Redesigning OEM Products Using PC/104 Computers

Upgrading CPUs and memory to accommodate new features implemented in software and firmware is a common theme for OEMs. Since many of the I/O and signal requirements for OEM systems are done as specialized board designs, CPU/memory upgrades can be made easier by partitioning the design.

by: Ken Finster, Micro/sys, Inc.

Intel, Motorola, AMD and others continue to ship truckloads of low-end 16-bit CPU devices to OEM companies who use these devices to provide internal automation to their products. Quantities are even higher for 8-bit microcontroller chips to OEMs. So where are these CPUs being used, and what does this mean to the 16-bit and 32-bit PC/104 market?

A significant percentage of these chips continue to be used in proprietary "unified controller boards"—that is, custom-designed printed circuit boards that include CPU, memory, specialized application I/O circuitry and specific connectors that cable directly into the OEM's next higher assembly (Figure 1).

But these days, everybody knows that features can be added by "merely" adding firmware, so a significant number of OEMs are looking to add features. This often forces an upgrade to a more capable automation platform. Certainly more memory is required and more compute power is probably required as well.

This shift is not driven by a focus on lowering system costs—it's difficult to match the cost of an 8-bit or low-end 16-bit unified controller board. But cost is always a factor. Additional memory and compute power at the same cost, or even at a lower cost, is not an unheard of request.

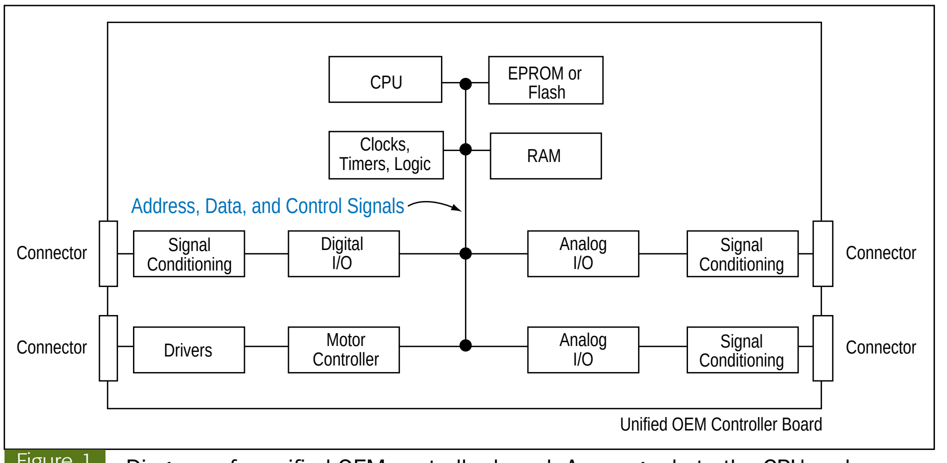

Figure 1 Diagram of a unified OEM controller board. Any upgrade to the CPU and memory requires re-laying out the entire board, including the specialized I/O that is not actually being revised.

When upgrading an OEM product that currently uses a unified controller board, there are some forward-looking decisions that can make the next upgrade easier. The design challenge is to maintain the best possible cost structure, kick up compute power and memory size to allow new features, and to decide if it might be wise to outsource some portion of the redesign with off-the-shelf CPU modules. That specific challenge is where PC/104 and PC/104-Plus fit into such an OEM product redesign.

From the Outside In

PCB-mounted connectors, for wiring to the next higher assembly, are a fairly one-of-a-kind proposition. A medical system may have isolated patient probe connectors, a SCADA system may have carefully protected (electrically and mechanically) terminal blocks and a vehicular system may have high current motor connectors. With no least common denominator, this "peripheral connectors" part of the electronics package is best kept on a proprietary PCB designed and manufactured by, or for, the OEM.

