MSP430 Energy Meter IC solutions for Electricity Meters

Smart Grid Series

Q3, 2012
Energy Metering Applications

- **Utility meters**: *vertical*
  - Residential electrical meters
  - Commercial and industrial electrical meters
  - Electrical Vehicles charging stations

- **Sub-metering**: *broad*
  - Smart Plug
  - Power Distribution Units (PDU)
  - Server power
  - Smart Appliances
  - Trend in the smart home/smart building
MSP430 energy meter IC portfolio facts and update

• 15 years experience - Large portfolio today from 1-phase to 3-phase

• MSP430AFE very popular in metering and sub-metering applications

• Recently introduced device MSP430F6736 getting a lot of traction

• Two new series are in early samples stage
Energy Meter IC market trend

• **Utility meters:**
  – 500 Millions residential electricity meters will be deployed with the next 6-10 years
  – Meters are becoming smart with communications functions changing electrical meters requirements
  – Need for robustness, anti-tamper, low-power consumption, integration
  – 3 big classes
    • Need for system cost optimization “just measure energy”: **Analog Front End** (AFE)
    • Need for **low-end Metrology SoC** (ADC metrology + MCU core + LCD + RTC) ~ from 12kB to 64kB Flash range
    • Need for **higher integration Metrology SoC** (memory up to 256kB/512kB, encryption, 1-phase, 3-phase)

• **Sub-Metering:**
  – Consumers want to take control of their energy consumption
  – Concept of smart-home and smart building is rising
  – It starts by measurement energy in a simple way: AFE approach
  – Grid connected appliances
Smart Home: Grid Connected Appliance

- New ENERGY STAR specification effective January 2013

- Provide **alerts** and future **demand response** capabilities for appliances for the consumer to **save energy**

- **MSP430AFE253**: sensing + RF com interface
- Strong interest from appliance manufacturers WW
Sub-Meter Block Diagram

Metrology AFE = Sigma Delta + MCU + RTC
• small memory footprint, lower cost than SoC
Topoloy for a mid-end electrical meter

Metrology SoC = Sigma Delta + MCU + RTC + LCD
- Memory up to 128kB flash with growing requirements with 256kB+
- Encryption coming-up (AES128)
What You can get from TI?

• Single Stop System Solutions (all types of meters, interfaces/AMR/PLC/Wireless, LPRF, Analog)

• Broad line of chips to cover every smart grid requirement

• Always Ultra Low Power – no need in expensive power supplies
  – Low Power Cap Drop based power supply with MSP430 (cost effective)

• TI delivers all the protocols you may need: DLMS/COSEM, M-Bus, Wireless M-Bus, PLC G3/PRIME, ZigBee (all IPs), etc

• Robust roadmap with F67xx platform helping customers to manage multiple designs using one platform

• Technical SW/HW Support, Ref. Designs, Metrology SW
**MSP430AFE**

**Performance**
- 16-bit RISC architecture, 125ns instruction cycle time
- Ultra-Low-Power, Integrated Analog, and Easy-to-Use

**Features**
- Low supply voltage range 1.8-3.6V
- Ultra-low power in active and sleep modes and ultrafast wake-up from standby mode in <1 µs
- 3 independent ΣΔ converters
- USART communication
- 24-pin TSSOP (PW)

**Benefits**
- **Cost optimized** for analog front end in metering, power monitors, high-precision measurements
- **<0.1% accuracy** for precise measurements with a 2400:1 dynamic range with ΣΔ convertors
- **Anti-tampering** capabilities with an additional ΣΔ convertor
- **Lower system power** due to world’s lowest power MCU
- **Small Footprint** of 24-pin (35-50sqmm) enables solutions for in-system power monitoring and industrial sensing
- More robust performance and software development with simultaneous sampling

**Applications include:**
- Single phase e-meter (with anti-tampering)
- Power Monitoring (Servers, Appliances, Branch Meters)
- High-precision measurements
- Digital Sensors

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**MSP430AFE2xx Microcontroller**

**Memory**
- 16/8/4 kB Flash
- 512/512/256 B RAM

**Debug**
- Real-time JTAG / SBW
- Embedded Emulation

**Power & Clocking**
- Clock System:
  - High Freq Crystal Osc
  - Digitally Controlled Osc (DCO)
  - VLO
- Power on Reset
- Brownout Reset
- Supply Volt Supervisor

**Timers**
- 16-bit Timer A with 3 cap-comp Regs

**Converters**
- 3x Sigma-Delta

**Serial Interface**
- USART (UART, SPI) @8MHz

**Connectivity**
- 11 I/Os
AFE 430 Results

• Provide raw data of voltage and current samples
• Energy
  – Active
  – Reactive
  – Apparent
• Power
  – Active
  – Reactive
  – Apparent
• Power factor ($\cos(\varphi)$)
• Voltage and Current
  – Peak
  – RMS
• Frequency
• Temperature
• Tamper detection
• Energy pulse output for calibration for active and reactive energies

*Target accuracy 0.1% for active and reactive energies*
## Example of Competitive Advantages of MSP430AFE2xx

