WHITE PAPER

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Creating solutions for health through technology innovation

TI technology helps medical system developers implement new ways of delivering medical care and wellness

Introduction

Medical care provides a diverse growth opportunity for designers and manufacturers of electronic systems. The growth is fueled by new discoveries, the need to contain treatment costs and enhance diagnostics, and the increasing number of people who are demanding affordable medical care.

TI offers leadership in low-power, high-performance integrated circuit (IC) technologies that meet a wide range of medical application requirements. TI technology includes analog bipolar, with its extreme accuracy for signal measurement; CMOS for extremely low-power logic, processing and mixed-signal functions; plus FRAMs, radio transmission and small-scale packaging options.

Health care is advancing rapidly around the world, driven by new medical discoveries and ongoing demographic and economic changes. Industrial countries are experiencing an aging population, while countries in development are demanding better basic health care to match their newly won prosperity. At the same time, new tests, procedures and medicines make medical care increasingly expensive, forcing the containment of costs even while overall effectiveness improves. In addition, better-informed patients now demand to know more about their health and the treatment they receive, and they are backed by legislative initiatives to make medical data more readily available. All of these factors underline the need for more cost-efficient, more therapeutically effective means of delivering health care.

Electronic systems have an important role to play in meeting all these expectations. New developments in IC manufacturing and design help make medical systems smaller, more power efficient, more accurate, less expensive and more easily integrated into information networks. The result is that the entire health care chain —ranging from hospitals, labs and emergency vehicles, to physicians' offices and clinics, homes and even wearable devices — can provide more effective diagnosis, monitoring and treatment of patient conditions (Figure 1). Combined with social, political and economic trends, advances in electronics technology are rapidly changing the practice of medicine to make quality health care more affordable and better tailored to the needs of the individual patient.

Among the many companies whose innovations are driving these changes is Texas Instruments. TI's analog, digital and mixed-signal processes supply leadership high-resolution and low-power components that enable a wide variety of medical equipments. Applications ranging from state-of-the-art imaging machines in medical labs, to inexpensive over-the-counter kits for blood pressure and glucose monitoring are benefitting from TI product advancements.

Figure 1. *Healthcare trends and opportunities*

TI has a long history of developing the technology needed for medical equipment designs. Since the mid-1980s the company has created low-power digital signal processors (DSPs) that were used to implement major advances in hearing aids. TI's long-term experience with wireless technology, including early leadership in the digital cellular revolution, contributes to in-depth expertise in applications used for network transmissions in hospitals and personal medical technology. Solutions also include a variety of packaging options that can are used to make medical equipments smaller, lighter-weight and better protected.

Technology extends medical practice

The overall market for medical electronics varies from equipments found in labs and hospital wings, to doctors' offices, and finally to the home. These systems range from being large, stationary, low-volume and costly, to being increasingly small, portable, high-volume and affordable. At the personal end of the care spectrum, some devices that are wearable are beginning to emerge, such as wristbands for example, which are as lightweight and inexpensive as possible. In a group apart, and different from other small systems, are implants such as pacemakers, which are neither inexpensive nor consumer-selected; nevertheless, they do represent the ultimate in portability.

Extending throughout all of these application areas is the need for network communications, frequently wireless, to report on readings and aid in diagnostics and treatment. Dubbed e-health/telehealth or telemedicine, depending on the emphasis of the application as preventive or curative, wireless network communications are rapidly becoming

an essential part of medical practice (Figure 2). Telehealth enables the continual monitoring of patients' conditions, wherever they may be, helping to gather data for a more complete medical profile and thus enabling physicians to personalize treatment and make it more proactive. Telemedicine has many uses, not least of which is that it allows medical establishments to gather more complete data, run more sophisticated analyses, and consult more effectively to obtain better diagnoses.