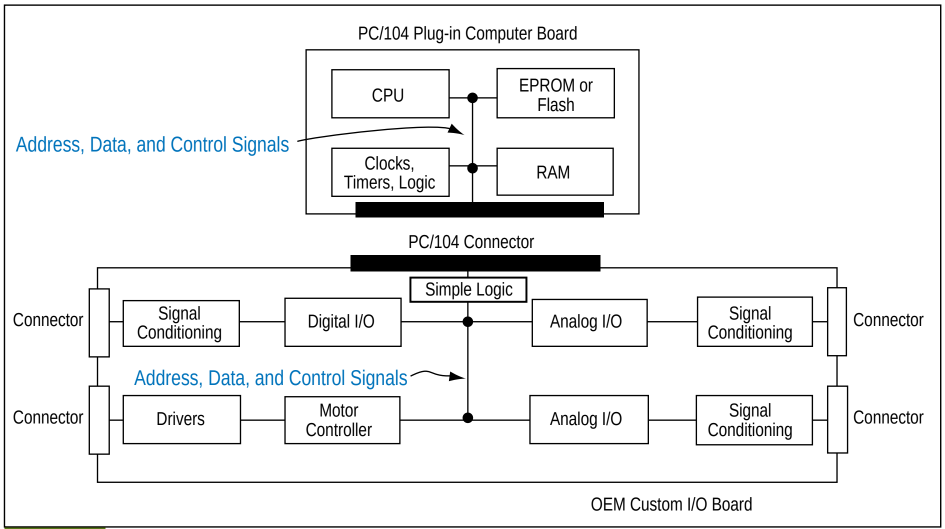

Figure 2 Diagram of a partitioned OEM system using a PC/104 plug-in board. The part of the system that relies on custom design can remain unchanged, such as system-specific I/O devices, signal conditioning circuitry and special connectors remains stable. This allows processor upgrades with very little engineering investment.

Any signal conditioning circuitry connected to these connectors is also best kept on the OEM's proprietary PCB. Microvolt sensors may require excitation, amplification, frequency roll-off, input protection and linearization between their I/O connectors and the automation system. Outputs may require high current, high voltage or isolation circuitry between TTL I/O signals from the automation section and the I/O connectors. Again, there is little common ground here between different OEM systems.

Next, look at the processor and its related circuitry. On the existing unified controller board, the processor's address, data and control lines exist as various traces on the PCB, but they may not be brought to a single connector. Changing the processor or memory requires revising the entire PCB, including the I/O connectors and signal conditioning circuitry that are not changing.

While a unified controller board architecture provides the lowest production cost for large quantity runs, the savings are often completely offset by Engineering Change Orders and PCB redesigns if the quantities are not high enough. Separating the CPU, memory and simple I/O from the application I/O can create a much more stable signal conditioning and I/O connector PCB. At the same time, it is easier to "swap out" the processor and memory, as features dictate, under this type of architecture.

Design Element	PC/104 (ISA-based)	PC/104-Plus (PCI-based)
Connector	64 or 104 pins	120 pins
Data path width	8 or 16 bits	32 bits
Address & data multiplexed on same pins	No	Yes
Bus clock	~8 MHz	33 MHz
Burst bandwidth	~8 or ~16 MBs	132 MB/s
Critical timing concerns (i.e. clock skew)	Low	High
Interfacing of non-computer I/O (i.e. analog/digital I/O, motors)	Easy	Complex
Cost of devices and connectors	Low	Medium
Streaming media capabilities across bus	No	Yes
Requirements placed on BIOS	Low	Enumeration & Resource Allocation
Devices available with specific bus interface logic	Tapering off	Many Computer I/O Devices

Table 1 Comparison chart for deciding whether to add PC/104 or PC/104-Plus connectors to an OEM custom I/O board.

PC/104 as an "Automation Socket"

The partitioning of an existing unified controller board into a custom signal conditioning and connector assembly that accepts a "plug-in" CPU is a good strategy. Most often, the schematics for the signal conditioning and connector sections can be used as is, including data latches, A/D converters, D/A converters, etc. The processor, memory and other controller circuitry can be deleted, and in their place a PC/104 connector can be added. The address, data and control signals that used to be created by the onboard CPU and support devices are now provided by the PC/104 connectors (Figure 2).

If the previous controller was using 8-bit data transfers to the application I/O sections, a single 64-pin female connector can be placed on the custom I/O PCB. If 16-bit data transfers are desired, or if additional IRQ lines are needed, 64-pin and 40-pin female connectors can be placed on the custom I/O PCB. The PC/104 standard specifies exact positioning of these connectors and the 4 mounting holes that are used for rigid attachment of the PC/104 plug-in to the custom I/O PCB.

In this way, mechanical and electrical interfaces to the next higher assembly are less subject to disruption in case the CPU is changed. Any circuitry on the custom I/O PCB that is driven by PC/104 signals can remain unchanged, even if the PC/104 plug-in processor is changed. The same is true for the software driving these I/O circuits.

PC/104 vs. PC/104-Plus

The majority of present day unified controller boards do not have high-bandwidth data buses. For these systems, PC/104 transfer rates are sufficient. As a rule of thumb, a PC/104 data transfer takes approximately 1 microsecond, so the maximum attainable bandwidth could be pegged at 1M transfers per second. Depending on whether the PC/104 is operating in 8-bit or 16-bit mode at the time, this would be 1 Mbyte/s or 2Mbytes/s, respectively.

