COM-Based SBCs: The Superior Architecture for Small Form Factor Embedded Systems

A White Paper from Diamond Systems Corp.

Embedded systems designers are under pressure to reduce the cost and size of electronics while improving time-to-market and overall system reliability. Today, many designers achieve these goals by using off-the-shelf x86 single board computers (SBCs) with I/O modules stacked above or below to implement the special-purpose I/O that makes the embedded system fit the application requirements. An alternative to this traditional approach is to use a Computer-on-Module (COM)-based SBC. By using a COM-based SBC, a designer may gain significant benefits over traditional SBCs in the areas of:

- Scalable CPU performance
- Long product life
- High feature density
- Access to the latest CPU technology sooner
- Compact size
- Single vendor solution for purchasing and support logistics

Figure 1
Older design consisting of cumbersome stacks of SBC and I/O modules

Traditional SBCs

Traditional SBCs are usually built around an existing industry standard form factor, such as PC/104 or 3.5". They often include expansion buses to enable easy adaptation to a particular application by adding one or more I/O modules. The large number of I/O modules available from manufacturers around the world makes this strategy appealing to a wide range of customers and enables rapid development of embedded solutions for a large number of applications.

Yet standard SBC-based systems with large I/O requirements have a number of significant drawbacks that have vexed embedded designers, including:

- Relatively large sizes due to the number of add-on I/O boards needed to obtain the complete solution (see Figure 1)
- Packaging difficulties resulting from the odd format of a stack of boards with I/O connectors on all sides
- The cabling nightmare resulting from having to bring the I/O from all these connectors to the enclosure bulkhead
- The difficult assembly and maintenance efforts associated with a tightly integrated stack of boards and a maze of cables
- Increased purchasing efforts and planning complexity resulting from dealing with multiple suppliers
- Increased system cost due to the presence of expensive interconnects between boards

COM-Based Solutions

A COM-based solution takes an entirely different approach. The CPU, which is the highest complexity, highest risk, and shortest lifecycle component, is made into a standard form factor, interchangeable module that can be purchased from a variety of manufacturers. The rest of the system consists of a "baseboard" which contains most or all of the remaining circuitry and I/O connections required for the solution. The form factor of the baseboard may be highly customized to meet packaging requirements, or it may be more general purpose to fit a range of applications. The baseboard may also include expansion connectors to allow for future upgrade or configuration needs.

Because the COM-based SBC utilizes an off-the-shelf, standard format module for the processor, the designer has the option to swap out the processor for a different one with minimal effort. In most cases the effort is limited to rebuilding the application software with a new set of software drivers for the processor and various peripheral ICs on the COM.

This swapping ability yields two significant benefits. First, the lifecycle of the product is greatly extended, since an end of life COM can be easily replaced with a new generation module, adding five or more years to the product's lifecycle. Second, a single baseboard design can work with multiple COMs at different price / performance levels, offering the designer the ability to support performance upgrades, cost reductions, and other scalability features.

COM Tradeoffs

The attractiveness of a COM-based solution is demonstrated by the fact that COM CPUs far outsell in unit volume all standard small form factor SBCs (including PC/104 SBCs) combined. However, COM-based solutions pose their own set of challenges to the embedded designer:

- The design of a custom I/O baseboard for each new application
- The requirement for expertise in the needed I/O circuitry and board design in general
- Longer product development cycles
- Higher development costs

COM-Based SBCs: The Best of Both Worlds

A middle ground is now available in the form of off-the-shelf, I/O-rich COM carrier boards in standard SBC form factors, giving designers the best of the SBC and COM worlds without the budget and schedule risk associated with a full custom baseboard solution. Combining such a baseboard with a COM creates the COM-based SBC. These off-the-shelf two-board solutions usually still include industry-standard expansion connectors to allow customization in the same manner as traditional SBCs.

