Designing Reliable, Secure, and Highly Integrated Medical Systems using SmartFusion® cSoC

Minal Sawant
Product Marketing Manager
Factors Affecting Medical Electronics

- Small Form Factor
- Portability
- Emerging Markets (India, China)
- Cost Reduction
- Low Power
- Evolving Standards and Regulations
- Virtual Care
- High End Imaging

Power Matters

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Top Three Challenges in Medical Electronics

- **Integration**
  - With increased functionality, ability for components to integrate, reducing BOM, board space and thus cost

- **Low power and small form factor**
  - Power becomes key in rural areas where continuous charging stations are not available
  - Portability dictates need for small form factor components

- **Reliability and security**
  - For decision-making equipment such as insulin pumps, ability of components to make reliable decisions
  - Anti-tampering and anti-counterfeiting is a must for secure operation
Microsemi: The Leader in Flash FPGAs

Microsemi’s competitive advantage is our unique flash-based technology.

- Founded in 1985
- The only flash-based FPGA company
- Leader in antifuse, radiation tolerant devices
- Leader in flash-based low power and system critical FPGAs
- Only provider of cSoCs integrated with microcontroller and analog technologies
FPGA Fundamentals

- A field-programmable gate array (FPGA) is a programmable semiconductor device.
- The characteristics of an FPGA are primarily dictated by the technology used to make it programmable.

**Reprogrammable and volatile**
- **SRAM**
- **Flash**

**Reprogrammable and nonvolatile**
- **Antifuse**

**One-time-programmable and Nonvolatile**

Microsemi SOLUTIONS

Power Matters
Meeting the need for smaller & less power

- Power consumption as low as 2 µW
  - Flash logic cell leakage current much lower than conventional SRAM cell
  - No need for external EEPROM
  - Package size to 3mm x 3mm
Microsemi FPGAs Mitigate Risk of Radiation Effects

In Microsemi FPGAs high energy particles are **unable** to generate sufficient charge to cause the floating gate to erroneously change state.
Addressing Integration using ...
SmartFusion: Innovative Intelligent Integration

- Proven FPGA fabric
- Complete ARM® Cortex™-M3 MCU subsystem...& it’s ‘hard’
- Programmable analog
- In a flash-based device
- In production now!

**Offers full customization, IP protection and ease-of-use**
# The Microsemi Embedded Advantage

<table>
<thead>
<tr>
<th>Flash-based FPGA</th>
<th>SRAM-based FPGA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARM Cortex-M3 processor with its own embedded flash memory</strong></td>
<td><strong>CODE STORAGE</strong> Needs external flash memory</td>
</tr>
<tr>
<td><strong>On-chip nonvolatile FPGA configuration</strong></td>
<td><strong>CONFIGURATION</strong> Needs external configuration devices</td>
</tr>
<tr>
<td><strong>High-voltage analog co-exists with digital circuits</strong></td>
<td><strong>ANALOG</strong> Standard CMOS process not conducive to high voltage analog</td>
</tr>
</tbody>
</table>

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**Flash Technology Enables Innovative, Intelligent Integration**
An Inside Look at SmartFusion
No-Compromise FPGA Fabric

- **Proven flash-based FPGA fabric**
  - 60,000 to 500,000 system gates
  - 350 MHz system performance
  - Embedded SRAMs and FIFOs
  - Up to 128 FPGA IOs

- **Ultimate Differentiator**
  - Off load some often used or CPU intensive function into fabric
  - Add additional peripherals to meet design needs
No-Compromise Microcontroller Subsystem (MSS)

- 100 MHz 32-bit ARM Cortex-M3 processor
- Bus matrix with up to 16 Gbps throughput
- 10/100 Ethernet MAC
- SPI, I²C, UART, 32-bit Timers
- Up to 512 KB flash and 64 KB of SRAM
- External memory controller
- 8-channel DMA controller
- Up to 41 MSS I/Os
Programmable Analog

- Analog compute engine (ACE) offloads CPU from analog tasks
- Voltage, current and temp monitors
- 12-bit (SAR) ADCs @ up to 600 Ksps
- Sigma-Delta DACs
- Up to ten 15 ns high-speed comparators
- Up to 32 analog inputs and 3 outputs
Innovative Intelligent Integration
Why SmartFusion is a Smart Decision?
SmartFusion Benefits: **Integration**

