Enabling Breakthroughs in Medical Electronics

TI Medical strategy overview, October 2011
Veronica Marques
Strategic Marketing & Application Manager
Medical Business Unit
Opportunity for impact
Consistent market growth, strong global trends driving future

Aging populations
• In ten years (2019), 32% more people in the US will be over 65 years than today. By 2025 1.2 billion people will be over 50 years old, twice as many as in 2006.

Rising healthcare costs
• U.S. healthcare spending more than 17% of GDP, Europe not far behind
• Costs expected to grow from $2.5 trillion in 2009 to $4.5 trillion in 2019

Remote and emerging markets
• China healthcare expenditure increased from 3.7% of GDP in 1995 to 5.6% in 2007
• India government proposed in 2008 to increase public expenditure on health care from 1% to 3% of GDP

Personal healthcare
• 33% of medical semiconductor revenue in 2009 went into consumer medical devices

Sources: World Health Organization (WHO), National Health Expenditure Report 2009, Databeans, Frost & Sullivan, Economic Times
Healthcare trends and opportunities

Anywhere
- Personalized
- Sports/fitness

Doctor’s office
- Patient comfort
- Chronic disease

Hospital
- Portable/affordable
- Emergency care/Remote
- Early diagnostics/ Real-time monitoring
- Handheld/Bodyworn

Telehealth
- BLE
- Wi-Fi
- Bluetooth

Cost efficient
- Precision/Performance

Electronic Health Records
- Connected
Diverse and broad market

**e-Health / Telehealth**

- **Consumer medical devices**
  - Digital thermometers
  - Blood glucose monitor
  - Blood pressure monitor
  - Insulin pumps
  - Heart rate monitors
  - Audiology (digital hearing aids)

- **Diagnostic, patient monitoring and therapy**
  - ECG
  - EEG
  - Blood oxygen (pulse oximeter)
  - Blood pressure
  - Temperature
  - Ventilation/respiration
  - Defibrillators
  - Implantable devices

- **Telemedicine**
  - Medical imaging
    - Ultrasound
    - CT
    - MRI
    - X-Ray
    - Other imaging (nuclear, positron emission tomography)

  - Medical instruments
    - Laboratory equipment
    - Dialysis machines
    - Analytical instruments
    - Surgical instruments
    - Dental instruments

---

*Texas Instruments*
TI system advantage

More information see www.ti.com/medical
Diverse and broad product portfolio

- Consumer medical devices
  - Ultra-low power
  - Precision
  - Connectivity
  - ARM-based MCU
  - Precision Analog
  - Wireless Connectivity
  - And more...

- Diagnostic, patient monitoring and therapy
  - Low-power
  - User interface
  - Precision
  - Connectivity
  - Low-Power DSP
  - Wirelss Connectivity
  - And more...

- Medical imaging
  - High-performance
  - Low power
  - Integration
  - High-Performance DSP
  - Analog Front End
  - Data Converters
  - Pulsers & Switches
  - And more...

- Medical instruments
  - Real-time control
  - High performance
  - Precision
  - C2000™ MCUs
  - ARM-based MCU
  - Precision Analog
  - Clocks & Switches
  - And more...

- And more… And more…
Example: Bringing ultrasound to the Point-of-Care

Karl Dussik's apparatus for scanning the head, 1940

Images courtesy of Sonosite
Evolving: Ultrasound AFE
Greater integration and new architectures

- 97% smaller
- 67% less power
- 2x performance

- 40% smaller
- 50% less power
- 2x performance
System level benefits for ultrasound

**Analog signal chain**
- HV MUX
- T/R Switch
- Transduler
- FET Driver
- Tx Buffer Amp
- Passive LPF
- DAC
- Amp Stage
  - LNA
  - VCA
  - PGA
  - Low Pass Filter
  - Amp + Filter
  - Analog Front End
  - CW (analog) Beamformer
  - ADC
- Back End
  - CW Beamformer