A COM-based SBC usually includes a thermally conductive heat spreader, which provides both a mounting platform and an effective means of dissipating heat from the processor directly to the enclosure body (see Figure 2). Diamond's testing has shown that this type of conduction cooling can offer as much as a 23 degree C reduction in CPU chip temperature, resulting in higher ambient temperature compatibility as well as higher long term reliability.

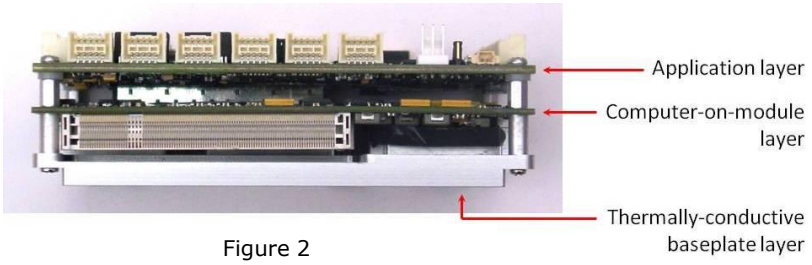

Figure 2
Anatomy of a COM-based SBC

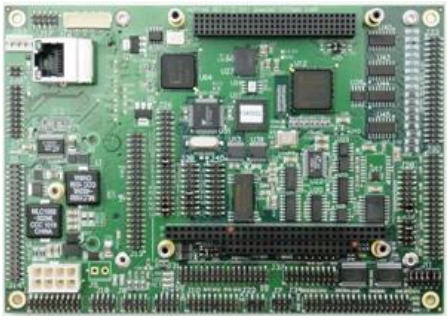

Figure 3
Neptune's I/O rich baseboard replaces the stack of modules in Figure 1

An example of a COM-based SBC is Diamond Systems' Neptune, a rugged, extended temperature, I/O rich highly-integrated EPIC-sized COM-based SBC as shown in Figure 3. By using the industry standard ETX interface, Neptune offers a wide performance range of available ETX COM CPU modules. The ETX CPU plugs into the bottom of the baseboard, which allows the implementation of an efficient heat spreader thermal solution by conducting the heat from the processor and chipset directly to the bottom surface of the enclosure.

Another example of a COM-based SBC is Diamond Systems' Vega, a rugged, highly-integrated COM Express-sized SBC with interchangeable COM-Express COMs as shown in Figure 4. Eliminating the PC/104-*Plus* connectors and changing the overall I/O connector strategy enabled shrinking the size of the baseboard to match the size of the COM. Again the two-board solution replaces a stack of four PC/104 boards: SBC, power supply, analog I/O, Ethernet.

Figure 4
COM-Express sized
Vega COM-based SBC

No matter what quantity and type of I/O exists on a COM baseboard or COM-based SBC, some customers will always need more. Therefore a well-designed COM-based SBC includes one or more expansion sockets for installing I/O modules, commonly PC/104 or PC/104-*Plus* stackable I/O expansion or a PCIe MiniCard socket. Many embedded computing vendors offer a selection of I/O modules for just this need.

Diamond Systems offers a wide range of stackable I/O modules in several industry standard formats including PC/104 and PC/104-*Plus*. These modules include analog I/O, digital I/O, networking, CAN and power supplies among others. We also offer a family of PCIe MiniCards for on-board I/O expansion providing most of the same functionality but in a much smaller size.

Diamond's Vega COM-based SBC includes a new high-performance expansion socket called EMX (short for Embedded Express). This socket is designed to offer high speed I/O expansion in a compact footprint with the lowest possible cost. The EMX connector offers 4 PCIe lanes, LPC bus, and USB, enabling it to support the most popular peripheral chips and circuits. One example is Diamond's EMX-ESG777 EMX I/O expansion module offering dual Gigabit Ethernet ports, six serial ports, 14 digital I/O lines, and a socket for a GPS receiver.