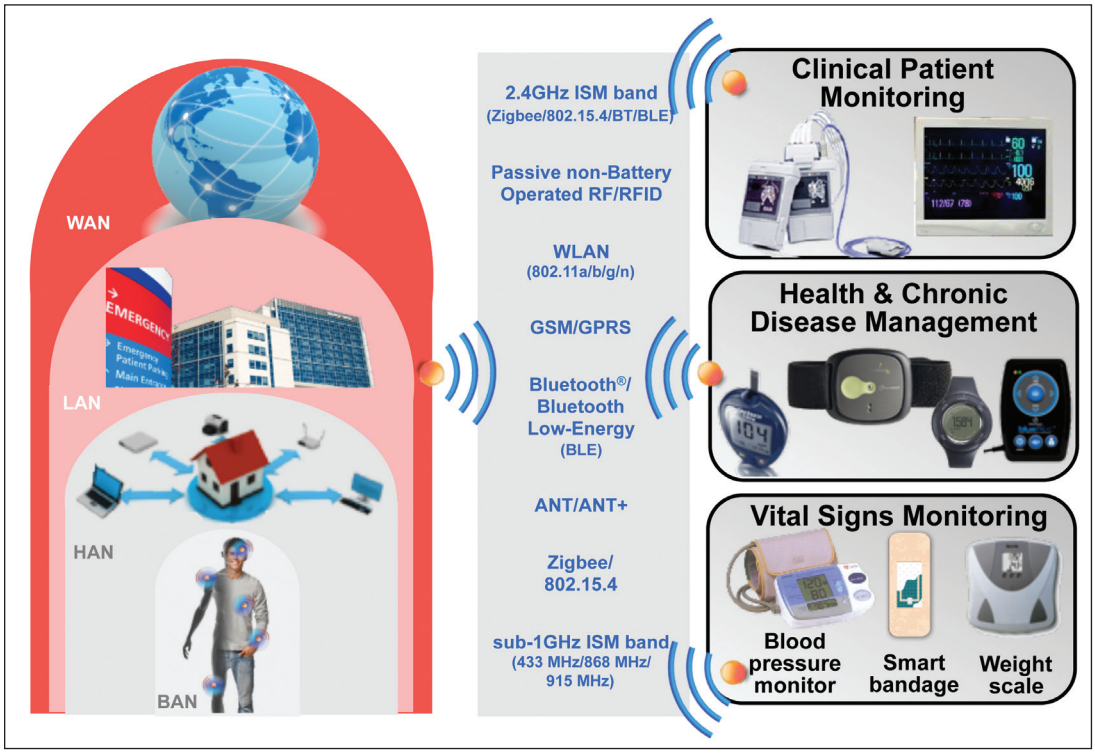

Figure 2. *Telehealth applications and technologies*

At present, various media, transmission and security standards for these networks are being employed, while still other standards are emerging. TI participates actively in standards organizations and develops ICs that support a variety of specifications, helping to enable the best networking solutions to emerge.

The accompanying table (Figure 3) lists some of the many design opportunities in medical equipments, ranging from applications available to consumers, through systems commonly used in medical offices and hospital rooms, to equipment used in medical test centers and labs. Medical imaging, listed as its own category, is in the vanguard of diagnostics and offers some of the greatest challenges to equipment designers.

Consumer medical devices	Diagnostic, patient monitoring and therapy	Medical imaging	Medical instruments
Digital thermometers	Electrocardiogram (ECG)	Ultrasound	Laboratory equipment
Blood glucose monitor	Electroencephalogram (EEG)	Computer tomography (CT)	Dialysis machines
Blood pressure monitor	Blood oxygen (pulse oximeter)	Magnetic resonance (MRI)	Analytical instruments
Insulin pumps	Blood pressure	X-ray	Surgical instruments
Heart rate monitors	Temperature	Positron emission tomography (PET)	Dental instruments
Audiology (digital hearing aids)	Ventilation/respiration	Nuclear	
	Defibrillators		
	Implantable devices		
e-Heath/Telehealth	**<----------> Telemedicine**		

Figure 3. *A wide range of design opportunities exist for medical end equipments and applications*

Technology requirements and process capabilities

With such a wide range of equipment under consideration, the requirements for individual systems vary extensively. However, certain applications push IC technology to the limit. For instance, imaging systems and diagnostic equipments such as EEG and ECG require extremely accurate sensing. In these cases, the IC manufacturing process used must offer exceptional performance to provide a high degree of accuracy. Other types of advanced systems demand the most of other process capabilities, such as extremely low power consumption in cardiac pacemakers and other body implants.

An ultrasound machine offers a good example of the performance requirements for high-end systems. The analog front end (AFE) has to read signals from its transducer input that may vary by up to 100 decibels. Within this large dynamic range, the signal converters must maintain high signal response at the low end, while performing with good linearity at the high end. The size of the circuitry used is also important, because the more channels that can be fit into the same space, the more resolution the image will have. Thus, a significant level of integration is needed, but with an extremely low noise level for optimum performance. Typically, bipolar amplifiers can best meet the combined requirements of low noise and good dynamic range, while still keeping power consumption low. Silicon-on-insulator (SOI) technology is also required, due to the high voltage and current needed by the transducers and the severe requirements on rise and fall times.

