High-Density Backplanes: Problems and Solutions

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Abstract

The backplane and crate infrastructure for the digital processors of the ATLAS Level-1 Calorimeter Trigger (L1Calo) are presented, The L1Calo system is a compact, high-performance real-time system based on a custom, monolithic 9U backplane populated almost completely with 2mm Hard Metric connectors.

The high pin count and monolithic design present challenges including high insertion/extraction forces, and maintenance and repair over the lifetime of LHC. We have developed solutions for these issues, as well as providing infrastructure for power distribution and cable strain relief, while maintaining accessibility,

I. INTRODUCTION

Real-time systems developed for LHC typically require high channel density and interconnectivity between modules. To achieve these goals, most system designers use 2mm Hard Metric (HM) connector systems to provide the desired pin counts. 2mm HM connectors introduce new problems for system designers. With insertion forces of up to 0.75N per pin, a 9U module requires hundreds of Newtons to insert or remove. Exposed male backplane pins are easily bent and damaged, presenting serious long-term maintenance issues over the lifetime of LHC. Crate infrastructure and power distribution must be designed to allow maximum accessibility for maintenance.

The ATLAS Level-1 Calorimeter Trigger [1] uses a common system-crate architecture for the EM/τ cluster and Jet/Energy-sum processor subsystems based on a custom monolithic backplane with very high signal density. This architecture has required us to address these issues by developing integrated solutions for force reduction, cable strain relief and power distribution that provide maximal access for testing as well as long-term maintenance and repair.

II. BACKPLANE AND CRATE

The processor backplane (Figure 1) is a monolithic construction with 9U height and 21 single-width module positions. It is populated almost entirely with 2mm HM connectors, with 1148 signal and ground pins to each processor module. The PCB is 4.9mm thick, with 8 signal layers and 10 ground planes, Up to 384 serial LVDS cable assemblies, plus two rear transition modules for system merger cables, are connected to the rear side of the backplane. Three high-current DIN connector pins at the bottom of each module position deliver up to 20A of low-voltage (3.3V and 5V) current.

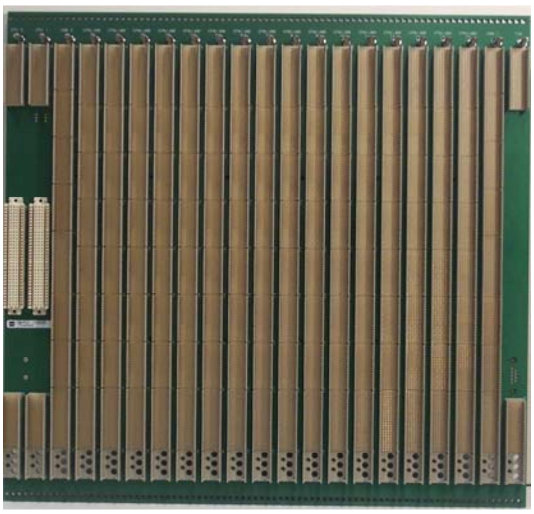

Figure 1: Front view of processor backplane.

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The backplane is installed in CERN-standard Series 6000 LHC crates [2]. This allows us to use standard solutions for power, cooling and crate control. Because our backplane is nonstandard, however, certain modifications have been made including longer power cables, a custom sense-wire assembly and card guides for two small daughter modules in the rear.

III. MATING FORCES

With 1148 signal and ground pins per module position, the nominal insertion force for a typical module is nearly 500N, and the extraction force over 400N. Without reinforcement the backplane PCB bows horizontally during insertion/extraction. The resulting pin misalignment adds dramatically to the mating forces.

Each backplane is equipped with six vertical reinforcement ribs (Figure 2). They are made of 5mm thick brass, fitting exactly in the gap between two module positions, and are 2 cm deep. They are bolted to the top and bottom crate extrusions through the backplane’s mounting holes, and secured directly to the backplane at 1/3 and 2/3 of the backplane's height to prevent bowing during extraction. This configuration reduces the maximum movement of the backplane to less than 1mm. Threaded mounting points on the back of the ribs provide support for the power bus bars and cable strain-relief system (Figure 3).

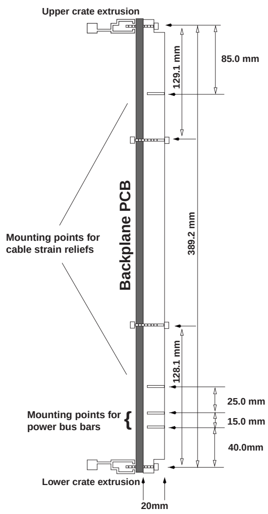

Figure 2: Mechanical sketch of vertical reinforcement ribs.

