System-On-Module Enables Breakthroughs in Medical Systems

by Jon Barnard, PFU Systems

Medical equipment OEM manufacturers are by nature highly competitive, requiring that their products be "breakthroughs" that clearly differentiate performance, value and brand. Once marketing defines a product's branding, price point, declares the product's value proposition, its features, attributes and life cycle, engineering must develop the product to marketing's specifications, make changes as required to add competitive features midstream and ensure scalability. Product development of such breakthroughs, complete with documentation, must be delivered on time and within budget.

System monitoring, security and communications determine which interfaces become adopted as standards and must ensure reliability. Government mandates as well as industry compliance drive these issues with a dizzying array of acronyms like HIS, RIS, PACS, DICOM, HL-7, FDA and GMP. Marketing of medical systems further requires compliance with set standards.

Issues and Hurdles

To overcome a variety of issues and hurdles, OEMs design proprietary, custom-single board computers (SBCs) with on-board host computing to manage system functionality. Single board computer design and integration usually takes between 12 to 24 months, and sometimes longer, depending on the level of hardware and software integration, and is often met with further challenges as products require upgrades to maintain a competitive advantage.

Today, medical OEMs increasingly face cost and time-to-market pressures and must make lifecycle decisions that may redefine product families. Products must be sustainable, scalable and offer multi-tiered products at different price / performance levels. 'Sustaining engineering' has a continual challenge toward expanding product capability and improved performance. Breakthrough products are essentially paradigm shifts that rely on shifts in technology at the component level. System-On-Module (SOM) architecture is an example of such shifts in technology.

What is SOM?

SOMs are macro-component subsystems that are used to develop single board computers. SOM integrates system functionality with graphic controller, chipsets and memory into a single component as small as an index card. The SOM block diagram in Figure 2 describes PFU Systems' 32 -Bit, 33MHz-SOM, Plug-N-Run™ architecture.

SOM-based systems compete with the traditional SBC. SOM components are built with commercial, standard, off-the-shelf components with associated costs. The small footprint is offset by the larger economy of scale that SOM components enjoy versus SBCs. With an SOM approach, OEMs are able to optimize form-fit-function, time-to-market and development cost and risk. System-On-Modules are proven, tested and qualified macro-components, with high MTBF, reducing the design and verification process to the unique functionality of the custom system board.

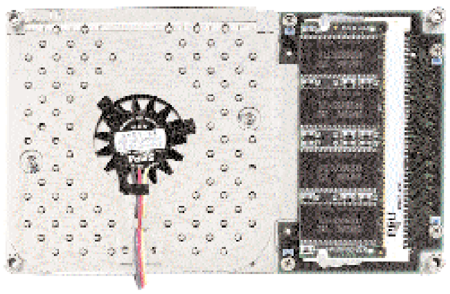

Figure 1. Plug-N-Run™ System-On-Module™ (SOM).

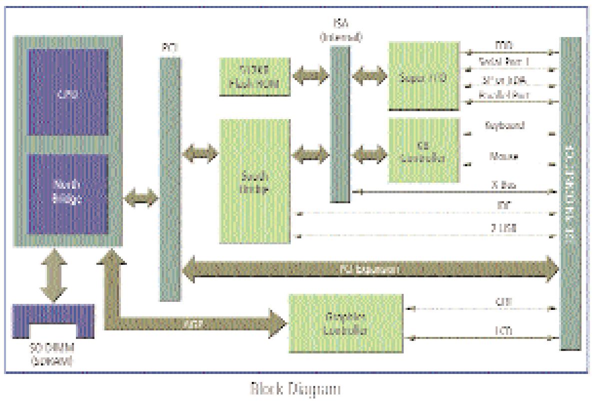

Figure 2. Block diagram of Plug-N-Run System-on-Module.

SOM's Evolution to Medical

First created in 1997, SOMs were a line of 16-bit, ISA-based micro- motherboards called CardPC and Card-I / O. The size of a business card, they were used primarily for computer aided machine (CAM) applications. SOM technology has since evolved to 32- and 64-bit, PCI-embedded architectures that provide host computer functionality for a broad range of medical systems ranging in size from compact diagnostic ultrasound to PET scanners, from patient monitoring to picture archiving and communications PACs, including color, volume and 3D applications.