COM-Based SBC Benefits

A COM-based SBC, with its off-the-shelf baseboard, yields almost all the advantages of both a custom COM solution and an off-the-shelf traditional SBC, while eliminating almost all the negatives of each. Its primary benefits include the following:

Scalable CPU Performance

By using off-the-shelf industry standard COMs as the CPU, each of these new carrier boards can support a wide range of performance – effectively an instant product line with scalable CPU performance. By virtue of being able to easily swap out one COM CPU module for another, the COM-based SBC can offer processing solutions ranging from low cost, lower performance entry systems to high end, processor intensive compute engines, often using the same operating system and drivers.

Longer Product Life

With product lifecycles (and ongoing maintenance requirements) in many industries lasting as long as 15-20 years, and processor lifecycles typically in the 7 year range, product lifecycle issues are paramount in any embedded system design. The ability to easily swap COMs greatly extends product lifetime. As the CPU chip on a particular COM reaches its end of life, new COMs adhering to the same form factor and with the latest CPU technology are already on the market. Physically replacing the EOL COM with a newer model is straightforward and can be done in the field. Software changes are typically minimal, often limited to only rebuilding the application software with a new set of drivers for the new CPU and various peripheral ICs on the COM.

High Feature Density

By using a 2-board sandwich, a COM-based SBC offers higher functionality for a given footprint. Neptune's baseboard integrates the capabilities of five traditional PC/104 I/O modules into a single EPIC-sized board, including: wide range power supply, multi-protocol serial ports, data acquisition, opto-isolated digital I/O, and Ethernet.

Early Access to the Latest CPU Technology

The nature of the embedded market is that the latest processors are usually made available in COM form factors before they appear as traditional SBCs. Therefore A COM-based SBC provides earlier access to the latest CPU technology. Existing applications can upgrade with very little effort and maximize their competitive edge.

Compact Size

With the ETX COM attached, Neptune offers an extensive set of standard PC I/O such as four USB 2.0 ports, Serial ATA (S-ATA) and EIDE hard drive interfaces including a CompactFlash™ socket and IDE flashdisk interface, 10/100 and Gigabit Ethernet controllers, six serial ports, audio, and legacy keyboard and mouse interfaces. While providing all this I/O, Neptune includes a PC/104-*Plus* expansion (PCI and ISA) interface to accommodate still more I/O if needed. Neptune packs all of the I/O and power circuitry into a tiny 4.5" x 6.5" (115mm x 165mm) board in compliance with the EPIC 2.0 industry standard specification.

Reduced time to market

Designing a COM-based SBC is a much quicker endeavor than designing a single board computer from scratch. Since the CPU and associated circuitry is typically the most complex and challenging part of an SBC's design effort, utilizing an off-the-shelf COM simplifies and accelerates the development cycle. It also simplifies the testing and debugging phase of releasing a product from R&D into manufacturing because the CPU circuitry is already a known working design. The resulting shorter development and test cycles allows COM-based SBCs to become commercially available faster than their SBC counterparts. This advantage is particularly valuable when considering a custom solution.

Single Vendor Solution

A COM-based SBC is a standard product intended for production deployment from a single vendor who takes responsibility for all compatibility and logistics issues. Having a highly integrated, one-vendor solution simplifies the overhead costs associated with procuring the individual pieces necessary to create the final solution, and makes field support of deployed systems much more cost effective and efficient. Total cost of ownership is thus greatly reduced, and operational efficiency increased.

Summary of COM-Based SBC Benefits

Many more embedded system manufacturers of all sizes can now move to the latest COM technologies and architectures without incurring the schedule, risk, and cost of custom baseboard development. The numerous benefits of this standard COM-based SBC approach include:

- Scalable CPU performance
- Increased product lifecycle
- High feature density
- Access to the latest CPU technology
- Compact size
- Reduced time to market
- Single vendor solution

The array of valuable benefits derived from a COM-based SBC is impressive and affects all levels of the organization. COM-based SBCs are the smart choice for today's embedded systems designs.