

Challenges in Designing Today's High Integration, High Performance Industrial SBCs

The design and development of today's high performance and highly integrated industrial Single Board Computers (SBC) presents many challenges to the development team. A successful design can only be obtained through proper decisions at the component selection phase, good techniques and practices in the design stage, a careful and well thought out board layout, and thorough validation and testing. This must be done in parallel with the coordination of all the required support groups such as software and BIOS development; manufacturing, assembly and test; procurement; and technical and sales support. Given the complex recipe for success, when evaluating the development of an industrial SBC for your application, serious consideration must be made to using the services of, or purchasing an existing product from, an established industrial SBC developer and manufacturer.

Today's industrial single board computers (SBCs) are following the trends of the semiconductor industry. Higher density, integration and performance are the requisites for current designs. In order to reduce system cost, complexity and physical envelope, and increase system reliability and capabilities, functions that were previously distributed on multiple cards in a system are now being integrated onto industrial SBCs.

While much different architecture exist, this article focuses primarily on PC architecture-based industrial SBCs. By leveraging on the PC industry, lower component, software and development costs have become attractive for telecom, medical, and industrial applications. Add to this the number of non-real time and real time operating systems available on these platforms, including Windows® 3.xx, Windows® '95, Windows® NT, O/S2®, SCO Unix™, Novell™, UnixWare™, pSOS™, QNX™, VxWorks™, etc., and the sys-

tem integrator is provided with an abundance of options. Just a short time ago, the performance and functional requirements of industrial SBCs were two to three years behind that of the desktop PC or workstation. Today's industrial SBCs have closed that gap and now incorporate the same technology and features, but at a much higher level of integration than the desktop PC. Examples of such are shown in Figures 1 and 2, respectively.

This level of integration and performance, while ideal for the end-user, poses many challenges for the design team. Thus, when tempted to begin the in-house design of one of these boards, serious consideration must be made of the required level of effort, technical difficulties, and the available time frame.

COMPONENT AND VENDOR SELECTION

There are many aspects which must be considered

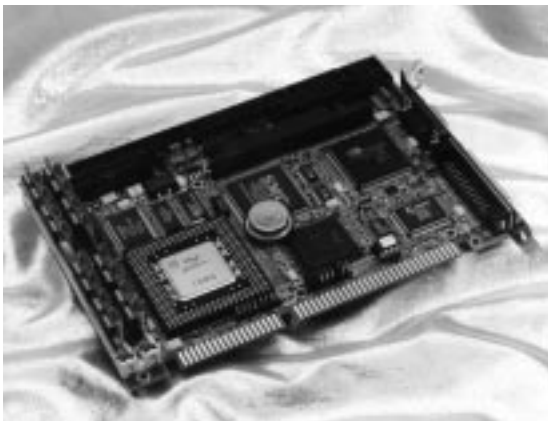


Figure 1: Teknor VPer820, Half-Size 200MHz Pentium® SBC with onboard CRT/Flat Panel SVGA and SCSI

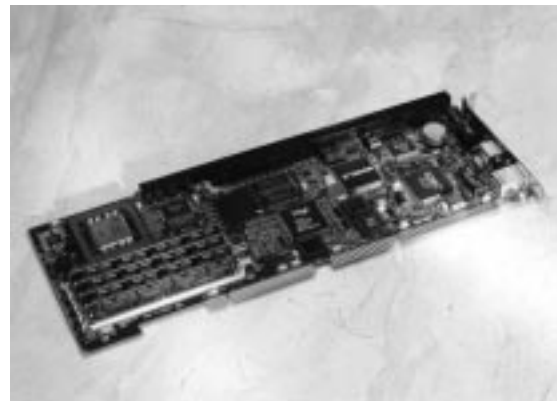


Figure 2: Teknor PCI-936, PICMG 200MHz Pentium® SBC with onboard CRT/Flat Panel SVGA, Fast-20/SCSI II, and 10Base-T/100Base-TX Ethernet

when selecting components in order to meet the requirements of the SBC, including:

