WHITE PAPER

Texas Instruments

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See the difference: DSPs in medical imaging

Introduction

Although Texas Instruments (TI) is a leading semiconductor company and the world leader in digital signal processors (DSPs), the company is also a leading semiconductor supplier to the medical market.

TI is no stranger to the world of medical imaging. Over the years, TI has shipped DSPs into magnetic resonance imaging (MRI), digital X-ray, ultrasound and computed tomography (CT) systems, performing everything from motor control functions to complex image formation.

Just as they have played a key role in advancing industries such as PCs, cellular telecommunications and automotive, DSPs are playing an increasingly important role advancing medical imaging to provide faster, more accurate diagnoses and treatment. The traditional imaging modalities continue to evolve from mere diagnostic machines to key equipment that helps revolutionize surgical procedures and therapeutic treatment, both of which require real-time processing, a specialty of DSPs.

DSPs help make innovative medical equipment that is more flexible, affordable and accessible, helping to revolutionize health care in the 21st century and beyond.

This white paper provides an overview of DSPs' role in medical imaging today and tomorrow. It discusses various families of DSPs, such as multicore, and lists their advantages over other types of devices, such as field programmable gate arrays (FPGAs).

This paper also presents some examples of TI DSPs used in medical imaging applications and discusses how the company is using its expertise and experience in military, cellular networking and automotive applications to further advance the field of medical imaging.

State of the art – today and tomorrow

Medical imaging is continually evolving and advancing to improve patient care. Here are some examples.

The migration of X-rays from film to digital files – Thanks to digital signal processing, X-ray signals now can be converted to digital images at the point of acquisition, with no trade-offs in image clarity. Digital files have a variety of benefits, including eliminating the time and cost to process film.

The ability to render images in real time has led to the use of digital X-ray machines in surgical procedures, allowing doctors to view a precise image at the exact time of surgery.

The evolution of MRIs to real-time functional – DSPs' real-time processing can play a key role in the evolution of MRIs into fast, highly detailed imaging machines, leading to more accurate diagnoses and more effective treatment. With increased processing capabilities, the DSP can help enable functional MRIs, which are able to rapidly scan the brain, measuring signal changes due to neural activity. These very specific images provide researchers with deeper insights into how the brain works – insights that can be used to improve treatment.

The portability of ultrasound – Over the past decade, ultrasound equipment has steadily become more compact, with cart-based systems increasingly complemented by portable – and now handheld – units. For portable medical imaging applications, DSPs' low power consumption maximizes battery life while minimizing both battery and product size.

Portability makes ultrasound practical for a wider variety of applications, including bringing health care to rural and remote areas, disaster sites, patient rooms in hospitals, assisted-living facilities and even ambulances. Portability is creating a paradigm shift that allows health care professionals to bring advanced care to the patient instead of forcing the patient to travel to a diagnostic facility.

The DSP-enabled reduction in size and cost will eventually enable a wide variety of home-based health care applications, such as home dermatology. Bringing new methods of health care into the home can improve care for people who otherwise might be unwilling or unable to visit a doctor, empowering them to identify problems early on, before a condition becomes irreversible.

The future of health care – Today's research will improve health care even further over the next decade, with DSP-based imaging continuing to play a key role. DSPs will not only help revolutionize the well-known modalities mentioned previously, but will enable completely new medical applications that border on the edge of science fiction.

One example is from an Israeli company, CNOGA[1] , whose technology uses a video camera to non-invasively measure vital signs such as blood pressure, pulse rate, and blood oxygen and carbon dioxide levels simply by focusing on the person's skin. Future versions of the technology may be able to identify biomarkers for diseases such as cancer and chronic obstructive pulmonary disease, as well as recommend the proper makeup to go with a person's skin complexion.

Another application is high-intensity focused ultrasound (HIFU). This technology is part of a trend in health care to reduce the impact of procedures by minimizing incision size, recovery time, hospital stays and infection risk. But unlike many other aspects of this trend, such as robot-assisted surgery, HIFU goes a step further to enable a non-invasive option for many procedures currently done invasively.

HIFU focuses ultrasound waves in such a manner that they can be used to cauterize bleeding or destroy a tumor – turning the previously diagnostic imaging modality of ultrasound into a therapeutic modality. HIFU includes transrectal ultrasound[2], which is used to destroy prostate cancer cells without damaging surrounding healthy tissue. Another potential use of HIFU is to melt fat, so it's a potential fit for a wide variety of procedures, including cosmetic ones.

