Intelligent Mixed Signal FPGAs in Portable Medical Devices

Overview

Home-based and consumer medical devices have traditionally been used for testing and monitoring. Examples of these devices include digital blood pressure meters, blood gas meters, and blood glucose meters. Today, medical devices are expected to do much more than just testing and monitoring. Some are now capable of logging and analyzing data as well as communicating accurate results to the health provider. Blood pressure meters are now benefiting from a more extensive data logging feature as well as communication ports for real-time sharing of information with the health provider. Insulin meters are now equipped with communication ports (IR/wireless) to transfer real-time measurement to the PC or to the insulin pump to effectively treat the disease. In the most basic form, portable medical devices are all battery-operated, microcontrolled handheld devices that take and analyze measurements using various bio-sensors that are used in a patient's treatment plan.

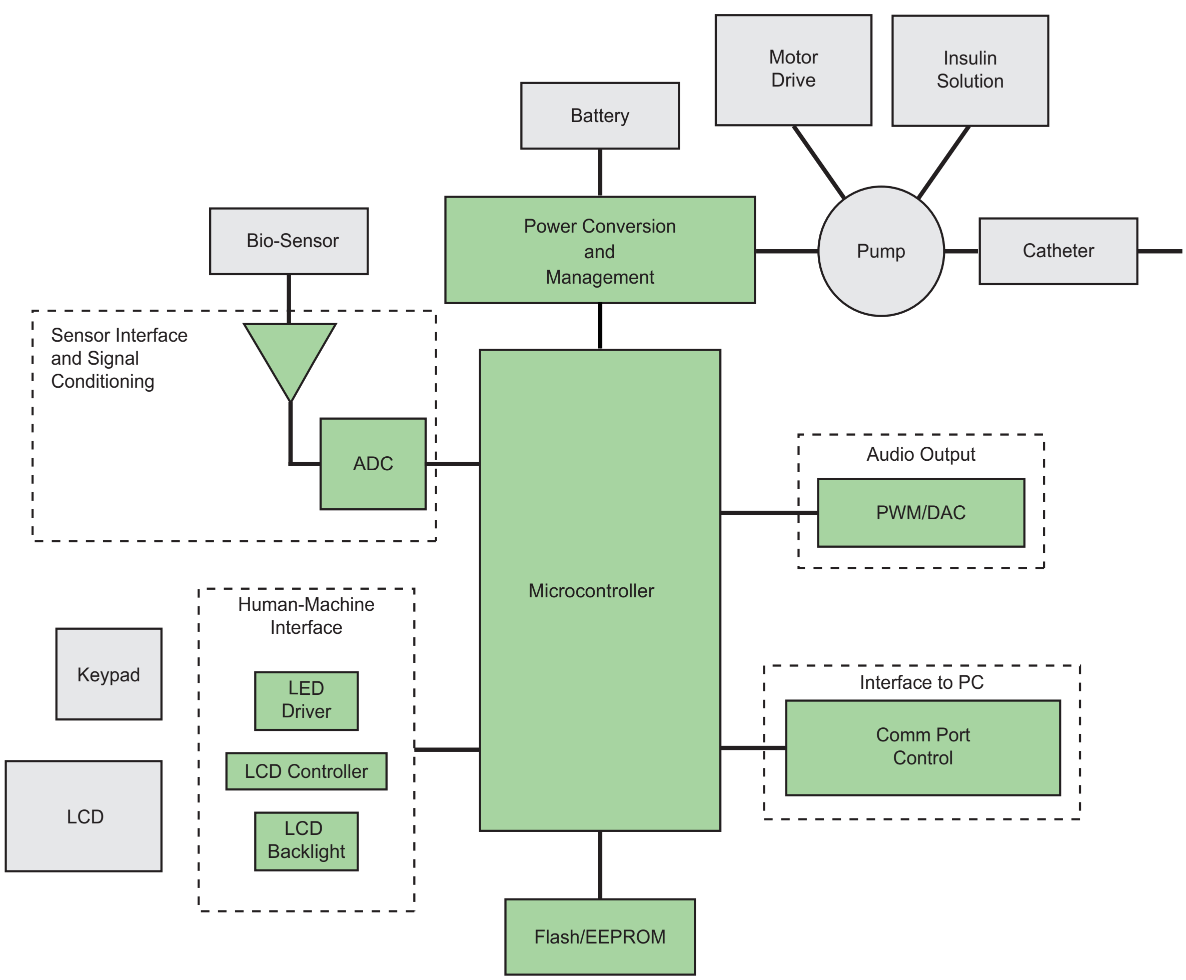

Figure 1 • **Block Diagram of Insulin Pump**

There are several functional blocks that are common to most portable home-based and consumer medical devices:

- Bio-sensor(s)
- Amplification and analog-to-digital conversion of the sensor input
- Power management: system power control and power sequencing
- Microcontroller: low power operation and control
- User interface: display
- Human machine interface (HMI): keypads, scroll wheels, buttons, and switches