Reliability
Power savings
Flexibility

Smaller footprint
Fewer vendors
Lower TCO

Actual SmartFusion Die
SmartFusion Benefits: Full Customization

- Build an SoC with exactly the features you need

- Easy design partitioning
  - For performance
  - For efficient silicon usage
  - For power management

- Innovate and differentiate in both software and hardware

- Extend product life
  - In-field upgrades
  - One platform for multiple products
Full Customization: Build an SoC with the features you need

SMARTFUSION™

- Microcontroller Subsystem
- Programmable Analog
- FPGA Fabric

Supervisor
- PLL
- OSC
- RC
- WDT
- 32 KHz
- RTC

ARM® Cortex™-M3
- JTAG
- NVIC
- SysTick
- SWD
- MPU

SCB
- Temp. Mon.
- Volt Mon. (ABPS)
- curr. Mon.
- Comparator

Analog Compute Engine
- Sample Sequencing Engine
- Post Processing Engine

IO Expansion
- Bus Interface

Proprietary Application

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SmartFusion Benefits: Unparalleled IP Protection

- **True nonvolatile single chip (FPGA+MCU+Analog)**
  - No bitstream communicated from external configuration device

- **FlashLock® technology**
  - Controls access to the security settings of the device
  - Used to lock the device with a 128-bit key
  - Device unlocked & reprogrammed by providing the same 128-bit key
  - Permanent lock is possible, which disables programming access

- **Physical design of the device**
  - Security key distributed throughout the device and below several metal layers
  - Very difficult to microprobe flash FPGAs

- **Data security**
  - IP cores available that provide AES or DES encryption or decryption of data
SmartFusion Prevents IP Theft in Manufacturing

Secured Manufacturing Flow

- 128-bit AES Encryption

- AES-encrypted programming file sent to manufacturer

- Devices pre-programmed with matching AES key sold direct to manufacturer

- Protection Against:
  - Overbuilding
  - Cloning
  - Reverse engineering
  - Tampering
# SmartFusion Family: Key Features

<table>
<thead>
<tr>
<th>Device</th>
<th>A2F060</th>
<th>A2F200</th>
<th>A2F500</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Gates (Kgates)</td>
<td>60</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>Tiles (D-flip-flops)</td>
<td>1,536</td>
<td>4,608</td>
<td>11,520</td>
</tr>
<tr>
<td>RAM Blocks (4,608 bits)</td>
<td>8</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>MSS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10/100 Ethernet MAC</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>eNVM</td>
<td>128K</td>
<td>256K</td>
<td>512K</td>
</tr>
<tr>
<td>eSRAM</td>
<td>16K</td>
<td>64K</td>
<td>64K</td>
</tr>
<tr>
<td>Analog Compute Engine (ACE)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ADCs (8-/10-/12-bit SAR)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>DACs (12-bit Sig-Del)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Comparators</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Current Monitors</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Temperature Monitors</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Bipolar HV Monitors</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Direct Analog Input</td>
<td>11</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Max. Total Analog Input</td>
<td>15</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Max. Total Analog Output</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Max. MSS I/O</td>
<td>28</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Max. FPGA I/O</td>
<td>68</td>
<td>94</td>
<td>128</td>
</tr>
<tr>
<td>Max. Total I/O</td>
<td>112</td>
<td>161</td>
<td>204</td>
</tr>
</tbody>
</table>

**MCU Sub-System (MSS)**

- **Analog Front End**
- **ProASIC3 Fabric**

**MSS Common to all Family Members**
- Cortex M3 (100MHz)
  - 2 – SPI
  - 2 – UART
  - 2 - I2C
  - 2 – 32-bit Timers
  - DMA
  - Watch Dog
  - RTC
  - External Memory Controller

**Availability:**
- Now: A2F200
- Now: A2F500
- Now: A2F060
SmartFusion: Software & Eco-System
SmartFusion Design Environment: Ease-Of-Use

- Full-featured traditional FPGA design flow
- Industry-leading software IDEs for embedded design
- Simulation, timing and power analysis reduce debug time
- Debug through FlashPro or standard RealView® header
MSS Configurator

