SLAC-PUB-2209
October 1978
(I)

A PROTOTYPE CRATE AND MODULE SYSTEM FOR A HIGH SPEED TOP-MOUNTED BUS

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ABSTRACT

A prototype crate and module system, which uses the top surface of the modules both for mechanical support and for electrical connection to data and power buses, has been built to evaluate its potential use in a fast ECL bus environment. Although the system was optimized for a wide, fast bus using transmission lines and emitter-coupled-logic buffers, the construction has advantages and economies which may make it useful in low performance systems as well. Both the front and rear module ends are available for user controls and connections. The vertical size of the modules is independent of the bus mechanics. Modules can be inserted and removed from either the front or the rear of the rack. Construction details of the prototype are given.

INTRODUCTION

A prototype system of electronics modules and crates, using a top plane rather than the usual backplane, has been built at the Stanford Linear Accelerator Center in order to evaluate some unconventional solutions for the packaging problems of fast data buses using emitter coupled logic (ECL) circuitry.

The primary goal for this system is the provision of a wide microstrip bus which can support 32-bit data transfers at high speed in an ECL 10K environment. The stub connections between the bus and the transceivers in the modules must be kept as short as possible, so the bus must be physically wide enough to accommodate the transceiver packages, say at most 8 signals and at least 2 grounds per inch.

Secondary goals include:

1. The capability of inserting and removing modules without turning crate power off.
2. The distribution of at least 10 Amperes per voltage per module.
3. Allowance for a variety of module board sizes, possibly even within a single crate.
4. Provision of access to modules for troubleshooting without installation of extender boards (which change system timing).
5. Maximization of the area on the ends of the modules which is available for user controls and connectors.

Other objectives include:

6. Minimization of total system cost, but especially minimization of crate cost, so that costs for systems with only a few modules are not dominated by the cost of the mostly unused crate.
7. Maximization of reliability through simplicity, improved connector technology, and appropriate interlocks.
8. Convenience in use due to capability of inserting or removing modules from either front or rear of crate.
9. Flexibility in module circuit board size and shape, optional end panels, arbitrarily large user connection areas.
10. Provision for several cooling methods, including a clamping action in the mechanism which could be used in conductive cooling systems.
11. Provision in the basic mechanical design for conventional printed circuit board edge insertion connectors, board edge connector to bus connector systems, and the new high pressure stacking type connectors.

Though any real system must compromise between conflicting objectives, the prototype system described below meets all of the above objectives fairly well.

CHOICE OF BUS POSITION

The top position for the data bus was chosen because it leaves both front and rear available for the user connections to a module. Furthermore, since space at the top is relatively inexpensive, it becomes practical to make a wide microstrip bus with low connector density so that buffer circuits can be placed very close to the transmission lines of the bus, reducing stub loading problems.

It also makes possible the insertion or removal of modules from either the front or the rear of a rack, which can be a great time saver when repairing systems obscured by a maze of user cables. Since the mechanical and electrical connections to the bus are both made at the top edge of the module, there are no intrinsic constraints on the vertical size of the module. In fact, different sized modules could be mounted next to one another on the same top plane, though in practice it would be preferable to have only a few standard sizes. Bumper regions should be provided at standard distances below the tops of modules which have no side cover plates, to facilitate sliding one module into place next to another.

The bottom position might seem to share these advantages, but was rejected due to the tendency of bottom planes to accumulate dirt, litter, and conductive debris, which makes them less reliable.

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*Work supported by the Department of Energy under contract EY-76-C-03-0515

(To be presented at the IEEE Nuclear Science Symposium, Washington, D. C., October 18 - 20, 1978)

CHOICE OF CONNECTOR

The prototype system was built around a relatively new type of connector, the gas tight high pressure connector. The connector used is the Teledyne Kinetics B409U025B, shown in Figure 1, which is currently $1.25 in single quantity. A gold plated version is also available. Burndy makes a similar family of somewhat larger connectors, but not available with gold plating. The mounting tabs were removed in the prototype, and the connector body attached to the module by adhesive and solder.