**Embedded processing**
- Front End
  - Transmit Beamformer
  - Beamformer Control Unit
- Receive Beamformer
- Mid
  - Preprocessing
  - Clocking
- Back End
  - B Mode Processing
  - Color/Power Doppler Processing
  - Scan Conversion Post Processing
- Ultrasound OS/UI
  - Audio Amp
- Memory Interfaces
  - IDE/ATA
  - MMC/SDIO
- Common Interfaces
  - LPW
  - RS232
  - USB
  - 1394
  - 802.11

**Main Power Supply**
- AC/DC Supply With Green Mode Controller
- System Power
- Supply Voltage Super.

**Interface**
- AC Line
- Plug
System level benefits for ultrasound

Analog signal chain
- HV_MUX
- T/R Switch TX810
- T/R Switch
- FET Driver
- Tx Buffer Amp
- Passive LPF
- DAC
- Analog Front End AFE5805
- CW (analog) Beamformer
- UCCxx
- TPSxx

Embedded processing
- High-Performance DSP
- CDC
- High-Performance DSP
- Ads16xx
- High-Performance DSP
- DSP SoC/Apps. processor
- TPaxx
- Interface
- Memory interfaces
- IDE/ATA
- MMC/SDIO
- Display
- Backlight
- Touchscreen

Common interfaces
- Power
- AC Line
- AC/DC Supply
- With Green Mode
- Controller
- Main Power Supply
- Voltage

- Memory interfaces
- IDE/ATA
- MMC/SDIO

- IEEE 802.11
- USB
- 1394
- RS232
- LPW
### Award-winning Analog front ends for ultrasound

<table>
<thead>
<tr>
<th>Platform/System</th>
<th>Production</th>
<th>Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>High End</td>
<td></td>
<td>AFE5808</td>
</tr>
<tr>
<td>Mid Range</td>
<td>AFE5805</td>
<td></td>
</tr>
<tr>
<td>Portable</td>
<td>AFE5804</td>
<td></td>
</tr>
<tr>
<td>Ultra Portable</td>
<td>AFE5801</td>
<td>AFE5851</td>
</tr>
</tbody>
</table>

- **AFE5804**: Analog front end for portable ultrasound systems.
- **AFE5805**: Analog front end for mid-range ultrasound systems.
- **AFE5808**: Analog front end for high-end ultrasound systems.
- **AFE5807**: Analog front end for ultra-portable ultrasound systems.
- **AFE5851**: Analog front end for ultra-portable ultrasound systems.
Example: ECG products enable patient mobility

Einthoven’s first practical Electrocardiogram, 1903

ADS1x9x – increasing patient mobility
ECG system block diagram

Product Availability and Design Disclaimer - The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.
Patient monitoring and ECG market

Number of Leads

<table>
<thead>
<tr>
<th>Many</th>
<th>Few</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest / Stress ECG</td>
<td>Consumer</td>
</tr>
<tr>
<td>Bispectral Index Monitor (BIS)</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>EEG</td>
<td>PBANs</td>
</tr>
<tr>
<td>Holters, Hospital AEDs</td>
<td>Public Access AEDs and Telemedicine</td>
</tr>
<tr>
<td>Fetal ECG</td>
<td>Patient Monitoring</td>
</tr>
</tbody>
</table>

Many

Few
ADS1298 AFE family simplifies design of portable ECG equipment

- Reduces component count and power consumption up to 97%
- New ADS1298R AFE is the first electrocardiogram (ECG) AFE in production with integrated respiration detection enabling highly accurate respiration measurement in portable ECG devices while providing ultra-low power consumption

