

Computer Architectures for Medical Applications

Overview

Today's hospitals are changing their attitudes towards computers in the wards. Previously medical staff would have kept computers at a distance from the patient in order to avoid any interference with sensitive medical devices. Now they make active use of personal computer systems to streamline processes and improve care whilst freeing them from administrative work to spend more time with their patients.

This, in turn, leads to new challenges that need to be answered by medical device manufacturers, using new architectures that map into the requirements found in hospitals. Some are presented in this article.

CONTENTS

Introduction: Computer Applications in Today's Hospitals *pg. 2*

From Surgery to Recovery: A Review of Requirements *pg. 2*

Additional Requirements Common to All Medical Equipment *pg. 4*

Meeting the Combination of Requirements *pg. 4*

Custom Design Where Needed, Standards Where Possible in Mobile Applications *pg. 6*

Looking to the Future of the Medical Device Market *pg. 7*

Introduction: Computer Applications in Today's Hospitals

For some time, computers have been used in imaging applications such as computerized tomography (CT) scanning, magnetic resonance imaging (MRI), and X-ray scanning to take data from detectors and perform image-enhancement functions. Doctors then review the enhanced images and use the insight they gain from them to inform their subsequent treatment on the patient. Indeed, more and more often this is becoming a real-time process in which live images are used in the course of surgical treatments, such as moving a catheter in a patient's blood vessel.

Another step in the treatment process is ultrasound: here, the devices themselves are becoming smaller and smaller, and more and more differentiated in their capabilities. In fact, medical device manufacturers are striving not just to differentiate but also to enable hospitals to make more, easier use of these devices, while providing scalability in terms of the applications that are run on these devices.

Closer to the patient are near-bed PCs. Medical personnel can log into the hospital network on a near-bed PC and update patient and/or treatment information. Patients can also use them to log on to the internet and access e-mail. The usage model for near-bed PCs is very similar to that of standard PCs for home or office use, and as a result they are very similar in architecture to normal PC. But they have some special requirements that will be discussed later in this paper.

Finally, to reduce the burden of administrative work on medical personnel, portable devices known as Mobile Clinical Assistants (MCAs) are becoming more and more common. These devices are small enough to be carried by medical personnel throughout the day, while their WLAN wireless networking capability enables data retrieval and storage at the patient's bed. Such ready access to essential information enhances treatment as well as streamlining flows of information. The combination of online, secure access to up-to-date treatment and patient information with the ability to



Figure 1. Handheld X-Ray Scanner

consult specialists online, while at the patient's bed, is very attractive to the medical profession. Paired with a well-protected back-end system for data storage and protection, the MCA promises to bring about big changes in hospital process and patient outcomes.

From Surgery to Recovery: A Review of Requirements Surgery

CT, MRI and X-Ray scans are usually performed either in a dedicated room, or within the operating theatre itself. Here, the imaging application itself is run on a remote device in a control room, so the computer equipment associated with the scanners is not subject to clinical specifications.

The key requirement, however, is for the highest possible processing performance to enable the smooth delivery in real time of the images captured by the scanner. At the same time, there is a need to minimize the amount of radiation emitted in the operating theatre, as this is a workroom which medical staff spend many hours inside each year. This calls for more sensitive detectors. This in turn adds more noise to the images taken, which then requires the imaging application to offer a greater ability to filter and enhance the images that are captured.

Finally, the imaging application must be acoustically low-noise, consume little power, generate little heat and occupy little space so that it will fit into hot and crowded operating theatres.

Taken together, this combination of specifications presents a conflicting set of challenges for the medical device manufacturer. Their equipment must provide:

- Low noise and good cooling
- Small dimensions but high performance
- Maging-specific algorithm support

Recovery: Mobile Devices for Ultrasound

The need to address mobile applications, together with the ever-improving performance delivered by today's computers has led to a new breed of devices next to the familiar hospital trolley: portable Ultrasound devices.

There are two sets of requirements that need to be mapped into the application. First, hospital trolleys have enough room to support a full-sized PC-style computer. Mobile devices, on the other hand, do not, but to maximize their usefulness they should offer similar performance, while operating at low power to allow a full day's operation on a single charge. These devices go near patients, so the exterior needs to be shielded and able to be wiped for disinfection purposes. Beyond that, of course they should also be quiet and cool.

