Advances in Applications and Ecosystem for FD-SOI technology

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Improving power Efficiency – Bringing high flexibility in SoC integration
UTBB FD-SOI, A Long R&D Story

- **1991, LETI.** SmartCut patent
- **1992, Creation of SOITEC**
- **1997, CNET.** Silicon On Nothing
  Fabrication of thin BOX on ordinary Bulk wafers within the CMOS process
- **2000, ST & LETI**
  Fabrication of SON silicon
- **2000, SON (Silicon On Nothing):** an innovative process for advanced CMOS
  IEEE, TED, Nov. 2000
  Prized with the Rappaport Award for the best IEEE EDS paper of year 2000
- **2000-2012. ST & LETI**
  Module development & device understanding
- **2009. FD-SOI on Thin BOX**
  Thin BOX (Buried OXide) wafers available from Soitec
- **2012. 28nm UTBB FD-SOI Available for production**
SOC PPA Demonstration – Jan 2013

- Board with Bulk silicon processor
- Board with FD-SOI processor

Graph showing:
- Same Perfs as 28LP with 200mV Less -400mV with 1.3V FBB
- Hit 3GHz Target

- >80% extra speed @ 1.3V FBB
- 1GHz with FD-SOI

Dhrystone Benchmark: 01:21

- Power consumption
- Energy [mJ/MD]
- Instant power saving [%]
- Remaining battery
- Package temperature
FinFET & FD-SOI: Just a rotation ultimately converging when scaling BOX to TOX
addressing Power sensitive Markets

FinFet

High end servers

Laptops & tablet-PC

Networking Infrastructure

Smartphone

Consumer Multimedia

Internet of Things, wearables

Automotive

Available from 28nm node

Ultimate Digital Integration

Ultimate Digital + AMS + RF + … Integration
FD-SOI Application Benefits

**Consumer**
- Optimized SoC integration (Mixed-signal & RF)
- Energy efficient SoC in all thermal conditions
- Optimized leakage in idle mode

**Infrastructure Networking**
- Energy efficient multicore
- Effective DVFS
- Excellent performance on memories

**Internet of Things**
- Ultra-low voltage operation
- Highly Scalable operation
- Efficient RF and analog integration

**Automotive**
- Well-managed leakage in high temperature environment
- High reliability thanks to highly-efficient memories
FD-SOI Network Infrastructure

- Performance and Power Efficiency
- Adapt power consumption to load
- Low SER enables simpler TCAM designs
Server Use-Case: Energy Efficiency

**Energy Gain of FD-SOI 28nm versus 28G(mobile) for a given CPU usage profile**

- **Cumulative power lower with FDSOI**

- **FD-SOI**: up to 70% better energy consumption vs bulk
Benefits for the IoT

- Ultra low voltage
- Low cost
- Easy integration of RF, connectivity, microcontrollers and power management
Example: Ultra Low Power in IoT

FSDOI - SoC

- RF
- Analytics
- CPU & Memories
- Power Management

SoC Power Consumption

- 34 mW* (Power Supply Loss)
- RF
- Analytics
- CPU & Memories
- Other

X3 to X6 Power Consumption Improvement with FD-SOI

- 40LP: <10 mW*
- FD-SOI 28nm: <10 mW*
- FD-SOI 14nm: <5 mW**

* Measured on Silicon / Product Simulation
** Projection
Benefits for Automotive

Challenges

- High ambient temperature = Limited budget for dynamic power dissipation
- Managing leakage in high ambient temperature environments ($T_j$)
- High reliability & safety critical requirements

FDSOI solution

- High performance at low voltage & power levels
- Advanced DVFS and Scaling techniques
- CPU architecture advantages
- Excellent reliability and soft-error performance
- Lowers cost to achieve ASIL compliance interfaces
Video Analytics Processor for Automotive

FDSOI - SoC

- Camera Processing
- Embedded Memory
- Quad Core CPU
- Video Analytics Processing

FD-SOI Soft Error Rate (SER) allows for less overhead in memories for error correction

Strict Safety Criteria met without systematic Usage of lockstep CPU operation
Less use of redundant standard cell Due to lower SER

SoC Power Consumption

- Bulk 28nm Full lockstep CPU: 5 W
- FD-SOI 28nm Full lockstep CPU: 4 W
- FD-SOI 28nm Optimized safety architecture: 3 W