Additional requirements may drive needs for

- Storage: interface to multiple standards
- Interfaces: wireless and wired
- Audio feedback or notification

A key design consideration for portable medical devices is low power consumption driven by the need for extended battery life. Other requirements are faster time-to-market, low cost, reliability, small form factors, and above all integration. Microsemi SoC Group SmartFusion™ intelligent mixed signal FPGAs are the key in achieving these goals. The functional blocks in green in Figure 1 on page 1 represent some of the functions that can be implemented in SmartFusion devices—the only devices that integrate an FPGA fabric, ARM® Cortex™-M3, and configurable analog, offering full customization, IP protection, and ease-of-use. Along with a microcontroller (MCU), FPGA fabric, and configurable analog, SmartFusion FPGAs integrate substantial flash and SRAM memory plus comprehensive clock generation and management circuitry. The SmartFusion architecture enables data storage and execution of code from within a single monolithic device. Based on the proprietary flash process of the Microsemi SoC Products Group, SmartFusion FPGAs deliver a true system-on-chip (SoC) solution that gives more flexibility than traditional fixed-function microcontrollers.

SmartFusion FPGA's as a Platform for Portable Medical Devices

SmartFusion FPGAs combine all the features that designers of portable medical devices require into a single chip, creating a true programmable SoC solution.

The Processor Core

At the heart of a SmartFusion device is an embedded ARM Cortex-M3 processor core. With its hardware multiplier and divider, this 32-bit RISC processor delivers high performance: about 125 Dhrystone MIPS.

Surrounding the Cortex-M3 core are a number of integrated peripherals: SPI, I^2C, and UART serial ports, up to 512 KB of embedded FlashROM (EFROM), 10/100 Ethernet MAC, timers, phase-locked loops (PLLs), oscillators, real-time counters (RTCs), and peripheral DMA controller (PDMA). The processor and its peripherals are interconnected via a multi-layer advanced high-performance bus (AHB) matrix (referred to as ABM). The ABM also provides the path for the processor and its peripherals to communicate with both the FPGA fabric and embedded analog functions.

Programmable Analog

Portable medical designs must interface directly with various bio-sensors.The programmable analog section or analog front-end (AFE) of a SmartFusion device contains the needed elements such as analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), along with more advanced features.

Each SmartFusion device contains up to three 12-bit successive approximation register (SAR) ADCs, capable of operating at 500 Ksps in 12 bit mode (550 ksps in 10-bit mode/ 600 ksps in 8-bit mode). To process signals in the other direction, each device comes equipped with one first-order, sigma-delta DAC per ADC, offering an effective 12 bits of resolution at 500 Ksps.

Further enhancing the functionality of the ADCs are up to five high-performance analog signal conditioning blocks (SCBs) per device. Each SCB comes packed with two high-voltage bipolar monitors (with 1% accuracy), a high-gain current monitor, a temperature monitor (with 0.25°C resolution), and two high-speed comparators.

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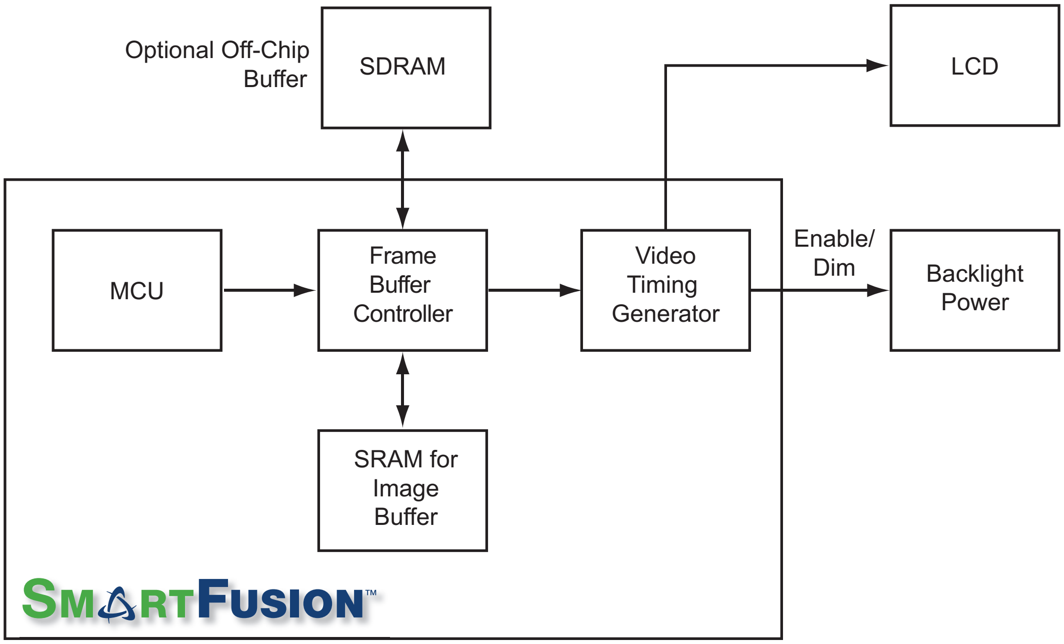

Figure 2 • **Simple LCD Controller**

You can view design examples for keypad control, brightness control for white LEDs, color mixing for RGB LEDs, and tone generation by the Microsemi SoC Products Group at http://www.actel.com/products/solutions/hmi/dcard.aspx#examples.