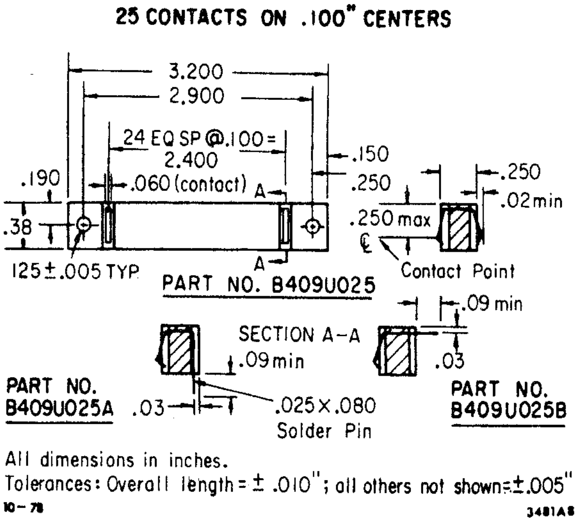

Figure 1: The Gas Tight High Pressure Connector

These connectors are mounted on the top edge of the module so that when the module is in its operating position, they press firmly against a suitably plated microstrip transmission line printed circuit bus. Thus, no connector parts or associated holes are needed on the bus itself, so it becomes a trivially simple printed circuit, which should be inexpensive even if gold plated. While conventional connectors can also be used with the mechanism described below, they result in a much more expensive bus and crate, are probably less reliable and shorter lived, and are unlikely to have better signal transmission characteristics. These connectors have been used in commercial equipment for several years with good results.

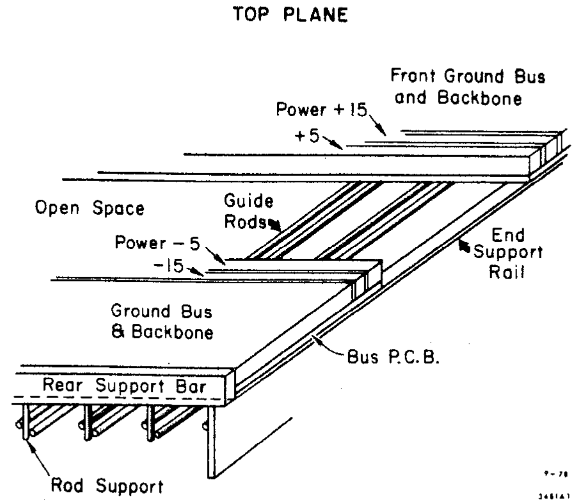

Figure 2: Top Plane Construction

MECHANICAL IMPLEMENTATION OF CRATE

In the prototype, the bus board is divided into two symmetric halves which are separated by a wide open space to allow cooling air flow. Figure 2 shows the general construction of the top plane. The bus circuit board is backed by a heavy plate which also serves as a ground bus. Pairs of guide rods are suspended below the top plane by support rods at each end. The guide rods are offset so that modules cannot be inserted backward inadvertently. Eighth inch stainless welding rod was used for the guide rods in the prototype. Heavy power buses are located adjacent to the center empty space so that expansion for extra user voltages is simplified.

Modules slide into position on the guide rods below the bus and are raised into contact with the bus by knob operated cams. As the module moves into position, its ground pins contact first, followed by the power pins and finally by the signal connectors. Thus power is provided to the module so that its bus drivers can reliably be in a high impedance state before the signal lines make contact, which facilitates live insertion and removal of modules.

