continuous improvements in ruggedization, durability, resolution and performance, displays of various sizes and capability have continued to proliferate within land-based vehicles, ships, aircraft and submarines, as well as in the hands of soldiers. Examples include the Panoramic Cockpit Display (PCD) aboard the F-35 Lightning II Joint Strike Fighter (JSF) (Figure 1), the upgraded Combat Information Centers (CIC) aboard the Navy's Aegis guided missile cruisers, and prototypes of wrist-mounted flexible Organic Light Emitting Diode (OLED) displays. As beneficial as these application-specific solutions have proven to be, nowhere is the influence of display technology more evident than the deployment of video walls in command and control centers.

In contrast to dedicated display systems, which tend to deal with limited data sets and serve individuals or small groups, centralized video wall systems can present multiple image, video and data feeds from sources throughout a theatre of operation to large audiences, both captive and remote. The size and scope of these implementations continue to grow as LED-based DLP cubes hit the market achieving 1920 x 1200 WUXGA resolution and 1920 x 1080 HDTV LCD panels now exceed 80" in diagonal viewing area. Driven by a new generation of video controllers loaded with multi-headed graphics cards, a matrix of LCD or DLP displays provides the viewer with a large virtual desktop that can be easily manipulated in response to rapidly changing situations.

Figure 2

The Activu system, operating on an IP network, enables any data source to become part of the display. Shown here is an Activu installation at Barksdale Air Force base.

Fundamental Changes

While the visual aspect of building large multi-unit arrays that can fill a conference room is impressive, a fundamental change is underway with regards to managing the overall system. "The new paradigm in video wall technology represents a fundamental shift from being hardware-based to software-based," says Paul Noble, CEO of Activu. "The old way of AV (Audio Visual) thinking has given way to a far more robust IT (Information Technology) mindset, similar to the transition that occurred when communication technology migrated from circuit switching to packet switching."

Rather than building standalone AV solutions, the approach Activu has taken is to use the existing IP network for the transmission, storage and management of information from all sources, which further enables the concept of visualization and collaboration (Figure 2). Operating on the network, any data source can become part of the display. For example, in addition to images and live motion video feeds, real-time data from systems such as access control programs, intrusion detection devices, SCADA management systems or chemical, biological and radiological sensors can be integrated into the view. New content streams can be reviewed on workstations before being pushed to the wall and manipulated on the fly, and bypassing the need for any operator intervention, preset alert parameters can be programmed to trigger automatic content inclusion when specific events occur or limits are exceeded.

Network-Based Sharing

Use of the network for data exchange also enables sharing of displayed information outside the center in a secure manner based on user authentication. When information is only available at one location, remote personnel are forced to spend valuable time in transit to reach the operations center. However, with video images distributed via broadband connections, the entire wall display, or any segment, can be replicated on a personal computer, laptop or wireless mobile device, thus accelerating and improving the decision-making process. When integrated into the network domain, user security is handled via Active Directory authentication.

This combination of network distribution based on user-level security allows

Figure 3

With Activu, a video wall can be displayed on a smartphone. In that way the software can push images like these into the field.

segmentation of the data so that different people can each view a subset of the overall picture on a strictly need-to-know basis with detailed log files tracking user activity. In the case of Activu's implementation, Federal Information Processing Standard (FIPS) encryption standards such as 192-bit Triple DES encryption between software modules, 256-bit AES encryption between agent and system server and 160-bit SHA-1 hash password protection are utilized.

Mobile Device Integration

In the past few years mobile devices, such as rugged laptops, smartphones and tablets, have become increasingly sophisticated with regards to capturing, viewing and editing images or Full Motion Video (FMV) and transmitting such data by way of cellular networks or Wi-Fi connections to the command center when using Activu's Mobility smartphone client (Figure 3). Using a device's built-in GPS, GeoTagging of photos and video in real time allows location coordinates to be included in the metadata along with other critical information such as date, time, annotations and user ID.

Accessing this metadata within a command and control center enables the images or video to be overlaid on a physical or topographic map. Multiple video feeds of an ongoing military operation from different points of view can also be displayed in a coordinated fashion. In addition to operating in transmit mode, these mobile devices can be switched to receive mode, allowing the user to see the same aggregation of information that is present on the command center's wall display, and using dual-touch technology, the device's screen image can be zoomed and scrolled.

Enabling Backplane Technology

Network-based video wall software and the integration of mobile devices create new opportunities for collaboration, but at some point all that data needs to be processed within a video controller. Taking a look inside the box reveals the need for backplane designs that employ a high-speed bus architecture such as PCI Express Gen 2, and provide support for higher video channel density. This requirement was brought to Trenton Technology as a challenge to design and build a backplane that could mount inside a ruggedized 19-inch rackmount enclosure, provide at least sixteen x16 PCI Express Gen 2 slots, and support other I/O such as multiple Gigabit Ethernet connections, standard USB I/O and an optional RAID array.

Supplying sixteen Gen 2 x16 PCI Express slots is not a native capability of any processor or chipset on the market today, as most CPU/chipset combinations support only one downstream x16 PCI Express port. The solution arrived at during the design of Trenton's BPG8032 backplane was to expand that single port using PCI Express switches that take the upstream x16 Gen 2 link from the CPU and multiplex that link to several downstream x16 Gen 2 devices or slots.