Sensor Interface and Signal Conditioning

The implementation of each functional block in medical devices differs depending on features such as sensing, processing, and information display demands of the device. Designers can choose from a myriad of sensors to capture and measure physical quantities such as temperature, pressure, brightness, position, speed, pH, gas concentration, level of chemicals in the blood, and time. These sensors transform the measurement into voltage, current, frequency, capacitance, or some other electrical quantity used for processing. Analog inputs from the above mentioned sensors can be processed by the embedded SCBs in the SmartFusion FPGA, then they are passed to the embedded ADC to translate the results to the digital domain for storage in the embedded SRAM blocks for further processing by the embedded controller.

Power Management and Motor Control

Power management is key to any portable device, monitoring batteries, and for controlling which peripherals are active at any given time. The SmartFusion mixed signal power manager (MPM) enables designers to integrate intelligent configurable power management with their own Cortex-M3 firmware and FPGA design using SmartFusion devices.

The SmartFusion MPM is capable of power-rail monitoring, power sequencing, closed-loop trimming, power-up and power-down control, and event data logging for up to 32 individual power supplies. Many portable medical devices need some sort of motor to either take samples or deliver therapy. SmartFusion FPGAs are uniquely suited to active motor control for permanent magnet motors, servo motors, series motors, separately excited motors, and alternating current induction motors.

A SmartFusion FPGA can actively manage multiple electric motors, including start and stop, control of rotational direction, speed and torque, protection against motor overloads or faults, and active control using closed loop performance algorithms.

Using the configurable analog available in SmartFusion FPGAs, the design can monitor motor performance in real-time with or without dedicated encoders, applying corrective control signals to maintain commanded direction, speed, torque and delivering precise motor position control.

Audio Output

Often a portable medical device needs to provide audio alerts, either to confirm data input, proper operation, or as a warning of an error condition. A small piezo can be driven by a PWM block constructed in the FPGA fabric or via one of the embedded DACs found in a SmartFusion FPGA.

Communication Interface

The ability to support multiple communication interface standards makes SmartFusion devices ideal for portable electronics, offering the benefits of rapid development, fast time-to-market, and integration. SmartFusion FPGA offer a wide range of embedded communication peripherals as a part of the microcontroller subsystem. Included are multiple I^2C interfaces, UARTs, and SPI ports, plus a 10/100 Ethernet MAC. If additional communication ports are needed, they can be implemented in the FPGA fabric, using the your own design or a variety of communication IP cores from Microsemi's SoC Products Group and its partners.

Storage

Storage technology has made tremendous progress in the last decade. The rapid advances and ready availability of small form-factor flash storage devices is driving the explosion of portable medical devices in the market place. SoC Products Group offer storage solutions that cover most of the hard drives and flash storage controllers for the portable market. As the storage device market proliferates, with ever changing protocols and interface standards, design teams are challenged to shrink design cycle times and yet create newer competing portable devices with additional features.

With the SmartFusion FPGA fabric, it is possible to implement a variety of storage functions without having to redesign the whole system based on changing storage interface requirements. SoC Products Group offers controllers for popular storage interface standards such as secure digital (SD), secure digital input/output (SDIO), microSD, MultiMediaCard (MMC), and consumer election-AT(CE-ATA), that are optimized for low power and suitable for the portable medical market.

Moreover, the SmartFusion microprocessor subsystem (MSS) contains an embedded external memory controller (EMC) used to interface with off-chip memory devices that can be addressed by the MSS or user logic in the FPGA fabric. The EMC provides a glueless interface to external memories, supporting both asynchronous memories and synchronous SRAMs. Also available to the embedded Cortex-M3 processor is up to 512 KB of flash memory and 64 KB of local SRAM, plus up to 24 4,608-bit SRAM blocks available in the FPGA fabric.

Microprocessor

Medical devices such as the insulin pump shown in Figure 1 on page 1 are typically controlled by a microprocessor. These microprocessors perform various functions, such as processing data from bio-sensors, storing measurements, and analyzing results. SmartFusion FPGAs make a high-performance 32-bit RISC processor available to the application. The embedded ARM Cortex-M3 processor core provides an unprecedented amount of processing power in a programmable device.

Conclusion

A well-designed, low power solution is an important part of portable medical devices. Clear displays, responsive controls, reliability, and simple operation contribute to better health care, greater product safety, and user satisfaction. SmartFusion FPGA, with its unique mix of a high-performance microcontroller, dense FPGA fabric, and programmable analog-all in a single package-delivers the ideal platform for these designs.

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