- Functionality and integration
- Available packages
- Available second sources
- Lead time
- Component obsolescence
- Long term availability of component
- Reliability
- Quality (component and company)
- Company history
- Company technical support
- Wafer supplier
- BIOS support
- Available software drivers and operating system support
- Price

Long-term availability is one of the main issues when using PC components in industrial SBC applications. The early obsolescence of components by manufacturers is common in the PC world. The situation, however, is getting better for the industrial and embedded market with some of the major component companies establishing "embedded groups". These groups develop new technologies, with a longer life and higher integration, and continue to support current technologies when their high volume/high profit stay in the consumer world is over.

The choice of component packaging is critical. While the trend is towards the use of higher density packages (finer pitch, more pins per square inch, BGA), the chosen packaging must also meet the manufacturing capabilities of the board assembler. Another important factor is the package's utilization of board space, especially when using double-sided surface mount technology (SMT). For example, an increasing number of highly integrated components are available in Ball Grid Array (BGA) packaging. While the number of pins on the device increases with BGA packaging, so does the number of vias required to bring out connections from these pins to the rest of the board. As a result, no device can be mounted opposite of a BGA device. Thus, for a double-sided board, a BGA device takes up the board space equivalent to twice its actual size. While solutions to this problem do exist (i.e., blind or micro vias), they are cost prohibitive and will only become viable in the future.

An often forgotten criteria when selecting the latest component is choosing those that are already in use in by the board assembler. This minimizes the logistics of adding a new component to the MRP and manufacturing system. There is thus a balance to be struck between the use of different, denser devices, and those that are already a part of a company's previous repertoire.

The choice of connectors must also be considered carefully. On a typical industrial SBC, connectors can use up to a third of the available board space. While the tendency is towards the use of higher density connectors, consideration must be made to provide a valid upgrade path from previous versions of the board.

The power interface must also be determined. Due to growing current requirements on 3.3V supplies, primarily due to today's processors, the use of an onboard switching regulator is becoming required. Not only does this increase the complexity of the board, but also requires more PCB real estate than a linear regulator.

ELECTRICAL DESIGN

With the use of high-speed devices, including mixed analog and digital technologies, careful design practices are required. Even with the decreasing footprint for termination and decoupling components (down to 0603 or 0402 SMT devices), the increasing use of these components results in the loss of board space. New technologies such as bulk capacitance and resistors embedded directly into the PCB must now be considered.

Designers must continually consult reams of technical information from component data sheets, application notes, technical publications and articles, technical support personnel, etc. Unfortunately, these sources of technical information are not always as accurate and complete as desired. The designer must also be aware of documented errata sheets (bug lists) for each component being utilized. While manufacturers do generate and distribute these errata sheets for their devices, it is not always easy to get your hands on them. It is therefore essential to establish a good working relationship with technical support personnel from each major component vendor.

Testability of the board must be considered, especially given the difficulty of accessing pins and signals on dense boards. Special design practices and components may also be required if the system, which is using the SBC, must undergo FCC, UL, CE Mark or other regulatory agency approval. While these requirements are generally borne by the system itself, the design of the SBC must take them into account in order to facilitate certification.

BOARD LAYOUT (ROUTING)

Component placement is one of the most critical, and often overlooked, phases of the design cycle. It must take into consideration critical signal interconnects, trace density, special constraints due to the manufacturing process or of the components themselves, as well as segmentation of the board into "noisy" and "non-noisy" areas. A good component placement can greatly simplify the routing of the board, reduce the number of vias or even reduce the number of layers required for the PCB.

While typical desktop platforms are designed on 4-layer boards, today's industrial SBCs, with their higher board density, typically require 8 to 10, or even 12 layer boards.