The pace of innovation – Despite these advances, medical imaging hasn't evolved as fast or as far as many other industries where semiconductors play key roles. One example is cell phones: Over the past 15 years, they've evolved from brick-sized, voice-only devices to units smaller than a deck of cards capable of TV-quality video and broadband faster than many DSL modems.

Fifteen years ago, a PC with a 1-GB hard drive and 100-MHz processor was considered state-of-the-art. Today, processors four times as fast are common in smartphones, while MP3 players have from eight to 120 times the memory. These hardware advances have enabled a wider range of applications – from streaming HD-quality video to 3-D rendering of geological data – than anyone could have imagined 15 years ago.

Why have cell phones and computers advanced so much faster than medical technology over this period? Part of the reason is because technology companies have focused their attention on these areas and helped advance the technology through investment, research and development, including dedicating entire businesses to look at these markets. In the meantime, medical imaging companies were usually left without dedicated support from vendors who had very little understanding in their area.

But this will change now that Texas Instruments, which helped enable the PC and wireless revolutions, has made medical imaging a company-wide focus. With a dedicated business unit, complete with an applications team and worldwide support, TI is directing more and more of its semiconductor resources and expertise toward medical imaging.

TI's goal in the medical imaging arena is to advance the state of medical imaging and improve health care throughout the world. A key component in the technology that will improve medical imaging is the DSP.

Why DSPs?

DSPs are embedded processors that are ideal for much of the processing necessary in medical imaging applications. TI has a broad portfolio of more than 15 DSPs for the medical imaging space. These processors can be grouped into three categories: single core, multicore and systems-on-chip (SoC).

DSP SoCs have all of the parts needed for the application, including appropriate acceleration, heterogeneous CPU architectures to support multiple application areas, and appropriate high-speed I/O to allow peripherals to be connected gluelessly. From a design perspective, one benefit of DSP SoCs is that it's easier to tweak performance and power consumption to meet the requirements of not only the application, but also cost, time to market and non-recurring engineering (NRE) budgets.

Multicore DSPs are an increasingly popular choice not only for medical imaging applications, but also for products ranging from smartphones to cellular base stations. This wide adoption is one reason why multicore design is more powerful and more efficient than single-core devices. As workloads increase, simply increasing a DSP's megahertz is no longer a viable solution because of the power required and the heat produced.

For example, if a system requires 3-GHz worth of DSP performance, a device that has three 1-GHz DSP cores in a single package will be more attractive than a single 3-GHz DSP core from a power, price, heat and yield perspective. A multicore design can more easily meet both power and high-performance targets. In fact, that balance of power and efficiency is a major reason why multicore DSPs are widely used in processing-intensive applications such as cellular network infrastructures.

