DETERMINATION OF AN OPTIMAL DATA BUS ARCHITECTURE FOR A FLIGHT DATA SYSTEM

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ABSTRACT

NASA/Marshall Space Flight Center (MSFC) is continually looking for methods to reduce cost and schedule while keeping the quality of work high. MSFC is NASA's lead center for space transportation and microgravity research. When supporting NASA's programs several decisions concerning the avionics system must be made. Usually many trade studies must be conducted to determine the best ways to meet the customer's requirements. When deciding the flight data system, one of the first trade studies normally conducted is the determination of the data bus architecture. The schedule, cost, reliability, and environments are some of the factors that are reviewed in the determination of the data bus architecture. Based on the studies, the data bus architecture could result in a proprietary data bus or a commercial data bus. The cost factor usually removes the proprietary data bus from consideration. The commercial data bus architecture's range from Versa Module Euro card (VME) to Compact PCI to STD 32 to PC 104. If cost, schedule and size are prime factors, VME is usually not considered. If the prime factors are cost, schedule, and size then Compact PCI, STD 32 and PC 104 are the choices for the data bus architecture.

MSFC's center director has funded a study from his discretionary fund to determine an optimal low cost commercial data bus architecture. The goal of the study is to functionally and environmentally test Compact PCI, STD 32 and PC 104 data bus architectures. This paper will summarize the results of the data bus architecture study.

KEY WORDS

Commercial Data Bus Architectures, Compact PCI, PC 104, STD 32.

INTRODUCTION

All programs whether large or small are always looking for methods to minimize the cost and schedule of their projects, while at the same time keeping the quality and reliability high. To accomplish the trade of resources versus quality, the project usually conducts several trade studies. One of the first avionics trades undertaken is the determination of the data bus architecture of the avionics data system components. The cost, schedule, reliability and expected environments are some of the factors that are considered when determining the flight data system components data bus architecture. Based on the trade study factors, the data bus architecture could result in proprietary data bus or a commercial data bus. Based on the cost and schedule factors, the proprietary data bus is usually removed from consideration. The commercial data bus architectures available range from Versa Module Euro card (VME) to Compact PCI to STD 32 to PC 104. If cost, schedule and size are driving factors, then VME is usually not considered. If the trade studies prime evaluation criteria are cost, schedule and size, then Compact PCI, STD 32 and PC 104 are good choices for the data bus architecture.

NASA/Marshall Space Flight Center's (MSFC) center director has funded a study to determine optimal low cost commercial data bus architecture for flight data systems. A small data acquisition system was the data system that would be tested. The goal of the study was to functionally and environmentally test a Compact PCI system (cPCI), a STD 32 system and a PC 104 system and determine their operating characteristics. The functional and environmental test requirements would be a composite of several different programs.

The original goal of the study was to choose a commercial data bus architecture that could meet the requirements of a variety of programs. To accomplish this goal, the testing would be done with off-the-shelf hardware and software. Several manufactures were sought for this study, though for comparison, it would have been a benefit to study bus architecture from a single manufacturer. For the STD 32 and cPCI systems, a single manufacturer was available and utilized. The PC 104 bus system had many vendors, none of which made STD 32 or cPCI for the purpose of this study. It turns out however, there is a manufacturer that fabricates both the cPCI and STD 32 hardware.

Several components were purchased for the study of bus architecture, comparing the PC 104, STD 32 and cPCI. Some components were acquired using project funding if the project was to benefit from the study. Fully functional systems along with individual components that would make up a complete system were procured. These components range from the Central Processing Units (CPU), video cards, hard drives and memory products, to enclosures and stack systems.

All the systems had peculiarities, especially between vendor's components. Though each bus system is a standard bus architecture, embedded or bios software was not always compatible with other vendor's hardware. When complete systems were delivered from vendors, anomalies were few and far between. Piecing the components together to make a system was the source of many disappointments. The operating system was the common thread used between systems. All were operated in ROM-DOS, an embedded computer operating system. Later, different operating systems were installed and evaluated on their ease of installation. During the procurement of the hardware and software, it became apparent that the original goal of comparing the data bus architectures equally could not be accomplished. Each architecture had problems that prevented a head to head comparison from taking place.