To sum up, the specifications that manufacturers of mobile ultrasound devices must meet are:

- Low noise and good cooling
- Wipe-able, if portable; immersible to support disinfection processes
- High performance
- Long operating time if running on batteries
- Extended temperature range for portable devices as they may be used in emergency vehicles as well



Figure 2. Ultrasound Treatment Room

Recovery: Entertainment and Information Access

On the ward, there are additional requirements that make it hard to use normal PC components. In particular, electro-static discharge (ESD) must be prevented to protect recovering patients. In many respects, however, normal personal computers fit the bill, as long as they are silent. Hospitals often put store by low-power devices, as this limits the burden on the building's power infrastructure and reduces energy costs.

Treatment: Mobile Access to Data

Anyone who has spent much time in a hospital will be familiar with the large trolleys wheeling round the reams of documentation used by doctors as they do their rounds. This paper is the repository for patient status and treatment information. Today, with fewer doctors and nurses looking after more patients, there is a need to centralize data storage, while giving the medical personnel instant access to all relevant patient data. This is the main reason why the category of device called the MCA has been introduced.

Basically, this is a portable computer which can be carried by medical personnel, can connect to the hospital network using WLAN links and offers additional useful interfaces for applications such as RFID, barcode reading and a camera. Once returned to the office, the device will be mounted in a docking station that has additional interfaces as well as charging circuitry.

The benefit of such devices is that they provide instant access to important data, while streamlining back-office work and to give medical staff more time with the patient.

Additional Requirements Common to All Medical Equipment

There are two sets of requirements that apply generally to medical equipment.

First, every device operates in a medical environment, and this means it must meet a certain set of standards for ensuring electrical safety, depending on how close the equipment is to patients. The closer a device is to a patient, the better protected it must be, especially when connected to a normal power outlet in the wall. In this case, special precautions are required to isolate from the device all outlets that are not permanently connected to it. Beyond that, most devices should be as high-performance as suitable, while keeping noise and heat as low as possible.

Second, there are normal medical industry requirements. For instance, devices are normally moved and handled by medical personnel, rather than personnel with special expertise in technology or engineering who might be familiar with issues such as ESD. As a result, devices must offer a high level of mechanical protection to ensure proper operation even after many years of constant operation.

The last general requirement is for the long-term availability of components. Medical devices in general have long product life-cycles. They also require certification—an expensive process—and they will be subject to service and repair procedures for many years after they are manufactured.



Figure 3. Mobile Patient Monitoring System

Standard PCs are very poor at meeting this requirement. PC parts usually have a life time of 6-9 months before they become obsolete. They are therefore not a viable option for medical device manufacturers.

Meeting the Combination of Requirements

This paper, up to this point, has shown how all medical devices share certain common requirements with each other, while also having their own specific requirements. The rest of this paper will explain how a well-planned architecture can meet these many, diverse requirements while controlling costs and accelerating the product development process.

Embedded Servers for Medical Imaging

Medical imaging is an important function carried out by embedded servers in the medical industry. The demands of real-time imagery and high data rates place a premium on computing performance. As these devices are found outside the operating theatre in a separate control room, another key requirement is good cooling and low acoustic noise. An embedded server must also fit in existing racks, which accommodate smaller or shorter form factors than is normal for IT equipment.

Certain of these requirements conflict with each other—low noise and cool operation is made more difficult when the size of the device is constrained, for instance. But Radisys can supply an embedded server system that, at 4U high, allows for the addition of multiple specialist full-size I/O or image-processing cards. Smaller solutions at just 2U height are also available, but these impose limitations in terms of the daughter cards that can be supported.

These daughter cards can be built to provide different functions for image processing. For instance, they might use FPGAs for hard-coded processes, or use general purpose CPUs or a graphics processor for sub-processing. The choice is determined in each case by the device manufacturer's strategy and the demands that its algorithms will impose on the computer.

Indeed, more and more applications call for not just one but several of these cards, as higher resolutions, higher frame rates and lower radiation demand more of the post-processing hardware.

The server also needs to support preventive maintenance through a management system such as IPMI (Intelligent Platform Management Interface). IPMI is well established (and, in fact, implemented in most current server motherboards), and has been widely adopted in other industries—users of AdvancedTCA equipment in the telecommunications industry have implemented IPMI. A combination of the IPMI management software and a generic interface called HPI (Hardware Platform Interface) provides a wealth of standardized software for monitoring the hardware in question and predicting early hardware failures.

For applications that do not require real-time performance or that are more limited in their performance requirements, desktop-style motherboards with a comprehensive set of I/O capabilities that meet the application requirements, such as imaging, might be sufficient. To address all of these applications, a good response to the I/O requirements plus the right choice of performance levels and different board designs are required.



Figure 4. Radisys Procelerant Z500 85mm x 70mm Board Compatible with Type 2 COM Express Pinout

Beyond that, these applications also require long-term availability of components, both to satisfy regulatory requirements and to support long operational lifetimes and product lifecycles.