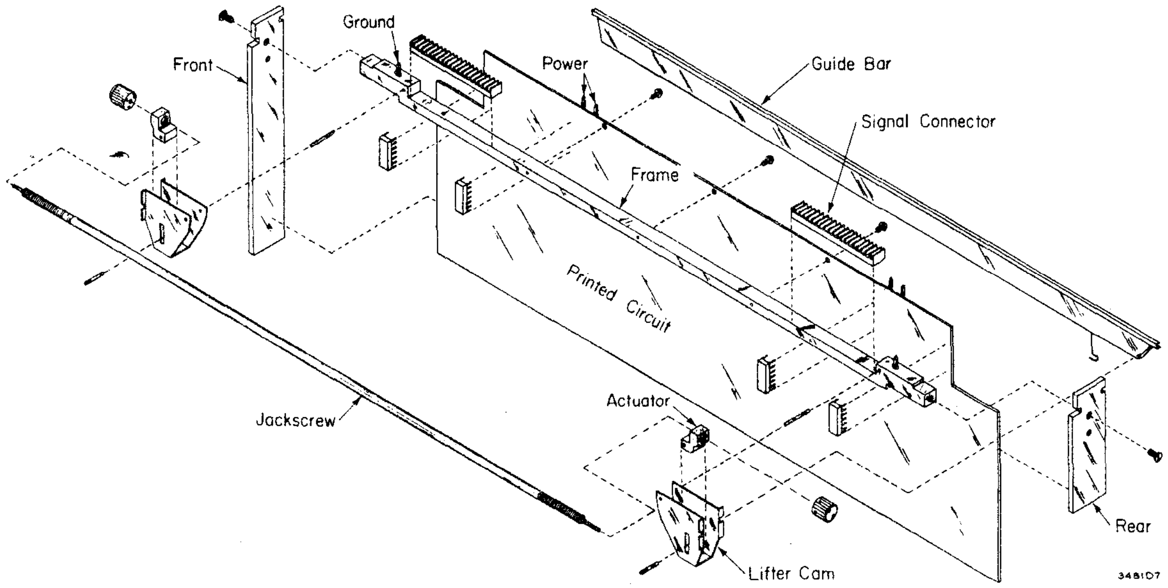

Figure 3: Exploded View of Module Construction

MECHANICAL IMPLEMENTATION OF MODULES

Figure 3 shows an exploded view of the module. The frame serves as the backbone of the module, providing support, alignment and dimensional stability. The jackscrew is mounted immediately below the frame, held in place by the front and rear end panels. The end panels are also required for orientation and initial alignment of the module, but need not extend below the jackscrew mounting hole. However, the module is strengthened somewhat if the printed circuit is attached to the end panels. The jackscrew has a right-hand thread at the rear end and left-hand thread at the front. Actuator nuts, cut from ordinary extruded turnbuckles for the prototype, ride the jackscrew and are forced toward each other when the module is lifted into place, forcing the lifter cam to pivot on the frame in such a way as to lower its notched ears relative to the module and thus lift the module.

This arrangement results in the jackscrew being under tension when the connectors are being forced upward against the bus, which is the condition of greatest stress. The frame sees compression stress and a bending moment at that time, but is stiffened by the printed circuit board, which is extremely stiff in that direction. The stress on the end panels is very small. The lift mechanism is also able to provide positive extraction force in order to disengage the power and ground pins and to operate conventional connector assemblies. Lift travel could be reduced if compatibility with conventional connectors were abandoned.

The guide bar consists of a brass tube soldered to a steel stiffener, with one side of the tube removed, leaving a "C" shaped cross section. The tube slides over the guide rod, capturing it so the tube cannot fall off. The open side of the "C" allows the support rods to pass by freely. The purpose of the guide bar is to support a partially inserted module until the guide rods are engaged by lifter cams at both ends, and as an aid in guiding the module into proper position.

Figure 4 shows details of the module connector area. The notches on the end panel prevent backward insertion of the module and prevent raising it into position before it is fully inserted. The ground pin is a spring covered banana-plug-style pin, and protrudes less than the end panel. The power pins are similar but even shorter, so the ground and alignment will occur before the power connection.