Handles manufactured to IEEE 1101.10 specifications [3] apply leverage against special front crate extrusions to provide the high insertion/extraction forces necessary. We have observed that these extrusions bow vertically from the force of the handles, which causes the handles to lose their grip and causes excessive wear on both the handles and extrusions. We have addressed the handle wear issue by using solid aluminum handles for the final production modules [4]. Extrusion flexing can be reduced by regularly securing module front panels to the extrusions, providing vertical reinforcement during insertion/extraction of nearby modules.

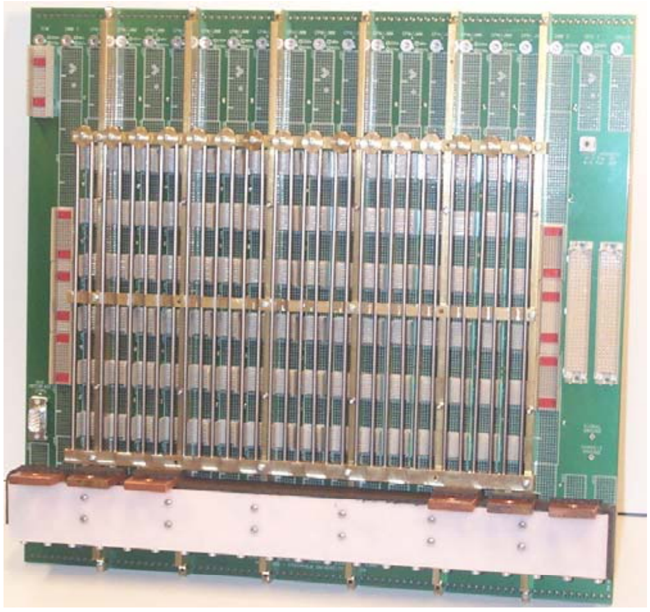

Figure 3: Rear view of the processor backplane, including the reinforcement ribs, cable strain reliefs and power bus bars.

Finally, guide pins on each module [5] ensure correct alignment during mating. This reduces the force of initial contact, and protects the pins from damage through misalignment.

IV. SERVICES

The backplane reinforcement system also serves as a mounting point for the cable strain relief system and the power distribution bus bars.

The cable strain relief system provides secure retention for up to 384 4-pair LVDS serial cable assemblies that provide the processor modules with input data. Vertical "forks" straddle the cables at each module position, and secure the connectors within the connector shrouds.

A robust power bus bar assembly of 6mm copper is mounted at the bottom of the backplane and distributes 5V and 3.3V power to each of the 21 modules through three high current pins [6] rated at 20A each. The ground pins are make-first break-last to minimize the risk from an accidental live extraction.

V. MAINTENANCE AND REPAIR

When signal pins become damaged, a repair and replacement procedure is critical. Tyco/AMP produces a toolkit [7] that we have successfully used for field replacement of single connector pins, without removing the backplane from the crate. This kit works best for AMP brand connectors, whose pins are loaded into the front of the shroud and held in place by friction. Other connector brands such as ERNI are less suitable for field repair, since the pins are loaded from the back of the shroud, and are therefore less easily extracted. Nevertheless we have also succeeded in replacing several ERNI pins with the AMP toolkit with satisfactory results.

For more extensive damage the backplane should be removed from the system and entire connectors replaced, usually by an external company. The backplane and its hardware are assembled as a single unit that can be relatively easily removed and replaced for this purpose.

VI. Conclusion

The performance requirements for the Level-1 Calorimeter Trigger led us to design a system backplane with high signal density and pin counts. We have successfully developed solutions for reducing and dealing with mating forces, providing power distribution and cable support, and long-term maintenance. It is hoped that our experiences and solutions may be useful in future high-density systems..

VII. References

[1] *The ATLAS Level-1 Calorimeter Trigger Architecture*, IEEE Transactions on Nuclear Science, Vol 51, No. 3, June 2004

[2] See http://www.wiener-d.com/, or the CERN ESS website.

[3] *American National Standard for VME64x $\times$ 9U $\times$ 400mm Format, 1997*

[4] Triple E Corporation, http://www.tripleease.com/

[5] Tyco/AMP part number 223956-1.

[6] See, for example, ERNI part number 130-147.

[7] Tyco/AMP part number 354687-1