FD-SOI Adaptive Body Bias solutions to accelerate energy-efficient SoC designs

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Not just a supplier of Technology, but provider of the Dolphin Integration know-how!
IoT SoC: Missions & Challenges

- Increase Battery Autonomy
- Boost Performances
- Reduce Time-to-Market
### Energy-Efficiency Challenges

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Leakage Current (μA / MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active</strong></td>
<td>SoC running - All blocks ON</td>
<td>µA / MHz</td>
</tr>
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</table>
| **Active-Low Power, Sleep** | SoC running in low-power mode  
MCU OFF - RF OFF - Peripherals are active | µA / MHz                    |
| **Deep Sleep, Trigger, ...** | Logic Domain & SRAM in retention mode  
IO and AON/RTC active | < 1 μA                      |
| **Stop**              | Logic domain OFF - SRAM OFF  
IO disabled - AON/RTC active | < 500 nA                    |
| **Shut Off**          | Only wake-up pin remain active  
AON/RTC is OFF                | < 200 nA                    |

**Energy-Efficient IP**
- For Mostly-Off Domain
- Low Leakage IP
  - for Sleep Mode & AON Domain

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FD-SOI ENABLES SINGLE CHIP SOC

Power Management Unit
Clock Management Unit
Security Unit
Processing & Memory
Energy Harvesting
Always-On Domain
RF
Audio CODEC
IOs & Interfaces

mmWave RF-CMOS
Best CMOS mmWave with similar performance to SiGe radios
Source: GF, GTC2017

Ultra Low Voltage
Operation at minimum energy point (<0.4V)
Source: Sugii, Low Power El. Appl. 2014

Body Bias
Untrimmed
Leakage limit
Trimmed
Frequency
Leakage spread reduction
Performance Boost
Source: ST, ICICDT17, P. Flatresse

Reliability
Neutron-SEU FT-Mb
20x Soft Error Rate improvement vs. bulk
Source: ST, Shanghai FDSOI forum, 2015

Ultra Low Voltage Operation at minimum energy point (<0.4V)

Source: Sugii, Low Power El. Appl. 2014

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Best CMOS mmWave with similar performance to SiGe radios

Leakage frequency performance boost

Leakage spread reduction

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Trimmed
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Source: ST, ICICDT17, P. Flatresse

× energy efficiency gains at ULV

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20x Soft Error Rate improvement vs. bulk

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5X energy efficiency gains at ULV

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Vendor A 45nm Bulk
Vendor A 45nm Bulk
ST 28nm Bulk
ST 28nm Bulk
ST 28nm FD-SOI

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5X energy efficiency gains at ULV
**BODY-BIAS: A KNOB FOR ENERGY-EFFICIENCY**

**Past**
- Low $V_{dd}$ potential and UWVR capability
- Intrinsic radiation hardness
- Body-bias **boost** mode

**Now**
- **Static FBB** for process variations trimming

**Future**
- **Adaptive Body Bias (ABB)** for compensating
  - Temperature variations in Low $V_{dd}$ range
  - Aging variations in Nom to High $V_{dd}$ range

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**Future**
- Adaptive Body Bias (ABB) for compensating
  - Temperature variations in Low $V_{dd}$ range
  - Aging variations in Nom to High $V_{dd}$ range
• **ABB IP** for Process, Voltage, Temperature & Aging compensation

• **All-in-one IP** including body-bias voltage regulator, low power sensors and control loop

• **Foundation IP** independent

• **Ultra wide voltage range**: 0.4V to 0.945V

• < 1% area overhead vs. logic area

• < 10 µW power overhead
• 2 Sensors
  ➞ VBBCO monitor for coarse-grain compensation
  ➞ Distributed Timing Monitors (DTM) for fine-grain compensation

• 2 independent N- & P-WELL regulation loops
  ➞ VNW regulation refers to Fclk
  ➞ VPW regulation refers to VNW
Energy Efficiency Gain
Adaptive Body-Bias VS. No Biasing

Typical IoT power range

- ARM® Cortex®-M4
- GF 22FDX™

High performance: Nominal Voltage (V)
- 0.9 x1.5
- 0.8 x1.8

Nominal performance
- 0.65 x2.3

Low power
- 0.5 x4.8

Ultra low power
ADAPTIVE BODY-BIASING IN 22FDX™ SoC DESIGN FLOW

Seamless Integration in 22FDX™ Design Flow

Scalable to any SoC Architecture
**Stand-Alone Body-Bias Generator**

- Several configurations to support various loads size
- Ultra low current consumption < 10µW in active/shutdown mode

**Zero Power BBGEN for Always-ON Domain**

- AON is dominated by leakage
- Hungry charge pump not an option
- RBB only as an attractive solution to reduce leakage

**Adaptive Body-Bias for Mostly-Off Domain**

- All-in one IP for PVTA compensation
- Ultra Wide voltage range
- < 1% area overhead vs. logic area
- < 10µW power overhead

**Energy-Efficiency is a function of PVT sensors accuracy**

- SlackGuard™: Aging monitors
  - Timing margin detection of critical paths
- DTM: Delay Timing Monitor
  - Fine grain compensation
- VBBCO: Body Bias Controlled Oscillator
  - Coarse grain compensation
**Power Management IP Platform**

**Embedded PMU/ACU**
- Scalable and configurable
- Boot-up sequence management
- Body-Bias, DVFS, AVS support

**Voltage Regulators**
- High Efficiency DC/DC
- Ultra-low quiescent LDO
- 95% Efficiency
- Quiescent down to 150 nA

**Power Gating Solutions**
- Ultra-low leakage IO & logic power gating
- IO Leakage reduction up to x14

**uLP Oscillators**
- 32 kHz RC & XTAL
- Ultra Low power < 80 nA

**Body-Biasing**
- PVTA Compensation
- 5x Energy-Efficiency ABB
- 7x Energy-Efficiency ABB + AVS
ADAPTIVE BODY-BIAS ROADMAP

**IoT**
- **2018**: Proof of Concept
- **19'Q1**: Preliminary Design Kit
- **19'Q2**: Ready For Production 22FDX™
- **20'Q2**: Design Kit

**Automotive**
- **2018**: Preliminary Design Kit
- **19'Q1**: Design Kit SlackGuard™
- **20'Q1**: Ready For Production 22FDX™

Q1: First Quarter
Q2: Second Quarter
Q3: Third Quarter
Q4: Fourth Quarter
Q2/Q3: Second and Third Quarter

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thank you