SOM as Standard Architecture

As a component, SOM is not governed by the same rules or restrictions of SBC standards. Although SOMs may be used to build an SBC within PC104 / PC104+, or CompactPCI standards, SOM product architecture is often better suited to build systems independent of either of these two standards such as those with unique buses or backplanes. Just as with System-on-Chip, the SOM may be soldered or socket-mounted onto a carrier board that connects to the system I / O.

Specialized medical products include laptop-sized portable ultrasound imaging and bedside point-of-care, mobile e-charting and mobile patient records management. All require smaller footprint, networking and greater reliability, improved security, serviceability and are more rugged with higher shock specifications. Managers must figure out the fastest, least expensive, most reliable way by building or buying while minimizing risk and maximizing product longevity.

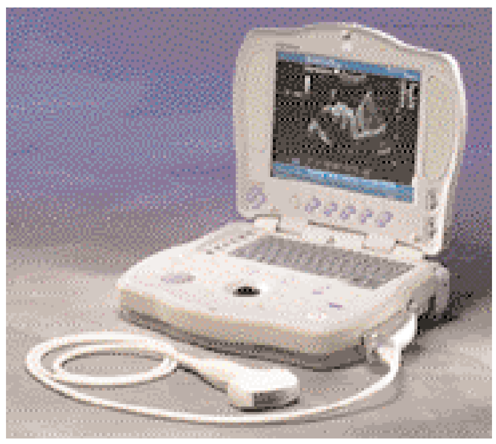

Figure 3. LOGIQ Book portable ultrasound system. Photo courtesy of GE Medical Systems, Milwaukee, WI.

Figure 4. "Stinger Solution," mobile hospital IT system. Photo courtesy of Stinger Industries, LLC.

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Build or Buy?

With increasing frequency, OEM medical manufacturers today find that the best decision is embedded SOM. System-specific I/O may be designed onto a "carrier" board that they build. System-on-Module plugs onto a custom carrier board and routes all signals to and from the host-module. SOM components save considerable up-front development cost, risk and time. SOMs help assure performance-scalability and design reuse that allow for low-impact system upgrades and product-line extension when necessary.

Economic Advantages of SOM

Up-front decisions regarding volume of purchases may not always be precisely forecast over the entire product line life cycle. SOMs help reduce uncertainty of long product life with scalable design. Modules are interchangeable across a broad range of cost/performance points. As a modular component, SOMs from PFU Systems are road-mapped for seven years plus, with off-the-shelf availability, and they bring greater continuity to sustaining the product. BIOS may be customized with System-On-Module products permitting further product differentiation, password-protection security and proprietary maintenance, upgrades and monitoring features.

Selecting a System-On-Module Supplier

Selecting a best-of-class manufacturer of SOM components is easier than selecting an SBC manufacturer for three reasons: First, as with SOC manufacturers, the number of SOM manufacturers is relatively small when compared to SBC manufacturers. This is due to a higher level of component integration and production processes involved. Second, the likelihood of a SOM manufacturer with poor product quality surviving competition is low compared to SBC manufacturers. Higher levels of investment are required of System-On-Module manufacturers to maintain quality. Third, larger investments in marketing are needed to recover the higher product development and manufacturing costs. Product design with highly integrated SOM components, however, do not translate into higher development cost compared to a single board computer design.

Popular Standards, Inherent Problems

The popularity of x86 processors in embedded electronics devices is supported by several single board computer industry standards such as PC104/PC104+, EBX and CompactPCI. Entire industries have risen around these "standards," delivering products based on prescribed form factors and interfaces. SBC products designed around these "standards" compete with each other on price and I/O integration. Inherent problems include variable quality, unwieldy form-fit-functionality, and unpredictable total cost of ownership (TOC). Manufacturers of SBC product designed around the PC104/PC104+, EBX, or CompactPCI standards compete with price and integration on a single board, resulting in varying quality, unwieldy form-fit-functionality making the total cost of ownership less predictable.

"Spare the Host---Spoil the Brand"

Partial solutions where host computing may be spared have not proved to be effective in marketing PC-based medical system devices. Shifting PC-host functionality to the end-user's computer should be avoided.

The graphic display ought to identify the system and brand during start-up. If your start-up "splash-screen" displays a manufacturer logo other than the medical OEM during system boot, brand equity is quickly spoiled.