TI's leadership in analog manufacturing processes enables the company to develop superior solutions for high-end imaging and diagnostic systems that can meet such requirements. For instance, TI's ADS1298 analog-to-digital converter, based on a bipolar manufacturing process, provides eight conversion channels with 24-bit resolution. Used in an eight-lead ECG machine, the ADS1299 ADC provides a single-chip solution for designs that formerly required approximately 50 components. The ADS1299 ADC pushes accuracy even farther with the industry's lowest noise in this type of device.

In contrast to high-end imaging and diagnostics, devices such as cardiac pacemakers that are placed inside a human body are required to operate for years with a limited power supply. Such applications need to detect physiological signals from the body, process and store the signals, and often communicate via low-power radio to base units outside the body. Typically, these devices are active only for very short periods, often less than one percent of the time, then asleep for the rest of the time. Bandwidths and sampling frequencies for the data converters can be limited to the low kilohertz range, since most body signals are of low frequency.

Mixed-signal ICs that combine extremely low CMOS power and bipolar performance on a single device are a natural choice for these types of systems. Two factors that must be built into a mixed-signal process used in such applications are a low off-state leakage current, to minimize power loss during the long quiescent periods of the system, and a low-power, non-volatile memory that is both reliable and compact. In addition, both the die and the packaging used must be as compact as possible to keep the system size to a minimum, and both must be rigorously qualified in testing. Only an IC vendor with low-power mixed-signal design and manufacturing expertise is in a position to supply such devices.

A broad portfolio of solutions

While the high-end systems used in hospitals may push IC technical specifications, over-the-counter products, too, have strict requirements of cost and size. For instance, an armband that can monitor blood pressure and pulse has to be small and affordable, while at the same time draining very little power from a battery. The same device may also require a low-power transmitter to communicate with, say, the user's smartphone, which can display the readings and relay them to a centralized health system. Industrial versions of these same types of equipments are already saving lives as stress monitors in the uniforms of fire fighters and soldiers, where the wireless transmission of stress readings enables a command center to withdraw individuals from the scene of action if they are on the verge of collapse.

These kinds of high-volume personal systems require technologies that keep power consumption to a minimum while providing the necessary sensing, processing and transmission in a small form-factor solution that is inexpensive. TI's wide-ranging analog technologies include low-power data converters for sensing, and power management functions that maximize battery usage. Advanced mixed-signal processes allow these and other analog functions to be integrated along with low-power CMOS logic. Additionally, dense ferroelectric memories (FRAMs) offer an attractive non-volatile memory choice for many applications, providing fast, RAM-like write speeds, low voltage, low-power write operation, high cycling endurance lifetime and architectural flexibility.

For processing, highly integrated TI MSP430™ microcontrollers (MCUs) offer the industry's lowest-power family of options for 16-bit control. These devices are widely used in small-footprint systems that need to operate off a battery charge for a prolonged period, with applications ranging throughout the medical field and beyond. For instance, an MSP430 MCU with integrated system-level functions provides a single-chip solution for a lightweight over-the-counter device that monitors blood glucose. In the future, as energy harvesting from body motion and temperature become increasingly important for powering personal medical devices, TI's MSP430 MCUs will offer excellent solutions for system control.

TI's power-conserving RF solutions support home-area and body-area networks for a wide range of transmission standards. Frequently, wearable monitors must report to a body-area central system, for which the patient's smartphone offers a reasonable option. Not only can the phone relay messages to a remote medical system for processing and to inform physicians and emergency medical personnel, but it can also display data from the monitor readings and receive health messages from the remote system. TI's extensive offerings for wireless phones provide a natural platform for building health information networks such as these.

For most products, TI design technologies support ease of customization when volumes justify an application-specific solution. When single-chip integration is not optimal, either for technical reasons or cost, multichip modules (MCMs) can save space, especially when the dies are stacked. TI offers MCM options, along with more conventional packages and other advanced options such as bare chips for in-board mounting. The company also keeps abreast of new developments such as flexible packaging that will be of interest to medical electronics manufacturers.

Conclusion

The health care industry is on the verge of revolutionary changes enabled in part by advanced electronics. To make wellness more widely available and affordable without compromising quality is a major challenge. Fortunately, advanced IC technology is creating solutions that can help make medical systems more accurate and easier to use while communicating information more effectively. TI's in-depth expertise in IC manufacturing processes that lower power consumption and increase performance make the company a leader in providing these solutions. As the world increasingly turns to its medical community for the promise of health and well being, TI provides innovative technology that helps make the fulfillment of this promise possible.

For more information, visit www.ti.com/innovation_medical.

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