RFSOI and FDSOI enabling smarter and IoT applications

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Digital Products Group
STMicroelectronics
ST in the IoT already Today
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ST is leading the IoT Standard Component Market with STM32 and MEMS today

Wearable
Fitness
Smarthome
Metering
Entertainment
Wellness
IoT Market Dynamics

Cloud & Network infrastructure

Traffic & storage explosion driving

Technology impact
- Higher integration & performance
- Power efficiency
- 5G and 60GHz enablement

IoT and Mobile Phone Devices

Explosion of connected devices

Technology impact
- Ultra low power sensors
- Integration Digital, RF, Power Management
- Higher performance at lower power

FDSOI, RF BiCMOS and Silicon Photonics are enabling 100G+ and 5G infrastructure for the IOT Explosion

Today's Discussion:
RFSOI and FDSOI
Acceleration of smarter integration in the IoTClient

- RFSOI – 130nm and lower
  - Higher Integration of RF components for the interface to the internet
  - LTE, Wifi etc
  - Able to replace RF Filters and GaAs discrete components required today

- FDSOI – 28nm and lower
  - Perfect fit for Advanced IoT Main SOC
  - High Speed with Low Power and Leakage
  - Easy Integration of Analog SOC interfaces into main SOC
RFSOI - RF and Wifi Front End Modules integration for IoT
The IoT: Leveraging the Internet to make Things smarter…
RF demands increasing in clients

More bands with LTE

Carrier Aggregation for faster data transfer

MIMO – Multiple Input, Multiple Output, 60GHz, 5G

Envelop Tracking
RF Front End Development trends

**Switch**
- LTE-A increasing switching requirements
- MIMO techniques increase complexity of antenna switch
- CA requires level of linearity at target of -90 dBm harmonic

**Power Amplifier**
- PAs number increase to support the growing number of frequency bands and more complex MIMO architectures
- Demand for high-performance PAs push towards new architecture

**Filters**
- High number of bands and co-existence with other wireless technologies (WiFi, Bluetooth both operating at 2.40-2.48GHz) drives more use of both BAW and SAW filters
RFSoI Adoption

<table>
<thead>
<tr>
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<th>GaAs</th>
<th>SoS</th>
<th>CMOS</th>
<th>RFSoI</th>
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<tbody>
<tr>
<td>Insertion loss</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Isolation</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>PA linearity/PAE</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Low Cost</td>
<td>-</td>
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<td>+</td>
<td>+</td>
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<tr>
<td>Integration</td>
<td>-</td>
<td>-</td>
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The answer to FEM complexity growth is the RFSoI integration

RFSoI is closely following GaAs PA performance now

Benefits of Monolithic Integration

- Reduced size and cost
- Improved performance
  - Reducing inter-die signal routing and constrains of MCM
  - Taking advantage of shorter and faster on die interconnection
- Simplified supply-chain
- Reduced and simplified product development cycle time
RFSOI FEM Integration: The Next Step

Front-End integration is the path for small, performing and cost effective solutions to address 3G LTE/4G CA and WiFi 802.11ac
ST H9SOI_FEM: The Technology for FEM integration
From H9SOI to H9SOI_FEM
14 Years of History

• H9SOI is the result of a close collaboration started in 2000 among CEA-Leti, STM and SOITEC

• H9SOI in production since 2009
  • More than 500M RF switches produced for Mobile Applications

• H9SOI_FEM introduced in 2013 with
  • Better performances
  • Optimized and simpler process
  • Reduced lead-time
  • Switch/PA/Filters integration capability
H9SOI_FEM: developed for FEM integration

Switching |
---
2G Switches
3G / 4G Switches
Antenna Tuning

Power Amplifier |
---
MMMB PA
MMMB PA + Switches

Filtering |
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MMMB PA + Switches
Antenna Tuning
ET Energy Management Filtering

Antenna Tuner
Tunable Duplexer

LNA

ST testchips
FDSOI – For IoT SoCs and Infrastructure SoCs
A Transistor Technology

Typical Transistor in today CMOS System on Chip

Change of Substrate adding the thin Buried oxide

Improving power Efficiency – Bringing high flexibility in SoC integration

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FD-SOI addressing Power sensitive Markets

- **FinFet**
  - High end servers
  - Laptops & tablet-PC

- Ultimate Digital Integration

- Ultimate Digital + AMS + RF + … Integration
  - Consumer Multimedia
  - Internet of Things, wearables
  - Automotive