Embedded Motherboards and COM Express Modules for PC Applications

PC-style applications in a medical environment can take advantage of the lower cost of high-volume, standardized hardware, while also benefiting from the wealth of applications that already exist for this architecture.

On the other hand, in applications such as the ones mentioned, there are additional requirements. First, the device must be future-proof. This can be achieved by using off-the-shelf components that offer long life and are robust. Products sold as 'Embedded Motherboards' by suppliers such as Radisys meet these requirements. Medical device manufacturers can implement extra functions that are required in the medical arena such as opto-decoupling of network connections through the addition of external devices. The additional cost of the external devices should be balanced by the economies of scale obtained by using a standard embedded motherboard, and should produce in total a more economical solution than the development and manufacture of a fully customized solution with all functions integrated in a single device.

Another option, however, is to place the non-standard components on a separate, custom carrier card and consolidate standard functions on a compute module mounted on this card. As a PICMG standard, the COM Express architecture is a good fit for this requirement. It offers the flexibility of a modular PC architecture together with long-term supply, and the peace of mind offered by the availability of multiple vendors supporting the standard. What is more, use of COM Express modules in other applications will drive up volumes, increasing the manufacturer's purchasing power and lowering system cost.

Such a modular design allows for the definition of external interfaces and their characteristics, such as opto-decoupling, protection areas, special formats and mounting, exactly according to the needs of the housing and application, while still making use of standard components. This speeds time to market, enables better scaling of the application and supports a differentiated, marketable design.

Indeed, mobile applications have been shown to be well suited to the standardized I/O of COM Express. The footprint sizes for COM Express modules have, however, proved to be too large for mobile devices. While the 95mm x 95mm form factor looks set to become part of the next generation of COM Express standards, this still appears to be too large for mobile applications, particularly for hand-held equipment. Several vendors, including Radisys, have therefore defined a smaller footprint module that maintains compatibility with COM Express signals and connectors. Some have chosen to follow the COM Express Type 1 specification, while others opted for Type 2 as the more versatile and future-proof option.

The reduced sizes also need to be considered when thinking of the future: additional functions, memory sizes and chipset real estate need to be matched to the quest for small size. In an attempt to balance these various trade-offs, Radisys has settled on a size of 85mm x 70mm, while maintaining COM Express Type 2 compatibility for optimal memory size and I/O capabilities.

Custom Design Where Needed, Standards Where Possible in Mobile Applications

Mobile applications encompass many different functions ranging from portable patient monitors to portable ultrasound devices to MCAs. All need certain common functionality based on PC technology, but each is different in its build and set-up. For a few very high-volume applications, the small extra cost of using a modular solution can be avoided by creating a full custom product. This is a business decision that should be taken with the support of a reliable supplier that has proven experience in the market in question.

Modular design, on the other hand, offers the security of scalability and provision for future upgrades to the compute module, while giving the flexibility of an application-specific carrier card. Because the carrier card has lower overall complexity in design and build, the overall cost for this solution is offset by the lower cost for this customized part. The core intellectual property remains in the manufacturer's carrier board design and so is protected. Should future volumes grow significantly, this proven design can be quickly turned into a full custom solution to further save cost.

Some solutions, however, need to follow a middle road between these two extremes. To support these, there is the option of a fairly complete but small motherboard paired with a custom extension card that holds application-specific I/O. Solutions like this available to the market today offer improved functionality while retaining flexibility. Another application for this custom card may be to create a docking station for the handheld device so data can be easily exchanged or uploaded to a server system.

All handheld devices, beyond being small enough to be held in the hand or at least carried, require batteries and monitoring functions that notify the user not just that the battery is empty now, but that it is time to re-charge or connect to mains in order to avoid data losses. Readily available modules that support this should be available from the module manufacturer.

Looking to the Future of the Medical Device Market

The medical market has many unique requirements that make it a specialized business area. Several companies have many years of experience in this industry as well as product portfolios that appeal to other markets as well as medical.

Companies such as Radisys take great care over component selection and qualification to ensure the products they ship into the embedded and medical markets are both available for many years, and also operate extremely reliably in the field. This high quality comes at a small premium, but gives medical device manufacturers a building block that will be supported in the long term, and that will provide long operational lifetimes.

Standards-based solutions such as COM Express and Embedded Servers enable Medical Device Manufacturers to take advantage of readily-available, advanced technology, while keeping their promises to their end customers, who rely on them to support their goal of providing the very best in medical care to their patients.

The Radisys logo consists of the word "radisys" in a lowercase, sans-serif font, with a registered trademark symbol (®) to the right. The text is white and is set against a dark red rectangular background.

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