A marketing pitch such as "runs on virtually any laptop computer having an IEEE 1394 (FireWire) port," attracts with a low-price message, but sadly results in unwieldy design, system crashes, lock-ups, BIOS compatibility issues, insufficient memory or multiple system reconfiguration. Restarts may be required to optimize performance to fit the lowest-common denominator customer laptop. Unlike PFU's seven year model roadmap followed by System-On-Module, CPUs and chipsets

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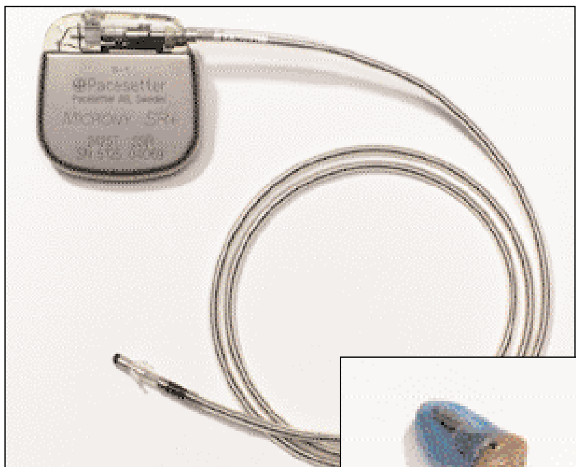
Doing More with Much, Much Less: Ultra-Low Power Design for Medical Applications

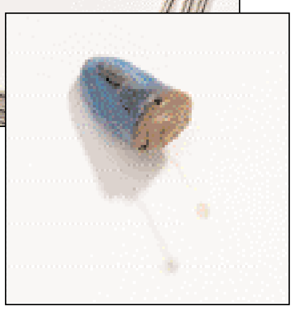

Francois Pelletier


Steve Morris

by Francois Pelletier and Steve Morris, Zarlink Semiconductor

Since the first pacemakers were introduced in the 1960s, ultra-low power (ULP) has been a defining element of medical electronics. The quest for long battery life and aggressive miniaturization has resulted in systems with vastly lower power characteristics than low power, handheld consumer electronic devices such as cell phones or PDAs (personal digital assistants). For example, a dual chamber heart pacemaker consumes less than 10 mW (4 mA at 2.5V), lasts more than seven years on a single battery, fits in an 8 cc case and weighs less than 18g. (See picture 1). A completely-in-the-canal (CIC) hearing aid draws less than 900 mA from a 1.25V supply, and that includes all the analog circuitry, the digital circuitry and a dedicated DSP core (see picture 2).


Dual chamber pacemaker — seven years on a single battery.


Completely-in-the-Canal hearing aid — draws less than 900 mA.

Medical component designers continue driving down the power curve. Next-generation DSP-based hearing aids — utilizing 0.13 mm processes and drawing on improved ULP design techniques — will offer more features with more DSP circuitry, while consuming less than 500 mA from the same Zinc-Air batteries as today's models.

Not surprisingly, ULP design techniques developed for medical applications are now attracting attention from the consumer market as PDAs, headsets, cell phones and other personal devices are beginning to require ultra-low power performance. To achieve ULP performance, IC engineers must optimize everything — the system architecture, design techniques, cell library, key components and manufacturing process technology. There is no magic in ultra-low power IC design; the keys to success are paying meticulous attention to detail, optimization and trade-offs.

Getting the Right Specifications

Attention to detail must be applied from the top all the way down to individual gates or transistors. Are the specifications suited to the application or is the design over-specified? Dynamic range (or SNR), linearity and distortion are often specified for historical reasons or because they come from a standard part supplier's catalog. In data converters, scrutinize the specification to ensure that the requirements are in line with the system specification. For instance, ensure that quantization noise is consistent with the system as overdoing this can be very costly in power.

Selection of supply voltage produces beneficial trade-offs. For digital circuits, power is considerably reduced (from CV2f) by choosing a lower supply voltage, but this does not necessarily hold for analog counterparts. For amplifiers, a higher supply voltage allows telescopic rather than folded structures so the current can be lower. For mixed-signal ICs, use a double supply on-chip by dividing the supply down for digital and using the higher supply for analog blocks. In general, lowering the frequency gives immediate return on power savings. This applies for digital circuits and for clocking sampled data and sigma-delta circuits.