Careful routing of critical signals, as well as special routing requirements of various devices, must be performed to ensure good signal quality. Some information may be found in the application notes of the various components, or in specifications and standards. The routing of critical signals is generally done manually, with the balance of the job being completed by autorouter software. Given the high number of critical signals on these boards and the density of the board and component leads, the task for the autorouter is very difficult. It is not surprising to see a board, especially in the half-size AT adapter format, which cannot be autorouted even with very powerful routing engines. This greatly affects the time required to complete the routing of the board.

Correct power and grounding for boards using high-speed components is essential. With the increased density of these boards, large numbers of vias reduce the amount of copper available on these planes. The number planes required and the copper weight on each plane must therefore be evaluated. Also, careful attention must be paid to the required cuts and islands in the power and ground planes. They are typically required for mixed signal devices, such as video and Ethernet chips. This is to increase noise immunity and reduce power and ground pollution to and from the rest of the board. This information is generally found in application notes associated with the devices. Improper design practices at this stage can lead to problems that are very difficult to isolate and correct during the testing phase.

It is also at this phase of the design cycle that the required stackup of the board must be determined. This is especially important for boards that require controlled impedance. Various factors must be taken into consideration, including number of layers, overall thickness of the board, trace width and spacing, location of power and ground planes and PCB core material. Generally, many analyses and compromises are made. For example, in an ISA or PICMG product, which can be mounted onto a passive backplane, the board thickness is limited to 0.062". Teknor's current line of Pentium® SBCs requires 12 layer PCBs. In order to use this layer count, along with the constraints of board thickness and controlled impedance, required trace widths could become "uncomfortably" small. Ultimately, the proper combination must be determined in order to have a PCB that is manufacturable, by multiple sources, and does not incur price penalties because of expensive processes or materials.

PCB MANUFACTURING

With proper decisions made during the routing phase of the board, especially with respect to board stackup, the PCB manufacturing phase can be greatly simplified. It must first be ensured that the PCB manufacturer is capable of meeting the trace thickness, core material, hole size, plating specifications, solder mask process and testing requirements of the board. It is critical evaluate the capabilities, quality, price, lead-time and actual delivery time of the PCB supplier. While trial runs provide a good indication, it is really only after a few prototype and production runs with the PCB sup-

plier that their performance can be assessed.

BOARD ASSEMBLY

Given the density and the types of components used on these latest industrial SBCs, older processes must be updated, and new ones developed in order to assemble the boards. Smaller lead pitches require special lines, more accurate pick and place equipment, and finely tuned processes for the type of solder paste and paste mask used. Difficulties exist even for the passive components, such as size 0402 SMT devices that require a smaller nozzle size and increased placement accuracy. For BGA devices there are new methods required for solder inspection, as well as special equipment and processes for rework of the components.

Double-sided surface mount assembly is used to maximize the board area available for components. Processes must be developed to keep the quality of these boards high, while at the same time maintaining low production costs. Any special constraints that arise from these processes must be forwarded to the design team to ensure a Design for Manufacturing (DFM) process throughout the entire development cycle.

It is extremely important that the board assembler qualify the assembly process for any new packaging technology. Since this may be a lengthy process, it must be done in parallel with the design phase of the board to ensure that it is ready for board assembly.

DEVELOPMENT AND VALIDATION TESTING

The high density of these industrial SBCs makes it virtually impossible to add extra test points for development and validation testing. Add to this the decreasing lead pitch of the components, or worse yet, BGA packaging and signal probing on the board becomes difficult or virtually impossible. Special adapter sockets and fine pitch test probes are required in order to access signals with high-speed digital and analog oscilloscopes, logic analyzers, etc.

Complete test and validation procedures are required, especially for general purpose industrial SBCs, since compatibility with virtually limitless numbers of operating systems, software packages and peripherals is required. These tests must be performed using a setup which is representative of the SBCs operating environment, and must validate all the specified requirements of the board.