This paper will briefly describe the STD 32, Compact PCI and PC 104 data bus architectures, give summary of the items procured and describe what the study was able to accomplish.

STD 32

The STD 32 bus architecture was established in 1990 and is a superset of the STD-80 series architecture. It extends the capabilities of the STD-80 series standard while remaining compatible with existing cards. Figure 1 shows an example of a STD 32 board. The board size is 4.5" x 6.5" with a 136-pin connector. The STD 32 bus provides a 32-bit wide data bus to support 8, 16 and 32 bit data transfers. The architecture uses a card cage. If VME power usage is considered high, the STD 32 power usage is medium. For more information concerning the STD 32 specifications, the STD 32 website is http://www.std32.com/.

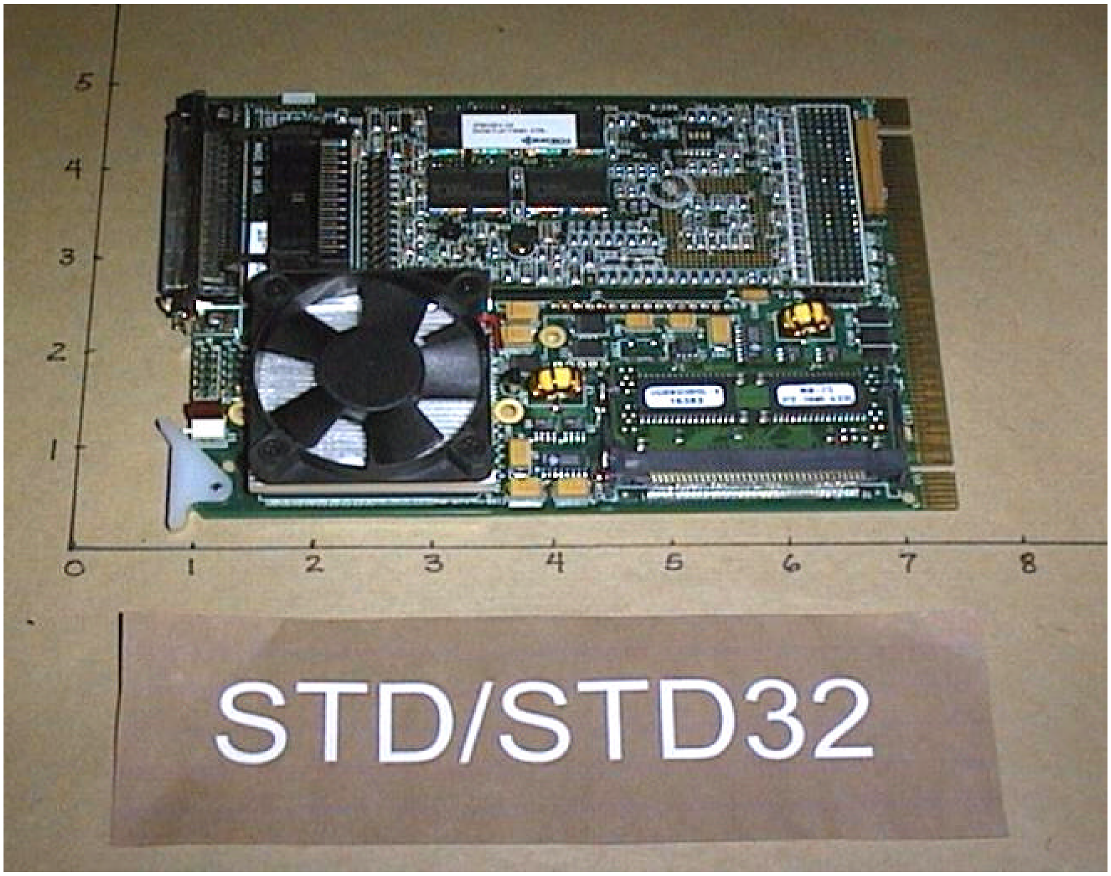

Figure 1- STD32 Form Factor

During the procurement of the STD 32 hardware it became very obvious that the architecture is not supported by many vendors and it appears to be slowly phased out. For example, a rugged flight chassis had been procured for a previous program and it was decided that this chassis would be ideal to test. However, during the procurement of the chassis, it was discovered that Kinetic Computer Corporation no longer produced a rugged STD 32 chassis. Kinetic Computer Corporation was the only vendor that was identified that supplied rugged enclosures. Table 1 shows a list of the hardware procured and its manufacturer. Table 1 shows that there are two principal vendors of STD 32. An extensive search was made for STD 32 vendors and it was determined that Versalogic and Ziatech produce the majority of the hardware. However, during the procurement of the hardware, it appeared that Ziatech was phasing out the production of STD 32 hardware.

The study did not purchase a complete and fully functional system from a vendor. Because there are very few manufacturers of this standard bus system, difficulty occurred during the acquisition of the necessary components to make up a system. This bus architecture was the most difficult to work with. Neither system worked from power up. Each system had to be adjusted and configured as necessary. After finally getting the system to recognize specifically required hardware, it would boot to the floppy disk drive or the resident memory chip. The BIOS on these boards must be original to STD. It was never able to recognize a hard drive greater than 2 gigabytes. After many changes to the BIOS, the best either of these systems would do is recognize a 2-GB hard drive and boot to DOS from the floppy. This difficulty makes this type architecture nearly useless in today's avionics systems. Several years ago, when this architecture was in its prime, the 2-GB limit was nearly unobtainable.