Power limit for mounted video analytics systems in a car ~3W
FD-SOI Roadmap

FD-SOI 14nm

-35% speed
-50% power

Body Bias, simplicity, reliability

Derivatives

FD-SOI 28nm

RF, Mixed Signal

Ultra Low voltage

Embedded Non Volatile

High Density & perf RAM

Additional 28nm options continuing differentiation leadership
FD-SOI Technology
Unique Design Benefits

- DVFS
- FBB
- Benefits in Analog Integration
- Radiation Immunity (SER)
Several techniques are limited in bulk processes (28/14nm)

<table>
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<tr>
<th>Technique</th>
<th>Limitations in Bulk</th>
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<tr>
<td>Wide range DVFS</td>
<td>• [Vmin, Vmax] range is limited by variability</td>
</tr>
<tr>
<td></td>
<td>• Performance degradation when supply V reduces</td>
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<td></td>
<td>• Memory Array minimum voltage</td>
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<tr>
<td>Dynamic transistor Vt control</td>
<td>• Limited body bias range</td>
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<tr>
<td></td>
<td>• Limited benefit in 28 nm / no benefit beyond</td>
</tr>
<tr>
<td>Poly biasing of the transistors</td>
<td>• Limited poly biasing range</td>
</tr>
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Extended design techniques enabled by FDSOI
• FD-SOI allows the widest $V_{dd}$ range for voltage scaling

• Still guaranteeing top speeds at very low voltage
  • >5x @ ULV compared to 28LP HKMG
  • >35% @ ULV compared to 28G

• DVFS energy efficiency optimization further extended by body biasing

Real measurements of continuous DVFS in the range 0.5V – 1.4V
Performed on a very large number of ICs, showing extremely good reliability of the DVFS in this range
FD-SOI: The FBB advantage

• What is Body Biasing?
  • A voltage is applied to the substrate (or body).
  • When voltage is positive, it is called Forward Body Biasing, or FBB

• Why FBB is much more efficient in FD-SOI?
  • The Insulator layer (UTTB) prevents the parasitic effects that normally appear during the body biasing
  • This allows much wider range of biasing compared to Bulk
  • FBB can be modulated dynamically during the transistor operation and the transitions are transparent to the SW

• FBB benefits
  • Performance boost
  • Reduce power consumption at a given performance requirement
  • Process compensation reducing the margins to be taken at design
  • Easy to implement: seamless inclusion in the EDA flow
FBB for performance boost and power efficiency

- FBB provides performance boost when over voltage is not possible
  - Limited impact on dynamic power, no impact on voltage drops
  - More efficient than tuning the voltage

- FBB improves power efficiency at a given frequency
  - Limited impact on leakage, slightly higher with FBB
  - Drastically decreases dynamic power

**Easy to implement**: seamless inclusion in EDA flows
Simpler Analog Integration

28FDSOI makes high-speed analog designer’s life easier

- Devices are faster (analog switches / fast logic / regenerative comparator & latches) – speed is higher than bulk technology
- Higher Gain and lower noise enable smaller ADC designs
- In High Speed ADC design, gain in speed versus Bulk:
  - 50% gain, just using LVT and FBB NMOS porting from bulk
  - 100% with redesign (NMOS oriented)
- Figure of merit better than FinFET technology thanks to lower intrinsic parasitic capacitance.
Complete Ecosystem available

FD-SOI
Wafer suppliers

FD-SOI
Design solutions
IP porting
EDA Suppliers
Design flow
Libraries

FD-SOI
Silicon manufacturing
Volume production at ST and Samsung facilities

Several SOI wafers suppliers
FD-SOI Fast Growing Ecosystem

Enabling Consumer, Mobile, Networking and Automotive markets today
Leti Design Center: The strength of a network

Design Center

- IC DESIGN PLATFORM
- ACCESS TO ADVANCED IPs
- EMULATOR & TEST PLATFORMS
- INDUSTRIAL MPW SHUTTLE
- EXPERTISE & SERVICES

One single entry point along product maturation

Industrial needs

IDEAS

Pre-series line

Innovative products

TESTCHIPS  PRODUCTION

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Help COMPANIES to LAUNCH innovative product powered by leading edge semi-conductor technologies
Complete Design Solution Available