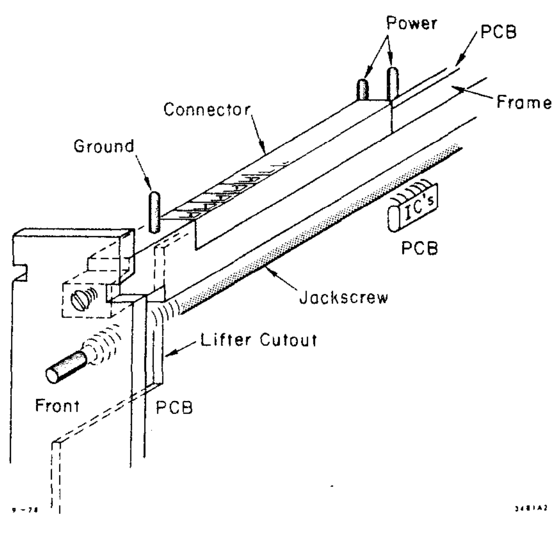

Figure 4: Module Connector Area

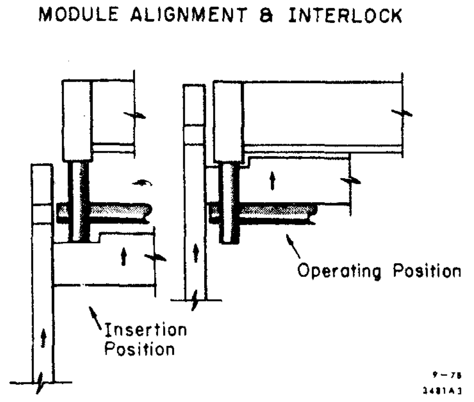

Figure 5: Interlock and Alignment Detail

Figure 5 shows how the notches in the end panels are aligned with the guide rods (and therefore the notches in the lifting cams) while the module is being inserted, and how the ends of the guide rods serve to provide approximate alignment of the module before it can be raised. The lifting cams are locked in the lowered (insertion) position by the guide rods and end panel notches at one end or the other until the module is fully inserted and the guide rods are free of both end panels. Thus it is impossible for signal connectors to slide across the bus traces and disturb the bus during insertion or removal.

Figure 6 shows the module from the printed circuit side, with the lifting cam mechanism installed. Turning the jackscrew by means of a knob at either end moves traveling actuator nuts at each end in opposite directions. The nuts each carry a roll pin which slides in a slot in the lifter cam to cause it to pivot on another (fixed) roll pin and thus raise or lower the notches in the lifter ears, and thus lower or raise the module relative to the guide rods and top plane. The forces occur near the support pins on the guide rods, so little strength is needed in the rods. Seven turns of the jackscrew provide about a half inch lifter travel, enough to accommodate conventional connector systems.

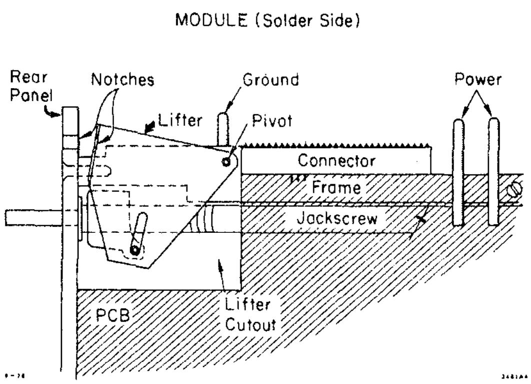

Figure 6: Module Lifter Side View

Figure 7 shows the layout of the sheet metal pieces which form the lifting cams. Stainless steel sheet approximately 0.040 inches thick was used in the prototype because of its strength, toughness and resistance to corrosion, but other materials could also be used.

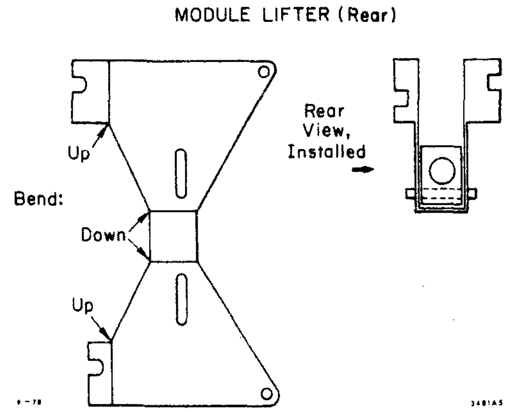

Figure 7: Lifter Cam Layout

Figure 8 is the end projection view of the module, showing the relative positions of the connectors, pins, and integrated circuits. Note that the path between the signal connector and the buffer circuits can be quite short.