Vendor	Description
Versalogic Corporation	Table mount 4-slot chassis
Versalogic Corporation	Hard Drive Carrier Card (no HD included)
Versalogic Corporation	AMD CPU w/ Video and I/O built-in
Versalogic Corporation	80 watt Power Supply
Ziatech Corporation	Intel CPU with Video and I/O built-in
Ziatech Corporation	Intel CPU with Video and I/O built-in
Ziatech Corporation	IDE Interface (no HD included)
Ziatech Corporation	Floppy Drive/Carrier
Ziatech Corporation	PCMCIA Interface
Ziatech Corporation	Development Kit
Sensoray	Smart I/O Data Card, 16 channel
Kinetic Computer Corporation	Rugged Flight Chassis

Table 1- STD 32 Hardware Vendors and Description

COMPACT PCI

Compact PCI (cPCI) is an adaptation of the Peripheral Component Interconnect (PCI) specification for industrial or embedded applications requiring a more robust mechanical form factor than desktop PCI. Figure 2 shows a cPCI board. The form factor defined for cPCI is based upon the Euro card industry standard. Both 3U (100mm x 160mm) and 6U (233.5mm x 160mm) board sizes are available. The 3U form factor supports the 64-bit cPCI bus. The 6U form factor is used when additional board area or connector space is required. A cPCI system consists of one or more bus segments. Each bus segment consists of one system slot and up to seven peripheral slots. The system slot board provides arbitration, clock distribution and reset functions for all boards on the segment. The peripheral slots may contain simple boards, intelligent slaves or PCI bus masters. cPCI uses a back plane. The board connector has 220 pins and is divided into two halves. cPCI's power usage is medium when compared to VME, which has a high power usage. For more information concerning the cPCI architecture, the cPCI website is http://www.picmg.org/gcompactpci.htm.

When initial research for the study was being done, it was very evident that cPCI had the most potential of any of the bus architecture's being evaluated. cPCI has all of the benefits of VME plus some without having the negative factors of VME. cPCI is based on the PCI bus protocol. Therefore much of the software and test equipment designed for personal computers is directly applicable to cPCI. The cPCI architecture is inherently fault tolerant. The 6U board form factors are so similar between VME and cPCI that all of the VME ruggedization techniques apply to cPCI. Even with all of the similarities between cPCI and VME, cPCI costs a fraction of VME.