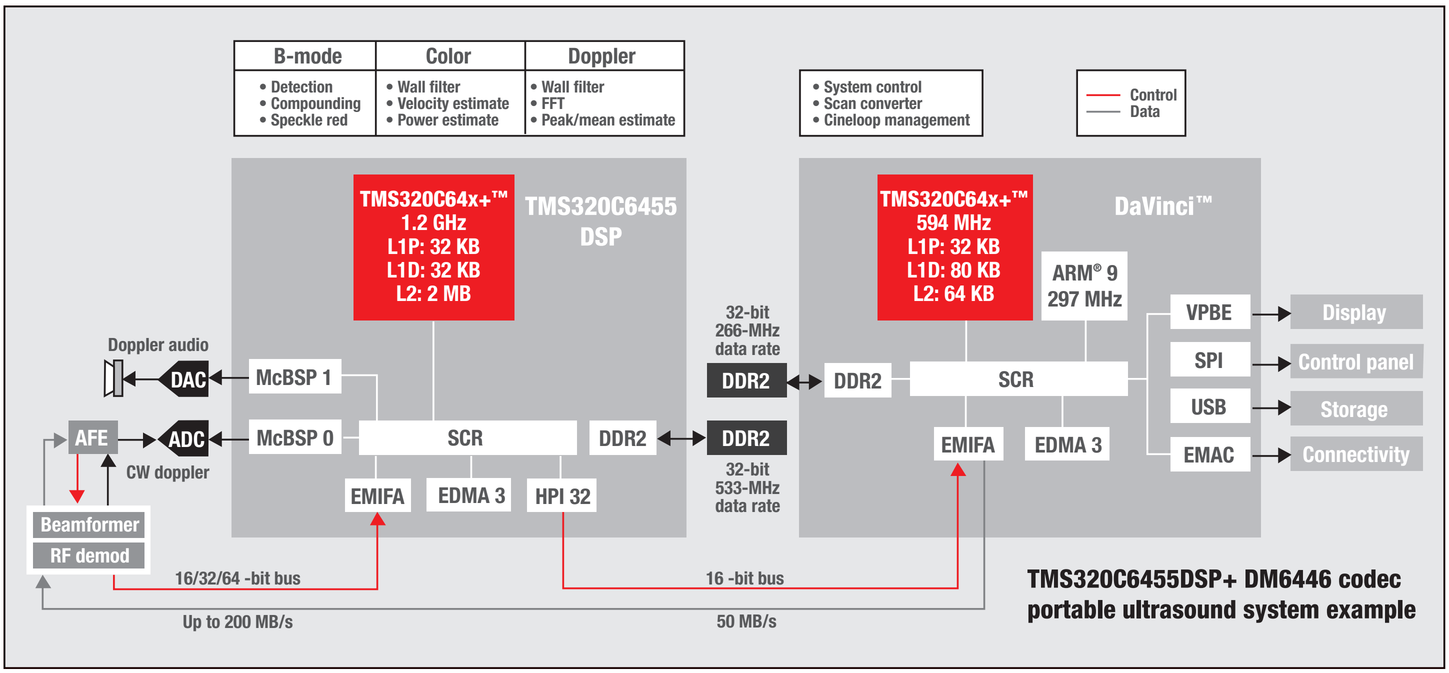
Another power-reduction technique for high-performance DSPs is TI's SmartReflex™ technology, which decreases both static and dynamic power consumption while maintaining the specified device performance. SmartReflex technology considers factors such as device-specific silicon characteristics based on the manufacturing process, as well as thermal parameters. This design effectively reduces power within the DSP while maintaining performance targets. TI DSPs that include SmartReflex silicon have proven their performance in years of processing-intensive applications such as cellular network infrastructures.

As DSPs become more powerful, they're able to efficiently take on tasks that once required adjunct components, such as general-purpose processors, reduced instruction set computer (RISC) processors and FPGAs. The latest multicore DSPs – such as the TMS320C6474 – have enough horsepower to shoulder medical imaging tasks, such as complex image formation, that previously required application-specific integrated circuits (ASICs) to be done cost-effectively.

However, with the large development costs and inflexibility of ASICs, many equipment manufacturers are finding DSPs a much more desirable solution in the medical imaging space, a market that generally deals in volumes small enough to make ASIC development prohibitively expensive.

DSPs can also reduce the role of power-hungry FPGAs and CPUs in medical imaging equipment, often replacing them altogether and helping system designers meet efficiency requirements, which are increasingly stringent for medical imaging devices designed for portable or handheld use.

For example, the TMS320C6455, one of TI's high-performance DSPs, and the TMS320DM6446, one of TI's SoCs, can be used together to perform all of the processing required in the back end of a portable ultrasound system. The C6455 can handle all of the B-mode, color and Doppler processing, while the DM6446 handles system control, scan conversion and cineloop management by utilizing its specialized video and audio drivers. This combination, shown below, greatly reduces system cost and power over FPGA and CPU designs.



TMS320C6455DSP+ DM6446 codec portable ultrasound system example

Advantages of DSPs for medical image processing

Over the past several years, technological advances in medical imaging have produced a number of accomplishments, including faster, more accurate diagnoses and more practical and cost-effective health care brought directly to patients.

Embedded processors are playing a key role in many of these advances – not just today, but tomorrow, too. That's because unlike ASICs and FPGAs, embedded processors are inherently flexible, programmable devices, so they can be upgraded in the field with the latest software and algorithms. Devices such as TI's low-power OMAP™ and DaVinci™ processor families also deliver significantly more performance versus power compared to FPGAs when considering a complete system.