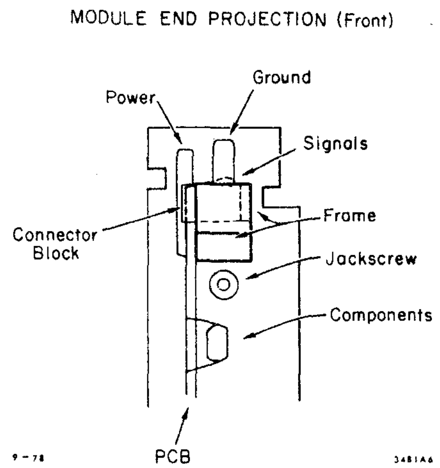

Figure 8: Module End Projection View

THERMAL BEHAVIOR

A fast ECL system may require high power dissipation capability. One of the simplest methods of cooling electronics systems is to blow high velocity cool air over the dissipating components. This approach is used in the Amdahl 470 LSI ECL computers, for example. High velocity air (approximately 1500 feet/minute) is used to improve heat transfer from the circuit packages.

A top mounted bus restricts air flow through the top of the system, preventing smooth flow from top to bottom over the full length of the module. In particular, one would expect possible stagnant air regions near the lifter mechanism in the corners of the modules.

The prototype modules were loaded with resistors and thermocouples in order to study the air flow problems. No definite general conclusions were reached. The dead air problem was not as severe as expected. No heat generating components can be mounted in the lifter areas, which reduces the problem. Air flow was more uniform when directed from bottom to top with blowers below the modules. Conduction through the PC board and frame helps remove heat from the corners.

In very high dissipation modules, careful attention must be paid to thermal design. Several strategies can be used in optimizing module design:

1. High dissipation components can be concentrated in the central region of the module where the air stream is best.

2. Heat can be transferred by conduction to regions with better cooling.

3. Air can be distributed more evenly over the module by means of a baffle which forms a plenum chamber across the top of the module.

4. Combinations of airflow and conductive cooling can be used.

Some large ECL computers (e.g., the Cray-1) use conduction to carry heat to board edges, where it is transferred to a liquid-cooled frame.

SUMMARY

A top mounted data bus has many advantages if suitable module supporting mechanisms can be developed. For example, in conventional module systems, the top and bottom edges of a module are used solely for guiding the module during insertion. The back is nearly used up by connections to its data bus, leaving only the front for the user's connections. In a top plane system, nearly all of the front and back edges are available to the user, and in some circumstances even the bottom edge can be used. In conventional systems, the module size is completely specified by the crate, while in a top plane system only one edge is constrained. Conventional crates ordinarily have closed sides in order to fix the vertical dimension, thus requiring modules to be placed on extender boards when access is required for repair. Extender boards can cause significant performance changes in fast systems, which may alter the problem under investigation. Since sides are not needed in a top plane system, the top plane can be moved out of a rack on slides, exposing the end modules for service without the use of extender boards.

Conventional crates frequently trap modules inside behind a maze of user intermodule cabling, making module exchange difficult during system debugging or repair. In a top plane system, modules can be removed from either the front or the rear of a rack, which often simplifies the exchange problem.

While this design is only a first attempt at a prototype, it already seems to demonstrate the feasibility of top plane systems. Presumably, future improvements will result in a still simpler design. The construction method chosen should lend itself to inexpensive fabrication, using standard bar stock, spot welded wire, and stamped sheet metal. Lower material costs also result from a design which produces its largest stresses in tension and which combines lifting, alignment and interlocking mechanisms.

ACKNOWLEDGMENTS

I am indebted to Robert Downing of the University of Illinois at Urbana for stimulating conversations about packaging for fast systems and about his experiences with his own operational and prototype systems. These conversations were the stimulus and inspiration for many of the features and goals incorporated into the top plane system.

Warren W. Maxwell of the John E. Striker company, formerly representatives of Teledyne Kinetics, introduced me to the connectors used in the prototype, pointed out some of their advantages, and provided me with a variety of samples to experiment with. John Risley of Teledyne Kinetics in Solana Beach, California was helpful in providing additional information and helping me find other users of the connectors, and L. R. Lingenfelter provided drawings of the connector and gave permission to use them in this paper.

I am also grateful to John Grant and Jack Schroeder of SLAC for their help in fabricating the prototype, to Arthur Lashbrook of SLAC who helped with the thermal studies, to the SLAC graphic arts department for preparing the drawings, and to Harriet Canfield of the Computation Research Group for assistance in the preparation of this manuscript.