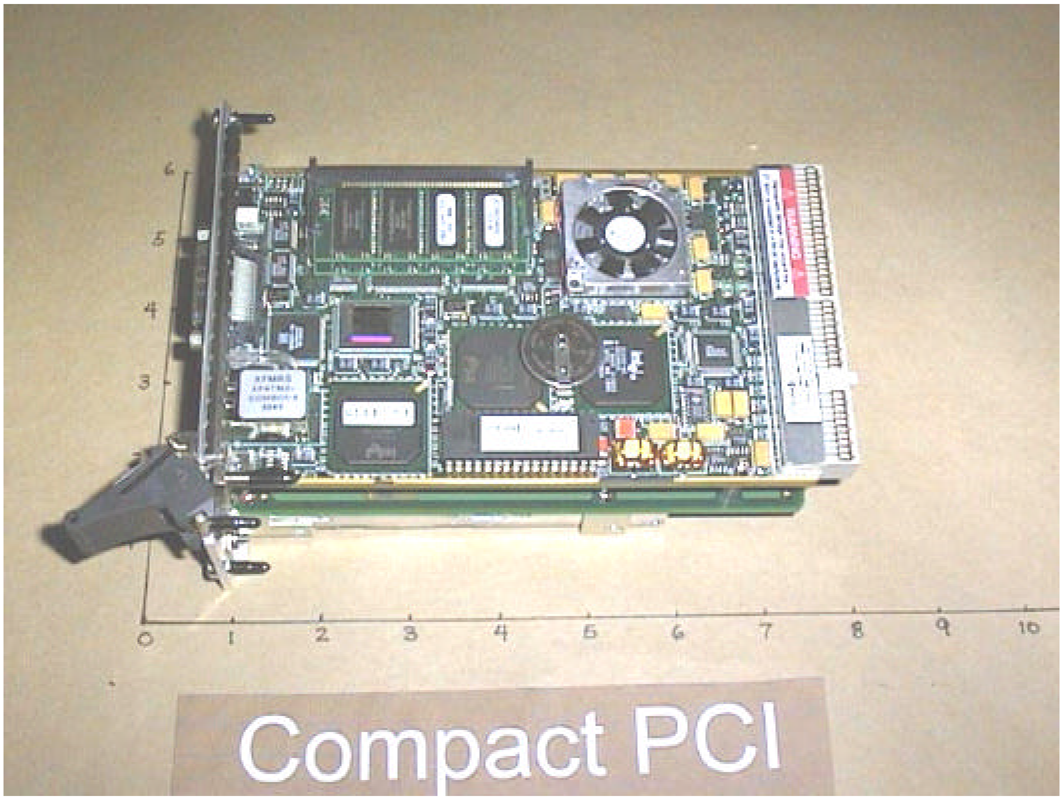

Figure 2- Compact PCI Form Factor

The cPCI hardware was easily procured and had a wide range of vendors supporting it. Table 2 shows a list of hardware that was procured. The study tried to procure hardware that either had a good heritage or was recommended. The study discovered that no rugged off-the-shelf cPCI chassis existed. Two complete 3U form factor operating systems were procured.