Embedded processors have three key requirements when used in demanding, critical applications such as medical imaging:

- **They must perform in real time,** which means immediate bootup, no delays in displaying images, and no freezing or hourglasses after changing functions or parameters. Examples of real-time applications include a video camera on the end of an intubator used in an ambulance to send images to the hospital while the patient is en route, and digital X-ray systems increasingly used during surgery.
- **They must be highly reliable,** which includes components that don't fail even after years of rough handling in the field; the ability to recover quickly from failures due to software bugs; and immunity to electromagnetic interference. Reliability directly affects the system's total cost of ownership (TCO) for end users such as hospitals and physician groups. By the same token, reliability and TCO also directly affect the brand reputation and competitive position of imaging system vendors.
- **They must be energy-efficient, compact and as affordable as possible,** all of which directly affect the level of patient care. For example, when embedded processors enable portable, energy-efficient imaging devices such as mobile ultrasound systems, they in turn enable faster, more accurate diagnoses in applications such as home health, first responder and trauma/triage. Treatment decisions can be made at the point of care, improving the overall speed and effectiveness with which treatment is delivered.

Affordability, meanwhile, means that state-of-the-art care can be extended to more people, such as residents of developing countries. Finally, compact size and low power consumption also enable handheld devices that, for example, dermatologists can use to identify precancerous moles on darkly pigmented skin – in a home health care setting, if need be.

Enabling new image modalities and future flexibility – Embedded processors are playing a key role in developing new imaging modalities. Advanced techniques such as vein viewing, tissue elasticity, optical coherence tomography (OCT) and 3-D/4-D imaging all leverage the inherent capabilities of high-performance, low-power devices:

- New algorithms developed on embedded processors enable tissue elasticity images to adapt to each patient in real time, delivering optimal diagnostics.
- New modality OCT uses light waves for direct imaging of tissue morphology at a near-microscopic resolution. Useful in early cancer detection, ophthalmology and surgical guidance, OCT requires the real-time, computationally intensive processing available from embedded processors.
- For 3-D/4-D imaging, embedded processors improve the richness of 3-D fetal modeling for clinical analysis while enabling effective 4-D cardiovascular applications.

Embedded processors also allow end users such as hospitals and physician groups to capitalize on new software and algorithms that universities, programmers and R&D centers are developing to improve diagnostic image clarity, depth and functionality. For clinicians and patients, improved images equal better diagnoses and care.

Equipment vendors also benefit because the ability to field-upgrade machines makes their products more attractive to potential customers by providing a certain level of future-proofing, as well as improving machine functionality. For system designers, the key is to select embedded processors that are powerful enough to support tomorrow's ever-greater processing-intensive algorithms.

TI embedded processors – TI offers a comprehensive portfolio of more than 15 DSPs for medical imaging applications. For the most computationally complex imaging applications, TI's high-performance multicore devices provide greater than 20 GMACs of computational processing. This enables newer, complex algorithms to run faster and lead to improved diagnoses.

TI's embedded processors are ideal for processing-intensive applications such as medical imaging. Their unmatched combination of low power and high performance makes them exceptional choices for a range of imaging applications, from handheld devices to real-time surgical imaging equipment.

These processors provide enhanced images and exceptional performance, yet they require very low power. Their efficient design enables equipment manufacturers to develop handheld and portable products with performance that once was available only with large, fixed machines.

Why TI: reliability and expertise

Developing DSPs that have the performance, reliability and efficiency necessary for medical imaging applications is no small task. Yet many of the underlying challenges – including designing for high reliability, high performance and low power – are ones that TI has been tackling for decades in industries such as telecom, military communications, and automotive. That experience has produced expertise that TI now brings to medical imaging, with a comprehensive portfolio of DSPs and related devices.

Conclusion: power to the patient

By enabling many advances in medical imaging, DSPs are making it more practical and cost-effective to bring health care to patients, instead of requiring patients to find time and transportation to medical facilities. They also help make health care more effective by providing ways to identify diseases and other conditions before they become untreatable.

TI is playing a key role in enabling these advances by leveraging its decades of expertise in industries such as telecom, where TI DSPs have produced devices capable of performing a wide variety of processing-intensive tasks in real time, with minimal power consumption and high reliability. By making medical imaging a major company focus, TI is leading the technical revolution that will greatly improve health care and medical imaging.

1. www.cnoga.com
2. www.prostrate-cancer.org/education/novelthr/Chinn_TransrectalHIFU.html