In the drive to cram more gates into a single chip, process feature size is the dominant factor. But at feature sizes below 150 nm the off-state leakage current rises rapidly due to lower VT scaling and oxide thickness. Eventually, leakage exceeds dynamic power. Techniques that reduce leakage power include multi-threshold CMOS (MTCMOS) for turning off the supply voltage to large internal low-VT blocks and variable threshold CMOS (VTCMOS) that allows the threshold voltage to be controlled via biasing, so that VT is increased during idle mode and reduced for normal operation. Another approach is to reduce the core supply voltage to just above a critical value for device performance.

The Impact of System Architecture

The choice of architecture has a major effect on device power consumption. For digital and DSP designs, the biggest gain in power reduction is to operate the circuitry at the lowest supply voltage at lowest possible speed while still meeting system throughput requirements. Thus, on an architecture level, concurrency and parallelism should be used as well as pipelining the data path.

For sigma-delta converters, the correct choice of over-sampling rate in conjunction with modulator order is very important. Multi-bit versus single-bit, and MASH versus single-loop trade-offs should be investigated, as should choice of continuous time versus switched capacitor implementations. If a good clock is available or jitter is not a critical parameter, then considerable power savings can be made by using continuous time rather than switched techniques.

With DSPs it is worth using custom-developed architectures to reduce power and achieve high utilization. The result is that non-conventional architectures are produced (probably non-Harvard), but the low-complexity implementation will use optimally low coefficient word lengths and therefore low data word lengths. This will reduce storage requirements and compound power savings.

For arithmetic operations, switching activity can be reduced by choosing a suitable number representation (e.g. sign magnitude over 2's complement) and by selecting an appropriate adder or multiplier (e.g. CSA rather than Wallis Tree). Multipliers should be judiciously shared with efficiency obtained by using shift-and-add when multiplying by constants.

At the algorithmic level, consider IIR filters rather than FIR, and radix-4 FFT's rather than radix-2. Further reductions can be achieved by producing highly efficient DSP blocks and re-using these for many operations. Similarly, for RF IC designs, optimizing the architecture for a given application is key to lowering power consumption. Choosing a modulation scheme allowing constant envelope techniques rather than high-level modulation can reduce power. Using DSP within complete receiver or transmitter sections can also yield power efficiency benefits even when considering the data conversion requirement.

Design Techniques and Components

Leave no stone unturned when eking out every nano-Watt of "wasted" power. When a part of the circuit (analog or digital) is not required, it can be powered down and/or the clocks gated. At the transistor level, devices should be operated in the appropriate inversion regime (weak/moderate/strong) to get the

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optimum saturation voltage, matching, transconductance and noise trade-offs.

For digital circuits, transistor sizing yields very high gains in power savings. By determining the ratio of parasitic capacitance to gate input capacitance, minimum size cells can be used and drivers sized only as appropriate between blocks and for off-chip signals. Clock tree buffering can also eat up power unless controlled carefully.

Careful component selection and moving some components off-chip can also save power. An obvious example is using just one external "bias" resistor to avoid over-dimensioning the analog circuitry to allow for the inherent ±30 percent variation that comes with the on-chip bias resistor. Sometimes it is worthwhile using trimming of circuit elements by automatic tuning techniques (in RF) or by trimming at wafer probe. If a special CMOS process is available rather than low VT transistors, high-resistivity polysilicon and double-poly or POD capacitors are useful to keep circuitry on-chip and avoid the necessity of wasting power by interconnection to external components.

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change so frequently in off-the-shelf computers that one customer's laptop--or tower-PC configuration will differ to the next and will likely have different software and BIOS, making technical support a real nightmare. This approach is always at the expense of system reliability and market share.

Conclusion

System on Modules, (SOM) provide an upgrade path for adding product features with technology that include the following:

•System-On-Module designs for single-board computing in medical devices provide effective PC-host functionality, integrating essentials in a single component allowing system-specific design of I/O for unique applications to be made on a carrier board.

•SOMs help speed the development process with proven and tested highly integrated technology.

•SOMs allow OEMs to streamline processes consistent with GMP so that products may be manufactured for years, ensuring availability.

•The SOM (as shown in Figures 1 and 2) have thermal system management integrated with a rugged frame and heat sink as a single unit, enabling system operation in challenging environmental conditions including heat and humidity across a range of shock and vibration.

Thermal management should be built in. Figure 1 shows the Plug-N-Run solution with heat sink and frame integrated in one unit, providing thermal dissipation and rugged (up to 50 G's) shock-resistant frame.

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