The largest readily available switches have 96 lanes of Gen 2 PCI Express, providing six x16 Gen 2 ports. One port on each switch is used for an upstream link to the host while the remaining five ports are able to support downstream devices or slots. With an objective of sixteen slots on the backplane, the answer was to cascade three additional switches below the first. With each of these three switches sacrificing one port for an upstream link, five ports remain available for slots, thus providing a total of fifteen slots. The primary switch in the layout used one port for the upstream CPU link and three ports downstream—one for each of the subordinate cascading switches. So out of the original six ports available, two ports remained to support additional x16 PCI Express slots on the backplane for a total of seventeen slots (3 x 5 + 2), exceeding the design objective.

Benefits of Cascade Approach

Implementing a cascade approach—as opposed to simply daisy chaining the switches in a downstream fashion—has advantages. It provides the benefit of reducing the total number of switches that data packets from any one slot must flow through—either upstream to the CPU or to another PCIe slot on the backplane. This can be an important factor in overall system design, as each hop through a switch adds latency and can adversely affect bandwidth. With this design, the maximum number of hops routed through switches was reduced to a maximum of three.

Creating a block diagram of a backplane that supports a PICMG 1.3 system host board and contains four 96 lane Gen 2 PCI Express switches is relatively simple, but translating that diagram into an actual design presented a number of technical challenges (Figure 4). Over half of the backplane's PCB real estate is consumed by the PICMG system host board and device slots. The switches themselves are physically large and also require supporting voltage regulation circuitry. In addition, each device and slot requires PCI Express clocks that are generated by other devices and their supporting circuitry, which means routing room must be available for all of the data signals to each switch and slot.

From the standpoint of board layout, placing these devices wherever there is empty space is not a viable option, as there are stringent requirements for routing Gen 2 PCI Express data and clock lines that must be met in order to ensure functional reliability. For example, at 5 GHz the PCI Express signals must be kept below certain maximum lengths to minimize signal loss, and the transition of these signals between circuit board layers must be kept at an absolute minimum in order to reduce noise and jitter in the signal. Therefore, placement of the switch devices to provide the most optimal routing was a critical design objective. In addition, each PCI Express lane is comprised of a differential transmit pair of signals and a differential receive pair of signals. The lines within the differential pair must be carefully matched for length and width and the spacing between them must be accurately maintained throughout the entire length of the signal. The signal pairs must also maintain a significant separation from other signals and ideally should maintain a solid reference to a ground plane without discontinuities.

Power Delivery Issues

Power delivery to the system host board, PCI Express slots and the PCI Express switch circuitry is an integral part of the design process. PICMG 1.3 system host boards can take well over 200W while the x16 PCI Express slot connectors need to provide up to 75W each, and the PCI Express switch circuitry itself needs significant power. Delivering that amount of power into and through the backplane without compromising the signal integrity can be tricky. Thermal issues also come into play as each device must be cooled effectively without the thermal solution interfering with cards that may be plugged into the PCI Express slots. And at the system level, the entire environment must be effectively cooled for long-term reliable operation.

Once video wall cards are plugged in and are ready to run, the next challenge is to make sure that the host board can properly provision the cards for operation in the hierarchical PCI Express environment. PCI Express as an architecture is designed to be backward compatible with PCI and inherits some of the limitations of PCI. When a computer initializes, one of the tasks of the BIOS is to discover each PCI or PCI Express device in the system, query these devices for the system resources required, then allocate those resources if possible. In a dense system with a large quantity of high-end cards, such as multiple output video wall cards, resource requirements can be significant, and in such situations, it is often necessary to modify the BIOS to overcome legacy shortcomings and properly support the configuration.

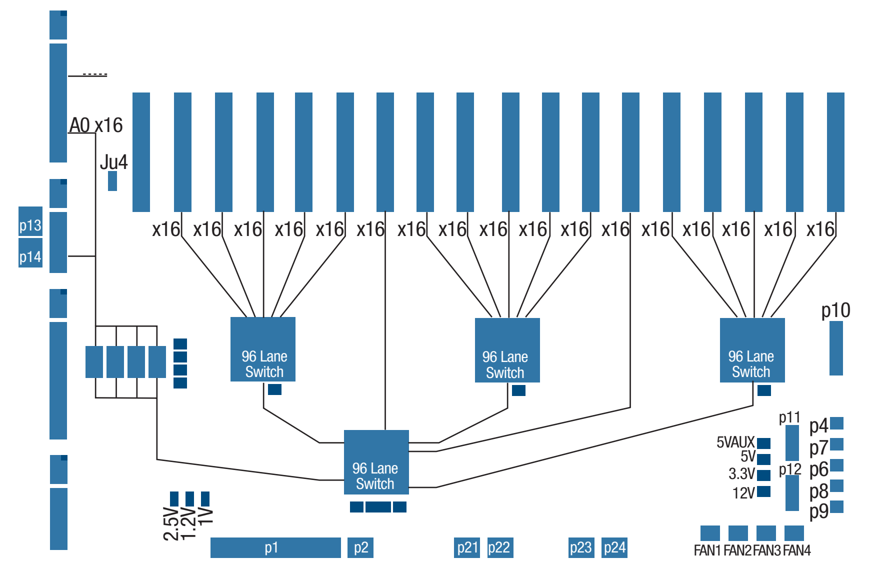

Figure 4

This backplane design supports a PICMG 1.3 system host board and contains four 96 lane Gen 2 PCI Express switches.

The evolution of display technology will continue unabated, as will the sophistication of visualization and collaboration software and the ubiquity of mobile devices. To drive it all, the release of PCI Express 3.0 will foster a new generation of video controllers and multi-headed graphics cards by mid-2012.

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