Introduced April 2011
### Award-winning ECG / EEG analog front end portfolio

<table>
<thead>
<tr>
<th>Product</th>
<th>Package</th>
<th>Channels</th>
<th>ADC Resolution</th>
<th>Maximum Sample Rate (kSPS)</th>
<th>Operating Temperature Range</th>
<th>Respiration Circuitry</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS1194</td>
<td>BGA</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td>ADS1196</td>
<td>BGA</td>
<td>6</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>6</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td>ADS1198</td>
<td>BGA</td>
<td>8</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>8</td>
<td>16</td>
<td>8</td>
<td>0°C to +70°C</td>
<td>No</td>
</tr>
<tr>
<td>ADS1294</td>
<td>BGA</td>
<td>4</td>
<td>24</td>
<td>32</td>
<td>0°C to +70°C</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>4</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>External</td>
</tr>
<tr>
<td>ADS1294R</td>
<td>BGA</td>
<td>4</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>Yes</td>
</tr>
<tr>
<td>ADS1296</td>
<td>BGA</td>
<td>6</td>
<td>24</td>
<td>32</td>
<td>0°C to +70°C</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>6</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>External</td>
</tr>
<tr>
<td>ADS1296R</td>
<td>BGA</td>
<td>6</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>Yes</td>
</tr>
<tr>
<td>ADS1298</td>
<td>BGA</td>
<td>8</td>
<td>24</td>
<td>32</td>
<td>0°C to +70°C</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>TQFP</td>
<td>8</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>External</td>
</tr>
<tr>
<td>ADS1298R</td>
<td>BGA</td>
<td>8</td>
<td>24</td>
<td>32</td>
<td>-40°C to +85°C</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Example: Taking healthcare into the home

View video at:
http://www.continuaalliance.com/connected-health-vision/vision.html

Courtesy of the Continua Health Alliance

MSP430 – the First Continua-certified Medical Platform for Agent Devices
Portable Medical system block diagram

E.g. blood glucose meter, digital blood pressure meter, blood gas meter, digital pulse/heart rate monitor, digital thermometer

Popular MCU Solution:
“It’s a fascinating little device that may have a huge impact on behavior modification. The armband has tremendous potential to educate the masses about their true activity level, which is often exaggerated, and motivate them to get up and get moving like they should be.”

Dr. Tedd Mitchell, President and Chief Operating Officer of the Cooper Clinic at the Cooper Aerobics Center, Dallas TX.

“TI continues to lead the industry as our gold standard in low power micro-controllers. Their highly integrated components, low cost development tools, and easy ramp-up to productivity cut our design time and provided our customers with a superior product.”

Scott Boehmke
Director of Hardware Development,
BodyMedia, Inc
Example: Connected health opportunities

- **Clinical Patient Monitoring**
- **Health & Chronic Disease Management**
- **Vital Signs Monitoring**

**Technologies:**
- **2.4GHz ISM band** (Zigbee/802.15.4/BT/BLE)
- **Passive non-Battery Operated RF/RFID**
- **WLAN** (802.11a/b/g/n)
- **GSM/GPRS**
- **Bluetooth®/Bluetooth Low-Energy (BLE)**
- **ANT/ANT+**
- **Zigbee/802.15.4**
- **sub-1GHz ISM band** (433 MHz/868 MHz/915 MHz)

Networks:
- **WAN**
- **LAN**
- **HAN**
- **BAN**
- **WLAN** (802.11a/b/g/n)

Devices:
- Blood pressure monitor
- Smart bandage
- Weight scale
TI Solutions for Telehealth

Personal Health Devices

Health Services

Certified to be interoperable

PAN Interfaces
- Bluetooth
- Bluetooth Low Energy
- ZigBee

WAN Interface
- WiFi

Continua CERTIFIED

TI Solutions for Telehealth

Personal Health Devices

Health Services

Certified to be interoperable

PAN Interfaces
- Bluetooth
- Bluetooth Low Energy
- ZigBee

WAN Interface
- WiFi

Continua CERTIFIED
High analog and digital integration

300+ Device Configurations
- **Flash**: Up to 256kB Flash, 512kB on the way
- **RAM**: Up to 18kB RAM
- **Package/Pin Count**: 24 packages, up to 113 pins
- **Cost effective**: MSP430 Value Line MCUs @ $0.25