Available from 28nm node

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FD-SOI: Performance and Simplicity

- Fully depleted transistor but different rotation
- FD-SOI re-use most of Planar Manufacturing

FD-SOI Process steps:
- Same as 28LP...
- FD-SOI specific 2%
- Adjusted from 28LP 14%
FD-SOI Benefits for the IoT

Challenges

- Ultra low power SOC
- Integration
- Power / performance flexibility

Benefits

- Ultra low voltage operations with high performance.
- Easy and efficient analog integration (ADC/DACs, RF, LDOs, …)
- One Devices for all voltages - sleep mode not needed

Smart Car
Smart Home
Healthcare wellness
Smart City
Smart Industrial

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Extreme Scalability in Power/Performance

**FD-SOI**

- Allows the widest $V_{dd}$ range for voltage scaling without impacting CPU performance
- Still guaranteeing top speeds at very low voltage
- Unique FDSOI techniques enable energy efficiency optimization further by body biasing

**Example – Application Processor running Dual Cortez A9 from 1Ghz to 3Ghz efficiently**

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
Example: Ultra Low Power in IoT

X3 to X6 Power Consumption Improvement with FD-SOI

* Measured on Silicon / Product Simulation
** Projection
**Advantages in Analog Design**

**Efficient Short Devices**
- Efficient use of short devices:
  - High analogue gain @ Low L
  - Low Vt mismatch (Avt ~ 2mV/μm)
- Performance example:
  - A 10μm/100nm device has a DC gain of 100, & a σVt of only 2mV!

**Improved Analog Perf.**
- Higher Gm for a given current density
- Lower gate capacitance
- Higher achievable bandwidth or lower power for a given bandwidth

**Improved Noise**
- Same normalized drain current noise between BULK and FD-SOI
- Lower noise variability for FD-SOI
- Improved noise in FD-SOI

*Porting of most Analog Macros simpler into FDSOI then FinFET or Bulk Planar*

*Courtesy, L. Vogt, F. Paillardet, C. Charbuillet, P. Scheer, STMicroelectronics*
Path for IoT Performance and Integration

+35% speed
-50% power

FD-SOI
14nm

Body Bias, cost, simplicity, reliability

FD-SOI
28nm

RF, Mixed Signal
Ultra Low voltage
Embedded Non Volatile
High Density & perf RAM

Differentiated options for the long lasting 28nm process node

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Fast Growing Ecosystem

Ecosystem
- Products
- Services
- IPs
- Tools & EDA
- Wafer & Foundry

Enabling Consumer, Mobile, Networking and Automotive markets today
• FDSOI has many designs on-going world wide
  • Multiple applications including IoT
  • Mature Design and Manufacturing available now

• Rapidly growing Ecosystem
  • Production of FDSOI products in various applications starting this year

• Key benefits for IoT applications
  • Performance vs. Power scalability
  • Analog Integration → RF Integration

• FDSOI has superior price vs. performance metrics compared to FinFETs for many IoT applications
IoT Device Development Trends and Supply Chain
The boom of connected devices

Source: Piper Jaffray / Cisco
Technology supplier chain

- Without an IP available by Process supplier – key value of process may not be met and speed and performance may not meet requirements.
ST – Continued Investment in RFSOI and FDSOI

- 3 Fabs
- 4,930 employees
- 26,500 m² of cleanroom
- 1,380,000 Wafers / year in 8” wafers equivalent
Complete Design Solution Available

Complete & flexible offering to match your technical and business requirements

FD-SOI
- IPs: SerDes, Multimedia, CPU GPU, Interfaces, System, Foundations
- Design Tools & Methodologies: CAD kits, Design Factory, Si Validation & Qualification

RFSOI
- IPs: Power Amp, Envelope Tracking, Switching, LNA and Filters

Technology & Manufacturing

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<td>RF - SOI the perfect technology for integration of RF Front End</td>
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<tr>
<td>28nm FDSOI</td>
<td>28nm FDSOI is the optimum technology for analog and RF integration for the next generation of IoT devices</td>
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<tr>
<td>14nm FDSOI</td>
<td>Best in market performance/power technology for Network Infrastructure ASICs</td>
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<tr>
<td>BICMOS9MW</td>
<td>BICMOS – Highest performance for RF infrastructure and future 5G RF</td>
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<tr>
<td>BICMOS55</td>
<td>BICMOS and Silicon Photonics are becoming the optimum solution for 500m+ Optical cable and future 1Tb Optical Products</td>
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