Vendor	Description
Gespac Corporation	Video Card
Gespac Corporation	Intel CPU with I/O built-in
Gespac Corporation	Power Supply
Gespac Corporation	6-slot rack
Ziatech Corporation	19" Rack mount System
Ziatech Corporation	Intel CPU with I/O built-in
Ziatech Corporation	SVGA Card
Ziatech Corporation	Intel CPU with I/O built-in
Ziatech Corporation	SVGA Card
Ziatech Corporation	Intel CPU with I/O built-in
Ziatech Corporation	SVGA Card
Sensoray	Smart I/O Data Card, 16 channel

Table 2- Compact PCI Hardware Vendors and Description

The first system was a table mount rack system from Gespac Corporation. It operated through a 266 MHz Mobile Pentium II, with 128 MB of RAM. Separate from the CPU card was the video card and power supply. It worked from the flip of the power switch. It booted to a hard drive with the Windows NT operating system. The other complete system, from Ziatech Corporation, was a 19-inch rack mount development system. It too was based on the mobile 266 MHz, Pentium II processor with 128 MB of RAM. The video card was also a separate card. Several spare CPU and video cards were purchased as backups.

PC 104

PC 104 and PC 104 Plus specifications were established in 1992 and 1996, respectively. The PC 104 Plus specification establishes a standard for the use of a high speed PCI bus in embedded applications. Incorporating the PCI bus within the PC 104 form factor provides fast data transfer over a PCI bus, low cost due to PC 104's stacking bus (no back plane or chassis required) and ruggedness. The module size is 3.6" x 3.8". Figure 3 shows a PC 104 module. Since the system is based on personal computer design, PC 104 is compatible to existing PC software and test equipment, thus significantly reducing the cost and schedule. PC 104 has a 104-pin connector, while PC 104 Plus has a 120-pin connector. The PC 104 Plus architecture is compatible with all PC 104 modules. Since there is no back plane, the modules attach to each other via the data bus and the four corner mounting holes. This makes the design inherently rugged. The power usage for PC 104 is low compared to all of the other architectures evaluated. For more information concerning the PC 104 and PC 104 Plus specifications, the website address is http://www.pc104.org/.

Based on its low cost several MSFC microgravity programs are interested in using PC 104. The study tried to utilize the experience of these programs when procuring the hardware. The MSFC Avionics Department is conducting another study to qualify a PC 104 system to a space environment

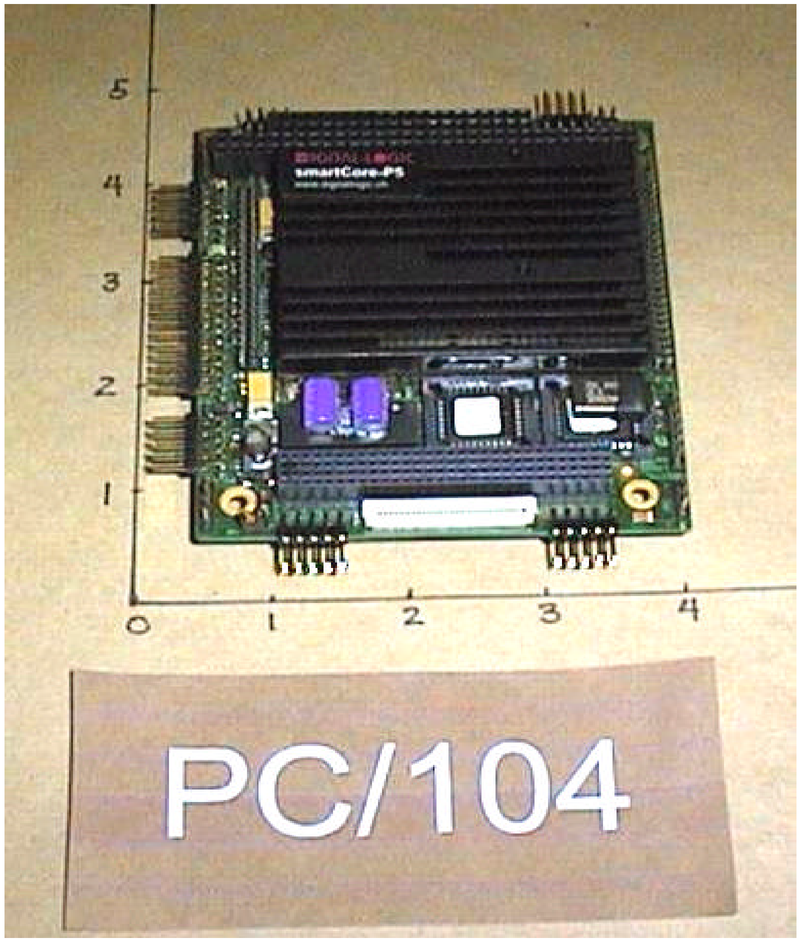

Figure 3- PC 104+ Form Factor

Since PC 104 has a large number of vendors supporting it, the study was able to procure one complete system and several additional modules. Table 3 shows the hardware vendors and a description of the hardware procured. Real Time Devices (RTD) built the system. It is similar in design to the system used in the Bridgman Unidirectional Dendrites in a Liquid Experiment (BUNDLE). The study procured a complete system to compare against the BUNDLE system. The RTD system consisted of a 233 MHz speed Pentium type processor made by Cyrix. It had a memory capacity of 128 MB. Stacked on the CPU card was a SVGA video card. The CPU and video cards were of the PC 104+ form factor. Continuing the stack was a hard drive utility module with a 5-MB hard drive. The system had a floppy drive connection as needed. Stacked upon the hard-drive utility card were two data module cards. For simplicity, these cards were not utilized. A Diamond Systems DMM-32XT, 32 channel A/D board, replaced them. Because the BUNDLE program had experience with this card, software was available that drove it. This system worked well from the beginning. The BUNDLE system had problems from the beginning. It was originally purchased as separate components and integrated in-house. It would never work when the cards were stacked in-house. Ultimately, it was sent to the vendor for repair and returned in working order, it has been operating since. This said, it is better to buy the entire system from the manufacturer in operating condition, loaded with the appropriate operating system. The RTD system came with aluminum rings that fit around the modules. When stacked together, the rings formed a rugged enclosure around the modules.

Vendor	Description
Advanced Digital-Logic	Intel CPU with Video and I/O built-in
Advanced Digital-Logic	Intel CPU with Video and I/O built-in
Advanced Digital-Logic	Intel CPU with Video and I/O built-in
RTD-USA	Cyrix Geode CPU - IDAN system
RTD-USA	Utility Module
RTD-USA	Hard Drive Utility Module (5 GB)
RTD-USA	SVGA Video Utility Module
RTD-USA	Data Module
RTD-USA	Data Module
RTD-USA	Power Supply Module
Ampro Corporation	Intel CPU with I/O built-in
Ampro Corporation	SVGA Video Module
Advantech	STPC CPU with Video and I/O built-in
Sensoray	Smart I/O Data Card, 32 channel
Diamond Systems	32-channel A/D card
Tri-M Systems	Vehicle Power Supply
Parvus	Fan Card

Table 3 – PC 104 Hardware Vendors and Description

Conclusion

Although the original goal of functionally and environmentally testing STD 32, Compact PCI and PC 104 bus architectures was not accomplished, the study provided valuable insight into the bus architectures. From all indications, STD 32 appears to be the least supported architecture and is not recommended for use in the development of a flight data system. PC 104 architecture is widely supported and has many positive attributes. For example, it is small and consumes low power. There are many vendors that manufacture PC 104 systems; therefore, there is minimal integration required. PC 104 was the only system that had a rugged chassis available. There were two problems identified with PC 104, the systems get very hot during operation and if an experiment requires a large amount of I/O signals, the system can become very large. Compact PCI has the most capability and potential of any of the architectures evaluated. It is widely supported by industry. Using a form factor of VME allows it to gain the benefits of VME without the cost of VME. The only Compact PCI drawback identified was the lack of a rugged chassis. However, it is only a matter of time before a chassis is developed.

The study was able to eliminate the STD 32 bus architecture from consideration for future use. Evaluating the functional and environmental requirements of different programs, there is not an ideal data bus architecture. Depending on the program requirements, Compact PCI and PC 104 are good options to develop a flight data system.