Innovative Integration
- **FRAM** – the future of Embedded Memory
- **Capacitive touch I/O** – directly interface with pads
- **Hi-Resolution Timer** – 4ns resolution
- **A-POOL** – Configurable analog blocks
- **USB** – Full Speed 2.0
- **RF** – Sub-1GHz (433, 868, 915MHz)
- **ESP430** – 2nd core for eMetering algorithms
- **24 Bit** – Sigma Delta ADC

Full peripheral set
- Devices integrated with:
  - 10, 12-bit ADC
  - 16-bit Sigma Delta
  - 12-bit DAC
  - 16-bit Timers
  - I2C, SPI, UART
  - LCD Driver
- USB
- Integrated RF
- Comparator
- OpAmps
- Direct Memory Access Module
- Hardware Multipliers
- AES128 Encrypt/Decrypt module
- Watchdog Timer
- Brown-Out Reset
- Capacitive Touch I/O ports
- Real-Time Clock
- Power Management Module
- MORE
Ultra-Low Active Power

Ultra-Low Power Active Mode
@2.2V, 1MHz, Flash operation

F2xx (Gen purpose, max 16MHz)
• 220μA

F4xx (w/LCD, max 16MHz)
• 200μA

F5xx (Gen Purpose + USB, max 25MHz)
• 160μA

MSP430 device with FRAM
• 100μA

Nothing to hide! Baseline current includes:
• Zero-Power Brown Out Reset
• All peripherals are clocked and accessible
• All peripherals are available in Low Power Mode
• Ports are enabled
• Timers, WDT
• All interrupt sources

uA/MHz improves as CPU speed increases

Active Mode Leader

Minimize Active Current Consumption

Energy = Power * Time
7 Configurable Low Power Modes

Optimize your power profile and minimize average current consumption.

<table>
<thead>
<tr>
<th>MSP430</th>
<th>Active</th>
<th>LPM0</th>
<th>LPM1</th>
<th>LPM2</th>
<th>LPM3</th>
<th>LPM3.5</th>
<th>LPM4</th>
<th>LPM4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>ON</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SMCLK (Hi-Freq peripheral clk)</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ACLK (Low Freq peripheral clk)</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Autonomous peripherals</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>Avail.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RAM Retention</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>-</td>
<td>YES</td>
</tr>
<tr>
<td>Brown Out Reset</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Most Applications spend 99 to 99.9% of the time in a Low Power Mode.

MSP430 has the most Low Power Modes for increased flexibility.

Power

- 7 Low Power Modes
- Minimize Average Current

Time
FRAM: The Future of Embedded Memory

- Universal Memory
- 100 Trillion cycles
- 100x faster write
- 250x lower power

- FRAM provides maximum design flexibility
  - Universal memory: Flexible use of code and data memory
  - Maximizes value of PCB designs and customer product qualifications

- FRAM enables extreme low power
  - 1000x faster means 250x lower power than Flash; beyond battery life
  - Lowest Active Power in the Industry (100uA/MHz) for active modes

- FRAM is robust
  - Undetectable effect of radioactive environment (ISO 11137-1:2006)
  - FRAM is not effected by electromagnetic fields

- FRAM excels in secure applications
  - Low-voltage high-speed writes minimize vulnerability to hacking
  - Drives new applications in security with lower power

- FRAM is reliable
  - Maximized endurance of over 1,000,000,000,000,000 write cycles
  - Guaranteed write completion with no bit tearing

- TI is 10 years ahead with the tech of the future
  - Leveraging 10 years of RAMTRON experience
  - No scaling roadblocks on the horizon as in Flash memory

www.ti.com/fram
Summary

- Rapidly growing market – semiconductor technology creates discontinuities
- Diverse and broad opportunity
- TI is committed to Medical
  - Broad catalog portfolio
  - Application-specific products
  - System understanding
  - Investment in the future
  - Foundation of quality, technology expertise and support
- Customer focus