PRODUCTION TESTING

Given the density of these boards, especially when double-sided assembly is used, it is impossible to use automated bed of nails testing. Higher-level manual functional testing is required, generally using specialized custom jigs and test equipment. This, of course is a slower process.

Continuous training of production test personnel is required, given the rapid addition of new technologies onto the boards and new tests to be performed. Also, during the design phase of the board, training of pro-

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duction engineering personnel must be performed. This is important so that they can generate the required production test hardware and software to adequately test any new components used in the design.

SOFTWARE DEVELOPMENT

The full in-house development of a PC-compatible BIOS is not practical, given time-to-market and compatibility issues, as well as the constantly evolving technologies, initiatives and standards in the industry. As such, this is best left to an established third party BIOS vendor. However, in general, no third party BIOS will work "right out of the box". This is because each BIOS is inherently linked to the particular hardware platform for which it was developed. Each new design normally has a new mix of components, or may require a new function, that will necessitate a BIOS update. In some cases, the industrial SBC company creates special BIOS extensions in order to provide additional features. It is for this reason that a BIOS development team is usually required in-house.

With respect to the core or system BIOS, it must be decided whether to have a third party BIOS company completely develop the code and ship linkable object code or to purchase the source code and develop the BIOS in-house. While purchasing the source code provides more flexibility and control, it is generally very expensive and requires a larger effort to establish an expertise with this very large piece of code. It is recommended to buy the core BIOS source code only when the price and developed expertise can be amortized over many similar designs.

Even though a chip may be integrated and powerful, it is also useless without good software drivers. This becomes especially complicated if the SBC is to be used with various operating systems, each requiring their own special driver. It is for this reason that the component developers are themselves getting larger software groups, in order to generate these drivers. However, in an imperfect world, there will always be a customer with an application where a new driver will be required. Thus, the SBC developer must also have a software team capable of generating these required drivers, as well as maintain good relationships with the component and O/S developers.

TECHNICAL SUPPORT

With the rapid advancement of the technology and the complexity of today's industrial SBCs, the technical knowledge and expertise of the technical support staff must also keep pace. As previously mentioned, good technical support from the manufacturer is a crucial criterion for the selection of a component from a specific vendor. The same is true for the customer who will select your product over your competitor's. Also a good technical manual that encompasses all aspects of the board's use, including hardware, firmware and software, must be generated. A team of technical writers, who ensure completeness, readability, understandability and consistency with previous manuals, is generally responsible for this.

Another factor to be considered is the sales force, which cannot sell what they are unaware of or do not understand. Given the growing amount of functionality being incorporated onto modern industrial SBCs, the internal and external sales people must be kept abreast of this information and trained on a continuous basis. Accurate, detailed and complete specification sheets are also required for both the sales force and the customers.

LOGISTICS

As is quite evident, a high level of coordination is required between all levels of engineering, management, procurement, production, technical writers, technical and customer support, sales, subcontractors, manufacturers and vendors, in order to fit all the pieces of the puzzle together, at the right time.

CONCLUSION

The development of today's high performance, highly integrated industrial SBCs is certainly not an easy task and should never be underestimated. The decision to begin the in-house development of one of these SBCs must be made very carefully, considering all of the challenges, difficulties, and decisions that must be faced along the way. A much more practical alternative, especially if your expertise lies in the system development or integration arena, is to have the industrial SBC developed by, or preferably purchased from, a well-established industrial SBC designer and manufacturer. Advantages include shorter time-to-market; lower development costs and resource requirements; guaranteed compatibility, especially for PC architecture-based products; long term availability; and the ability to concentrate on the system development as opposed to that of the SBC. Furthermore, these specialized industrial SBC manufacturers have developed an expertise and have established important relationships with suppliers and manufacturers based on years of experience with similar products and architectures. With the current levels of integration, power and functionality available from established industrial single board computer companies around the world, it is more than likely that you can find the board that exactly fits your needs, or can quickly get one developed that does. ■

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