<table>
<thead>
<tr>
<th>Objective</th>
<th>Benefit</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple &amp; Cheaper implementation</td>
<td>Needs only one IC instead of two to implement designs</td>
<td>Single MCU solution</td>
</tr>
<tr>
<td>Accuracy</td>
<td>More accurate ADC architecture enables meeting IEC specifications easily</td>
<td>24 bit $\Delta\Sigma$ ADCs</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Full code and metering algorithm provided to help those who are unfamiliar with metering</td>
<td>TI's Energy Library</td>
</tr>
<tr>
<td>Time to market</td>
<td>Saves time &amp; money</td>
<td>Calibration flexibility for sub metering applications</td>
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MSP430AFE for Three-phase E-meter
AFE For Single-phase E-meter with Tamper detection

From utility

N  L

MSP430 AFE

Analog to Digital

Pulse1
Pulse2

V1-
V1+
VREF

I1-
I1+

I2-
I2+

RST
VSS

VCC

CT

LOAD

HF crystal (Up to 16MHz)

Application interface

UART or SPI

UTXD0
URXD0

SPI
MSP430 AFE EVM

- EVM creation completed
- Early samples available today
- SW testing in progress
- Based on MSP430 AFE+MSP430 Apps processor
- Tool available by mid February 2011
MSP430 Energy Watchdog

- Fully functional smart plug tool allows quick and efficient development
- Measurements performed / displayed
  - Incoming voltage, current, frequency
  - Active, reactive, apparent power
  - Power factor
  - Energy consumption
- MSP430AFE253IPWR
- Interface to optional comm modules
  - ZigBee
  - Sub-1 GHz 802.15.4
  - Wireless M-Bus
- Will be available in the future
EVM definition
MSP430F6736 – 24 new devices starting at $2.00

24 New Devices
• Industry’s largest segmented LCD controller
• Up to 2MHz SD24 modulation frequency
• 3x auxiliary power supplies

Applications
• Single phase e-metering
• High-precision measurements
• Anti-tampering

Performance
• 16-bit RISC architecture, 40ns instruction cycle time
• Ultra-low-power, integrated intelligent peripherals and easy-to-use

Lowest Power in the Industry
• Low Supply Voltage Range 1.8 V to 3.6 V
• Ultra-low Power Consumption (@ 3V)
  • Active Mode: 140 µA/MHz
  • Standby Mode: 2.5 µA
  • Off Mode: 1.6 µA
  • Shutdown Mode: 0.78 µA
• Ultrafast wake-up from standby mode in < 3 µs

Package
• 100-pin QFP (PZ)
• 80-pin QFP (PN)
# Why MSP430 for Electricity meters?

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<tr>
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<th>Features</th>
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<tr>
<td>System Cost Optimization</td>
<td>Remove need for level conversion</td>
<td>Sigma Delta with Differential Inputs</td>
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<tr>
<td></td>
<td>Simplify and reduce power design</td>
<td>Ultra-low power (0.1uA power-down, 0.8uA standby mode, &lt;220uA/MIPS)</td>
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<td>High level of integration</td>
<td>RTC and LCD driver integrated</td>
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<td>Optimized implementation</td>
<td>Optimized 1-phase AFE</td>
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<tr>
<td>Time to market/Accuracy</td>
<td>No SW compensation for inherent delay between voltage and current</td>
<td>Sigma Delta with simultaneous sampling for current and voltage</td>
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<td>Better numerical result</td>
<td>Hardware MPY</td>
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<td>Ease of use and quicker time to market</td>
<td>Energy library and plug and play EVM</td>
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<tr>
<td>Anti-tamper implementation</td>
<td>Additional measurement</td>
<td>Numerous SD combination up to 7 for three-phase systems</td>
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<tr>
<td>Easy interfacing</td>
<td>Provides Easy options to interface with LR RF or wired coms</td>
<td>Various Serial Communication ports interfaces</td>
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<tr>
<td>Flexible long term platform</td>
<td>Software and Hardware re-use</td>
<td>1-phase and 3-phase platform with pin to pin compatibility options + roadmap</td>
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Get started: simplify development with tools and software

**Development Tools**

- **MSP-TS430PZ100B** - $75
  Standalone target board used to program and debug
- **EVM430-F47197** 3-phase meter EVM
- **MSP430F6736** Single-phase Meter EVM
- **AFE tool** – under qualification
- **Watchdog**

**Energy Software Library**

- Supports all metrology and SoC devices in the new MSP430™ architecture
- Allows easy startup for customers developing a utility meter product

**Free online download of the SW suite**

**MCU Selection Tool**

**www.ti.com/430metering**
TI’s metroSUITE metrology software

- Compliant with EN 50470-1/3, IEC62053-21/22/23, ANSIC12.1/10/20
- MID compliant (class-2, class-1, class-0.5)
- Including metrology lib, power analytics lib and energy disaggregation lib
- Available: Q2/2013
Finding more information

• TI Smart Grid Homepage:
  – www.ti.com/smartgrid

• Application Notes

• Software/Code Examples

• Reference Designs

• Videos:

• Smart Grid Blog:
  – http://e2e.ti.com/group/energy/default.aspx

• Contact smartgrid@ti.com