PC/104 architecture

By Jonathan Miller

By using the compact PC-compatible open standard, systems manufacturers can reduce the size of their control system and gain flexibility

When a leading vendor of semiconductor fabrication equipment set out to redesign its product line, one of the primary considerations was the standardization of its embedded control system technology. Achieving this end would not only reduce the complexity of purchasing, in-house support, and training; it would also allow for expansion capabilities in the future. Unfortunately, the company's engineers determined that the current embedded controller simply could not satisfy these goals.

The first obstacle facing the company was the constraint of using a single vendor's embedded CPU, which meant that the existing system was designed around a non-standard form factor. This situation limited the company's leverage with its vendor – locking it into the vendor's feature sets and product evolution plans.

A second problem revolved around the lack of the existing system to provide adequate expansion capability and flexible features. Considering the custom form factor of the various board-level components, the company could not easily add new boards to its controller to modify its features according to the particular needs within each of the five product divisions.

But perhaps the most compelling incentive for redesigning the control system was a matter of size: the current package was simply too large to squeeze into the space allotted by the new product designs. This combination of factors forced the company to search for new technologies that were capable of meeting its specialized application needs.

PC/104 provides a perfect fit

The compact size of PC/104 boards not only represented an ideal solution for size reduction, but the widely accepted open standard made it possible for the company to configure its system by selecting boards from nearly 200 vendors. The final configuration – which moved from concept to the first working system in just two months – included six boards from five different vendors:

- one 486 class CPU from Radisys
- one motion control board from Motion Engineering (MEI)
- one DeviceNet controller board from S-S Technologies
- one Seriplex interface board from Square D
- two custom I/O boards from Diamond Systems

Diamond Systems also provided two additional custom products: a front panel status display board (basically a collection of LEDs), and a back-panel cable transition board. The latter was used to convert the connector pinouts of the internal boards to configurations more suitable to the company's external hookup requirements. Figure 1 illustrates the seven boards that make up the heart of the embedded controller. Note the three

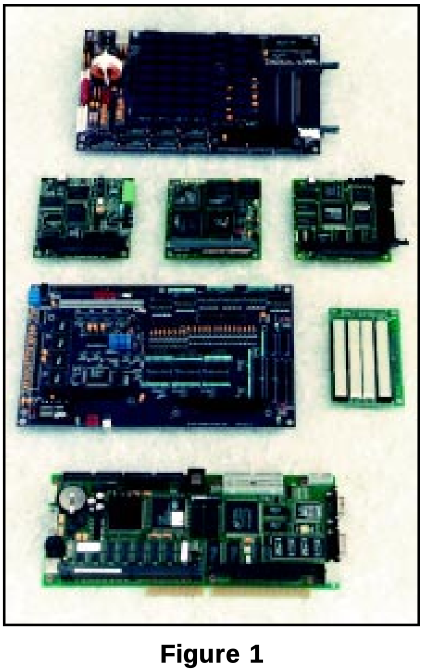

Figure 1

PC/104 modules. The remaining boards provide PC/104 mounting headers, and no backplane is required to connect the boards together.

All of the chosen boards were either PC/104-*compliant* (which means that they are shaped like a PC/104 board and are hardware/software-compatible with the PC/104 standard), or PC/104-*compatible* (shaped differently than a PC/104 board but offering hardware/software-compatible with PC/104 and containing the PC/104 bus connector). The Radisys EPC-34 CPU is actually an ISA slot-card CPU with a built-in 16-bit PC/104 connector. This board integrates core CPU functions – including standard port I/O, 10BaseT Ethernet, and SVGA video – onto a single board.

The two main custom modules from Diamond Systems were increased in size to house the large number of I/O points, power conditioning, and other custom circuitry that were required by the system specification. The first board provided...

- 24 optoisolated digital outputs with optoisolated readback
- 24 optoisolated digital inputs
- 32 12-bit analog inputs
- 16 12-bit analog outputs

All I/O points included short-circuit and overvoltage protection to protect the system from wiring errors during installation.

The second main custom board provided power distribution and conditioning circuitry, and a relay matrix used for interlock operation. The interlock feature is customizable for each system by means of a personality card that is installed in a socket mounted on the board and accessed through the front panel. (Safety requirements dictate that this logic be provided in hardwired form rather than in software.)

The boards from MEI, S-S Technologies, and Square D were all PC/104 compliant modules. MEI's 104/DSP board provided 1 to 4 axes of motion control and used a

DSP chip from Analog Devices to implement sophisticated motion algorithms. S-S Technologies' DeviceNet Scanner board served as a network controller to communicate with additional I/O modules distributed throughout the equipment. And Square D's Seriplex card provided a similar function for some devices that required that type of interface.

One of the more interesting concepts incorporated into the design was the use of the custom I/O board as a PC/104 expansion bus. This allowed two PC/104 boards to be placed side-by-side, which made it possible to accommodate the boards within the height limit imposed by the product design. This unique configuration did not impose any difficulties on the bus operation.

Assembly of the system was akin to making lasagna: layer upon layer of boards, cables and standoffs. In Figure 2, you can see the custom I/O board mounted on top of the CPU board, which lies at the bottom. The final assembly measured approximately 7" W x 5" H x 12" L. In Figure 3, the custom faceplate has been removed to show the status LED panel, the CPU peripheral connectors, and the configuration card slot.