But always remember that a program cannot keep the interface running at maximum speed because of the overhead of other instruction and data cycles. The above figures can only be achieved in DMA bursts. So you can, again as a rule of thumb, divide the above numbers by about 4 to get a more realistic prediction of program transfer rates across the PC/104 connector.

On the other hand, the 120-pin PC/104-Plus connector is capable of running 32-bit wide transfers at a 33 MHz rate. This multiplies out to a maximum DMA burst of 132 Mbytes/s. But again, program transfer rates will be less by a significant factor. Still, the rate is clearly far above that of PC/104.

Of course, increased bandwidth comes at the expense of design complexity and unit cost. The PC/104 set of signals is the same as the ISA bus—address lines for a 16 Mbyte address space, 8 or 16 data lines, and a set of read, write, interrupt and DMA controls. This is a well-known, easy to design to set of signals without any significant timing challenges. PC/104-Plus is based on PCI signals, including a multiplexed 32-bit address/data bus, significantly more complex control signals and more critical timing. It is unrealistic to consider PC/104-Plus I/O design without a large PCI target IC to do the actual PC/104-Plus to custom logic interface (Table 1).

Where Do VGA, Ethernet and COM Ports Go?

Many OEM systems are “headless”—that is, no CRT or keyboard is attached. Selecting a PC/104 plug-in processor card without these features may reduce system cost. However, if this type of “console I/O” is needed, it should be located on the PC/104 processor card to keep the custom I/O card from having to deal with these commodity items. The same holds true for Ethernet interfaces. While either or both could be designed into the custom I/O card, this type of logic is usually much more cost effective when acquired together with the processor and memory. Most PC/104 vendors offer integrated CPU and console I/O, and many offer onboard Ethernet as well.

COM ports are another feature that most PC/104 vendors include on plug-in CPU boards. This is a great benefit for a number of reasons. The COM ports can be used during manufacture and test for firmware loading and unit test. Also, an industrial BIOS can redirect VGA and keyboard transfers to a COM port if desired during OEM system operation. COM ports can be used for in-field updates and troubleshooting.

However, connectors for VGA, Ethernet, keyboard and COM ports may require additional thought. Each OEM system may have different needs in terms of external connection to these ports.. PC/104 cards will have their own connectors presenting these signals to the system. Some OEMs use short jumper cables to move these signals from the PC/104 CPU board connectors down to the custom I/O board, so that the I/O board can present a standard connector to the outside world along one of its edges. Other OEMs may choose to bring external Ethernet cabling, for example, directly into an RJ45 connector on the PC/104 CPU board.

COM ports can be cabled by ribbon cable from the CPU board connector to DB9 bulkhead connectors. Or short jumper cables to the I/O board might be used as detailed above. Another scheme offered by some PC/104 CPU vendors is to have COM ports available as male pins on the underside of the PC/104 CPU board, just like the PC/104 signal pins. The custom I/O board can then pick up these signals from a 10-pin female connector of the same family as the PC/104 connectors.

What About Disks?

If the OEM design uses a high-end processor, it may include floppy and IDE disk interfaces on the processor card. If the installed system does not need them, they just don’t have cabling connected to these connectors. If the OEM system does contain disk drives, this type of PC/104 automation plug-in offers great cost effectiveness.

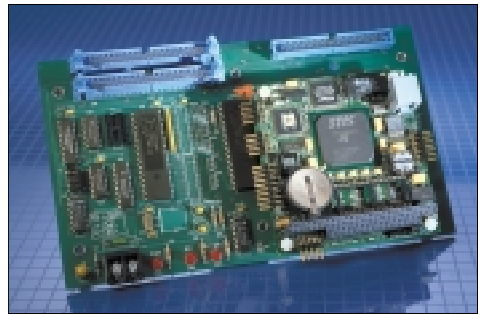

Figure 3 Example of a proprietary OEM controller board with a plug-in PC/104 module.

If disks are not needed in the installed system, and a mid-range processor is being used, there is good reason to mentally differentiate between the development environment for the OEM system and the installed, run-time environment. Burdening a PC/104 automation plug-in with disks, and an operating system to manage them, may push unneeded features and costs into the production model. Consider using a COM port or Ethernet port tied to a desktop PC during development, or installing a PC/104 disk card during development.

So if your company is coming up on an OEM product “next generation”, consider the approach of separating the processor, memory and core I/O from the application I/O—physically (Figure 3). An OEM designed and built I/O and connector PCB with a PC/104 or PC/104-Plus socket on it creates a stable PCB. Features can be added in the future by unplugging the current PC/104 automation card and replacing it with a newer, higher performance model with more memory and features. ◢

Micro/sys, Inc.
Montrose, CA.
(818) 244-4600.
[www.embeddedsys.com].