- Configure the MSS peripherals and I/Os
- Create or import hardware configuration
- Automatically generate drivers for peripherals
- Configure programmable analog components

*MSS configurator enables co-design between multiple users*
Ecosystem Partners: Industry Leaders

- **Microsemi**
  - HAL, drivers and IDE

- **ARM Cortex-M3 processor**
  - Leverage ARM ecosystem

- **GNU, Keil and IAR**
  - Compilers and debuggers

- **Micrium**
  - RTOS, TCP/IP and middleware

- **Mentor and Synopsys**
  - Synthesis and simulation
SmartFusion: Hardware & Solution Kits
Evaluation & Development Kits

- $99 – evaluate SmartFusion
- Evaluate and debug the entire system
- Tutorials and sample code to accelerate learning curve

- $999 Development Kit
- More on-board memory
- I/O expansion header
- External memory expansion header
- Industrial automation interfaces
Mixed-Signal Power Management (MPM)

- Demonstrates power management using SmartFusion
  - Power-up, monitor, voltage trim, data log and power-down
  - All configurable via standalone GUI tool on PC
  - Configuration changes via changing register values

- SmartFusion MPM solution includes
  - MPM daughter card: attaches to Evaluation kit
  - SmartFusion MPM design example
  - Standalone graphical configurator PC tool: Simplifies analog design
Fewer components, less board space, fewer vendors
Motor Control: Co-processing Benefit

Efficient co-processing performance between FPGA and MCU
SmartFusion in Medical Applications
# Trends & Requirements for FPGAs

## Clinical Equipment
- **General FPGA Needs**
  - Low power and reliability
  - Integration capabilities
  - Heritage as a supplier
- **FPGA Capabilities**
  - Data management functions
    - Serial to parallel data conversion
    - Level shifting
    - Offload processor functions
    - Data transfer
  - System Management
    - Timing generation
    - Voltage, temperature
    - Logic consolidation
    - Memory control
    - Monitoring capabilities
      - Position and angle steering
- **Device Types**
  - IGLOO
  - ProASIC3
  - SmartFusion
  - Fusion

## Imaging
- **Motor control**
- **Monitoring capabilities**
- **Portability**

## Home Diagnostics
- **Extended battery life**
- **Low power**
- **Small form factor**
- **Low-end signal processing**
  - Display interface
  - Data conversion
  - Signal generation, user interface control for display, key pad and communication interface
SmartFusion in Ultrasound Machines

SmartFusion in Heart Rate Monitor Systems

Portable Heart Rate Monitor

FPGA Functions
- Flash Memory Interface
- Sensor/Transducer Interface
- DSP Filtering (FIR) - Offload uC for DSP tasks
- Display Driver
- I/O Expansion

SmartFusion in Patient Monitor Systems

FPGA Functions
- LCD Controller
- Processor Interface
- UART Expansion
- Memory Controller
## Medical Device Portfolio

<table>
<thead>
<tr>
<th>Feature</th>
<th>SmartFusion</th>
<th>ProASIC3</th>
<th>IGLOO</th>
<th>AX, MX, SX-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>FLASH</td>
<td>FLASH</td>
<td>FLASH</td>
<td>ANTIFUSE</td>
</tr>
<tr>
<td>Key Differentiators</td>
<td>Embedded Cortex M3, eNVM, ADCs, DACs, Voltage, Current, Temp Monitors</td>
<td>In system programmable, extended IO support, large density, 1.2/1.5V support</td>
<td>Flash Freeze, small density small packages</td>
<td>5V compliant IOs, Debugging with Silicon Explorer II,</td>
</tr>
<tr>
<td>Configuration Cell Upsets</td>
<td>Immune</td>
<td>Immune</td>
<td>Immune</td>
<td>Immune</td>
</tr>
<tr>
<td>Production</td>
<td>1.5 years</td>
<td>6 years</td>
<td>5 years</td>
<td>20+ years</td>
</tr>
</tbody>
</table>
Summary

- Microsemi is continuously developing solutions to address key needs of Medical customers
  - SmartFusion: Cortex M3, Analog Capabilities → Integration
  - Devices: 20+ years of heritage as a supplier → Longevity
  - Firm Error Immunity, Security → Reliability
  - IGLOO: Low Power, Small form factor → Portability

Learn more about Microsemi Medical Solutions: