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## Introduction

CERN, the European Laboratory for Particle Physics, uses complex electronic systems to perform fundamental research: to study the forces in nature and the composition of matter. The principle research instruments are:

- Particle Accelerators: to accelerate particles, like electrons, positrons, protons, antiprotons, etc., to high energies and bring them into collisions with fixed targets or other particles.
- Particle Detectors: to observe the reactions that result from the collisions.

Consequently, at CERN, one finds two broad categories of electronic systems:

- (i) Control systems: to control accelerator and detector equipment, like magnets, vacuum pumps, radio-frequency cavities, power supplies, ventilation and cooling units, etc..
- (ii) Data-acquisition systems: to gather and process data from hundreds of thousands of detector channels.

## Mezzanines

The mezzanine concept, to have "mother" boards as carriers that provide generic functionality for application-specific "daughter" boards, has been in use at CERN since the early days of modular electronics, mainly in front-end applications, where one needs many identical channels (e.g., analog or time to digital converters). Designs were application-specific and followed "ad hoc" mezzanine protocols.

Industry considered for some time mezzanine implementations as bad and unreliable designs. The success of VMEbus, and the availability of reliable connectors, changed the situation. One could observe a proliferation of mezzanine specifications and implementations. In 1991, VITA (VFEA International Trade Association) conducted a survey on mezzanine specifications and received replies of such specifications from thirteen companies. The 1994 VITA catalogue (VMEbus and VXIbus Compatible Product Directory) lists products for thirty-two different mezzanine specifications. Currently, one can observe two market trends:

- (i) Consolidation: at present, efforts in VITA task groups are under way to have three multi-vendor-supported mezzanine specifications certified as ANSI standards (CXC, IndustryPack<sup>1</sup>, M-Module)
- (ii) Segmentation: "industrial I/O" (or relaxed bandwidth), and high-bandwidth applications.

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<sup>1</sup> The IndustryPack® specification originated from GreenSpring Computers. The VITA Standard Organisation's naming convention for the ANSI standard in preparation is "IP Modules, VITA 4-1995." Modules built to this specification are commonly known as "IP Modules," a term that is now in the public domain.

The specifications mentioned above (CXC, IndustryPack, M-Module) primarily address the industrial I/O segment, but peak rates of up to 100 MB/s are (theoretically) possible. In the high-bandwidth segment, one finds the PMC (IEEE-P1386.1) and SMC (IEEE-P1386.2) specifications. Both use the common-mezzanine-card mechanical specification (IEEE-P1386.0). Combining it (i) with the PCI (Peripheral Component Interconnect) electrical specification (maintained by the PCI SIG) results in PMC, or (ii) combining it with the S-Bus electrical specification (IEEE Std 1496) results in SMC.

## Applications at CERN

CERN's VMEbus Steering Committee has endorsed the IndustryPack and the PMC specifications. The number of mezzanine applications at CERN is growing and here are some application examples.

### IP-Module Applications

**Example 1:** Remote monitoring and control of power supply systems (660 power-supply channels in six special crates, RS485 interface) from a VMEbus system. A serial link connects the control units of three power-supply crates to a VMEbus system. Each of the two serial links needed for the six crates consists of two RS485 channels for full duplex communication, at a rate of 125 kBauds. On the VMEbus side, an IP Module (TIP865-30), occupying one of the four available ports on a simple slave carrier board (VIPC610), drives the two links. A small in-house designed transition board, with two DB-9 connectors on the front, plugs into the input/output connector of the VIPC610, and biases (for the quiescent state) and terminates the transmission lines. The operating system is OS-9 and the software driver for the TIP865-30 comes from the manufacturer.

**Example 2:** Communication and controls link between slave crates for radio-frequency (RF) equipment and VMEbus systems. Small crates (G64) contain the electronics to serve RF equipment used in particle accelerators (RF cavities). They communicate with the supervisory VMEbus systems via the instrumentation bus IEEE-488. For new installations, and as a replacement for existing ones to obtain a uniform structure, an IP-Module solution has been chosen. From a single VMEbus slot, and under OS-9, two IP-488 modules on 3U or 6U carrier boards (VIPC310, VIPC610) will control two independent instrumentation buses. The OS-9 driver for the IP-488s was purchased.

**Example 3:** Electric-valve control of a gas-mixture system and control of security-system equipment from a VMEbus system under OS-9. In particle-physics experiments, one finds a number of industrial-control applications, like systems to control the flow and composition of gas mixtures for detectors, access control and security systems. In this example, two IP Modules, an IP-Opto Driver and an IP-Digital 24, are mounted on a VIPC610 simple-slave carrier board, providing a single-slot solution. The IP-Opto Driver controls valves of a gas-mixture system, and the IP-Digital 24 provides inputs/outputs for an in-house designed security system ("Black Box L3"). Drivers and descriptors for these channel-oriented devices were written in-house in assembly code.

### PMC Applications

**Example 1:** PCI-SCI (Scalable Coherent Interface, IEEE Std 1596) bridge for high-rate data-acquisition architectures. Data-acquisition systems for next generation particle-physics experiments will process data from millions of detector channels. Studies are under way to come up with suitable, layered architectures that can filter and process massive amounts of data and are based on industry standards. In this project, the SCI serves to interconnect a

large number of data producer and consumer nodes. VMEbus computers and digital-signal-processing engines, with PCI as the local bus, will receive data from the detectors, process the data, and move them via SCI to the next-level consumers. A research and development project is to build a PCI-SCI bridge. Certain features of this bridge, like direct memory access, transparent memory access (i.e., mapping address windows of this bridge into SCI), multi-cpu support, and dual-ported data flow on the consumer side, are of particular importance.

**Example 2: PMC-based high-speed data links.** This project addresses the problem to move large amounts of data from producers to consumers using high-speed data link PMCs, such as PCI-FDDI, PCI-FiberChannel, or PCI-HIPPI.

## Summary

Some of the obvious mezzanine advantages, "finer-grained" modularity, reduced slot count, and availability of a good selection of functions, lead to a growing number of applications at CERN, in particular for industrial-control-type applications.

But mezzanines are also considered a cost-effective solution for in-house developments. The PMC examples mentioned above fall into that category. Designers can concentrate on the implementation of specific functions (PCI-SCI, PCI-HIPPI, etc.), without having to worry about infrastructure features (e.g., processor, networking, etc.) which do already exist on carrier boards. Because of this advantage, a team at CERN is currently investigating the requirements and the potential for high-energy-physics specific carriers and mezzanines. Such implementations are expected (i) to help reduce the number of different standards used in data-acquisition systems (e.g., CAMAC, NIM, VMEbus, etc.) and (ii) to facilitate the migration from one standard to another.

It is felt that, for the time being, IP Modules and PMCs address different segments. The basic distinction are band-width requirements, but some overlap exists. Market forces will determine to which extent this situation will continue in the future. It is beyond the scope of this article to make any speculations into that direction. Nevertheless, as users, we would appreciate a "unified" solution, covering in an optimal way both segments.

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## About CERN

CERN has its headquarters in Geneva, Switzerland. At present, CERN counts 19 Member States. Four countries, the European Commission and UNESCO have observer status. The laboratory is open for visits to the public. Guided tours take place on Saturdays at 9 hrs and at 14 hrs. Group visits can be arranged during the week. Call +41.22.767 8484 or fax +41.22.767 8710 to book your visit or to obtain more information.