Complete & flexible offering to match your technical and business requirements

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Technology & Manufacturing

FD-SOI
Extended FDSOI IP offer

Market Specific

- Networking Infrastructure
  - SerDes
  - TCAM

Consumer Multimedia

- HDMI, DP
- Multimedia (Video Dec., Enc., Display)

Automotive

- MIPI, ISP

Mobile Consumer

Advanced

- ARM CPU Subsystem
- DDR Interfaces
- GPU

- High Speed Interfaces
- DSP
- Security

Foundations

- Standard Cells
- Memories
- System & Process
- Analog
**Foundation FD-SOI IP offer**

- **8T / 12T**
  - RVT / LVT
  - Poly bias: 0, 4, 10, 16nm
  - Low power: Isolation, Level shifters

- **Low voltage**
  - Single port / Dual port
  - ROM
  - Ultra-high speed SRAM
  - Antifuse memories

- **Process monitoring**
  - Metal ECO 4Tune
  - Sensors (process, thermal, voltage)
  - Oscillators
  - Frequency synthesizer

- **PLLs, V/T sensors, eSwitch**
  - ADC / DAC
  - Voltage regulators
  - Vbias generators
  - IOs

- **Advanced**
  - System & Process
  - Analog

- **Foundations**
  - Standard Cells
  - Memories

- **Market Specific**
  - Multimedia
  - Networking
  - Automotive
  - High Speed Interfaces
  - Security
  - Automotive Multimedia (Video Dec., Enc., Display)
  - MIPI, ISP

- **IOs**
  - Standard Cells
  - Memories
  - System & Process
  - Analog

**Notes:**
- Low power: Isolation, Level shifters
- Ultra-high speed SRAM
- Antifuse memories
- Metal ECO 4Tune
- Sensors (process, thermal, voltage)
- Oscillators
- Frequency synthesizer
- ADC / DAC
- Voltage regulators
- Vbias generators
- IOs

**Process:**
- Poly bias: 0, 4, 10, 16nm
- Isolation, Level shifters
- ROM
- Ultra-high speed SRAM
- Antifuse memories
- Metal ECO 4Tune
- Sensors (process, thermal, voltage)
- Oscillators
- Frequency synthesizer
- ADC / DAC
- Voltage regulators
- Vbias generators
- IOs
Advanced FD-SOI IP offer

- **32bit**
  - Cortex R4
  - Cortex A7
  - Cortex A9
  - Cortex A15

- **64bit**
  - Cortex A53
  - Cortex A57

**Advanced**

- ARM CPU Subsystem
- GPU
- High Speed Interfaces

**Foundation**

- DDR Interfaces
  - DDR2/3
  - DDR3/4
  - LPDDR3
- DSP
  - XP70 32b
- Security
  - Crypto Acc.
  - AES
  - Hash

**Market Specific**

- Multimedia Networking Infrastructure
- Advanced IP offer

- TCAM
- SERDES

**Mobile Consumer**

- Automotive
- TV
- Multimedia (Video Dec., Enc., Display)

- MIPI, ISP
- HDMI, DP

**Standard Cells**

- Standard Cells
- Memories
- System & Process
- Analog

**ARM CPU Subsystem**

- Cortex R4
- Cortex A7
- Cortex A9
- Cortex A15

**GPU**

- ARM MALI
- Imagination ROGUE

**High Speed Interfaces**

- USB2, USB3
- PCIe
- SATA
- Ethernet

**DDR Interfaces**

- DDR2/3
- DDR3/4
- LPDDR3
Market Specific FDSOI IP offer

**Market Specific**
- Networking Infrastructure
  - SerDes
  - TCAM

**Consumer Multimedia**
- HDMI, DP
- Multimedia (Video Dec., Enc., Display)

**Automotive**
- MIPI, ISP

**Mobile Consumer**

**Advanced**
- ARM CPU Subsystem
- GPU
- High Speed Interfaces
- DDR Interfaces
- DSP
- Security

**Foundations**
- Standard Cells
- Memories
- System & Process
- Analog
Conclusion

• ST has over 18 active FDSOI projects across multiple applications
  • Consumer, Networking ongoing.
  • New applications emerging: Automotive, IoT

• Some key features benefiting new applications
  • Performance vs. Power scalability (DVFS, ULV)
  • Analog Integration

• The FDSOI Ecosystem is growing rapidly
  • Production of FDSOI products in various applications starting this year

• ST is providing IP, Design and Manufacturing Services for the FDSOI Ecosystem