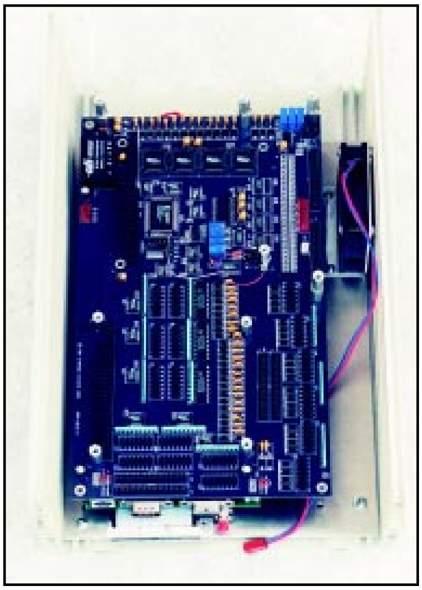

Figure 2

Figure 3

Issues of integration

As can be expected when working with embedded systems and tight quarters, cabling between the boards and the back panel required considerable attention. In this particular application, a comparison of methods to bring the onboard signals to the outside world revealed that an additional back panel board, acting as a transition between the outside and inside cables, would provide a more cost effective and time-saving approach than building custom cables.

This solution would allow the use of standard, off-the-shelf cables and avoid the expense of sourcing custom harnesses. (For the first prototype build, however, scheduling issues dictated the use of custom harnesses.

Power distribution was another prime concern. The main supply was 24VDC. From this source, it was necessary to generate...

- ❑ +5V for the logic
- ❑ ±12V for the DeviceNet network
- ❑ ±15V for the analog I/O

...in order to support +/-10V I/O ranges with enough headroom to maintain linearity at the extreme ends.

A decision was made to use a triple output DC/DC converter to generate +5V and ±12V from the +24V and distribute it onto the PC/104 bus, adding a second smaller dual output converter directly on the I/O board to provide the ±15V needed by the analog circuitry.

Another critical issue was the efficient dissipation of heat generated by the onboard main DC/DC converter and the CPU. Since one of the design requirements was a completely splashproof enclosure, open vents for air flow were not a viable solution.

Instead, the DC/DC converter was mounted to the top of the enclosure to vent heat as efficiently as possible to the outside, and a slim fan was mounted to aim the air flow directly onto the CPU heatsink. The rapid circulation of air inside the small enclosure maximized the amount of heat conducted to the case, further limiting the temperature rise of the CPU. As additional protection, a temperature indicator IC with a programmed setpoint of 50°C was selected to provide a warning signal, and a thermal switch with a setpoint of 60°C was included to offer protection against catastrophic failure.

Interface and configuration requirements

Because connection of the standard peripherals (keyboard, mouse, monitor, etc.) to the system is a necessary step during installation and system test, a hinged door was provided in the front to allow access to these ports. In normal operation, this door would be closed, sealing the enclosure from contamination.

In addition, the interlock logic needed to be configured according to the environment in which the system would be installed. This circuitry controls the cause and effect relationship between various subelements in the machine. For example, one machine might require that device C should turn on when both A and B events occur; whereas, a second machine may require that C should turn on when either A or B occur.

Rather than provide multiple complete controller boxes – each with different interlock boards built in – a single controller was provided with a generic logic board. A card and socket system similar to PCMCIA was chosen to configure the logic. (Although PCMCIA would seem to be a "natural" for this type of application, the limitation of 68 pins would be inadequate for the number of I/O points; so an alternate 100-pin system was utilized instead.)

Advantages of PC/104 from a customer perspective

The decision to use PC/104 architecture has accrued several advantages to the customer. Beyond obvious gains in economy of size, the fact that the standard is widely supported by board manufacturers has afforded the company a wide array of choices in the configuration of its system.

Another advantage revolves around the interchangeability of the components. For example, although the current configuration utilizes a slot-board CPU, this board could potentially be replaced with one or two PC/104 modules that fit into the same space.

Remember that the custom I/O board has two side-by-side PC/104 connectors. By removing the slot board and making the I/O board the bottom board in the assembly, space is made available for an additional PC/104 module on both the left and right sides.

Because of this option, the customer will enjoy enhanced flexibility in regard to features, gaining an edge in negotiations with its CPU vendor. In short, the company is no longer locked into the limitation of a single supplier!

PC/104 architecture

Jonathan Miller is founder and President of Diamond Systems Corporation, a supplier of standard as well as custom PC/104 data acquisition and communications boards. Prior to Diamond Systems, he held various positions in design, sales and technical support in the data acquisition field. Jonathan holds a BS degree in computer science from MIT.

For questions about this article, or further information about the products and services offered by Diamond Systems Corporation, please contact:

Diamond Systems
450 San Antonio Road
Palo Alto, CA 94306
Tel: 415-813-1100
Fax: 415-813-1130
techinfo@diamondsys.com

Other companies mentioned...

Motion Engineering, Inc.
33 South La Patera Lane
Santa Barbara, CA 93117
805-681-3300
http://www.motioneng.com

Radisys Corporation
5445 NE Dawson Creek Drive
Hillsboro, OR 97124
503-615-1100
http://www.radisys.com

S-S Technologies Ltd.
50 Northland Road
Waterloo, Ontario
Canada N2V IN3
519-725-5136
http://www.sstech.on.ca

Square-D Corporation
1415 S. Roselle Road
Palatine, IL 60067
847-397-2600
http://www.squared.com

