Reshaping the Industry with Application Optimized Technology

Subi Kengeri - Vice President, CMOS Business Unit
Let’s Do Some Math

1965 transistor count per Square Inch ~100

52 years of Moore’s Law ➔ 26 cycles of Innovation

$2X^{26} = 100,000,000X$ Improvement!
If a present graphic processor was built using the first integrated technology of the 1960’s…

…it would be the size of a football field
Automotive Industry Delivered ~1.5X Performance Increase in 52 Years

<table>
<thead>
<tr>
<th></th>
<th>1967 Camaro SS 396</th>
<th>2017 Camero 1SS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PERFORMANCE</strong></td>
<td>396 (6.5L) Big Block V8 375 hp (L78 pkg)</td>
<td>6.2L LT1 V8 455 hp</td>
<td>↑ 84 hp/L</td>
<td>1.3X</td>
</tr>
<tr>
<td><strong>0-60 MPH</strong></td>
<td>6.5 sec. (est.)</td>
<td>4.0 sec. (8-spd auto)</td>
<td>↓ 2.5 sec.</td>
<td>1.6X</td>
</tr>
<tr>
<td><strong>MILEAGE</strong></td>
<td>12 mpg city, 15 mpg hwy (est.)</td>
<td>16 mpg city, 25 mpg hwy</td>
<td>↑ 16 mpg city, 25 mpg hwy</td>
<td>1.4X</td>
</tr>
<tr>
<td><strong>BASE MSRP</strong></td>
<td>$3,256.65 w 396 and 4-spd $23,464 (inflation adj.)</td>
<td>$36,905</td>
<td>↑ $13,441</td>
<td>(1.55X)</td>
</tr>
</tbody>
</table>
What if the Automotive Industry had achieved the incredible pace of innovation as the Semiconductor Industry?

A Rolls Royce would cost only $40 and could circle the globe 8 times on 1 gallon of gas.

Source: McKinsey report on semiconductor industry
…But Automotive Industry Innovated in Other Ways

All Enabled by Semiconductors
Innovation

- Leading-edge innovation
- Competitive cost
- Value creation
- Faster time-to-market
Changing Dynamics of Innovation

Traditional scaling is reaching its limits…
but the economics of Moore’s Law and innovation are still holding…

BUT

Yes, scaling can still drive down cost

It’s exponentially more costly to develop

Atoms don’t scale

Continued advances mean changing the way we think about innovation

Technical Innovation
• Material & Process
• Device Architecture
• Design-Technology Co-Optimization

Business Model Innovation
• Long-term R&D Focus / Investment
• Shared Investments / Learning / Reuse
• Consolidation and Collaboration

INNOVATION
Semiconductor Technology Evolution

“Disruptive” Innovations cornerstone of performance & density improvements

- Planar CMOS
- Gate Oxide Limit
- Planar Device Limit
- Atomic Dimension Limit
- Materials Innovations
- 3D FinFETs
- 3D Chip Stacking
- EUV
- Interconnect RC Innovation
- Vertical Nanowires
- CNTs
- III-V Devices
- 3D Multi-chip Stacking & Photonics

Source: IMEC 2014
Knowing what will drive growth…

- One technology doesn’t fit all
- Intelligence is inherent
- Understand and anticipate the needs of the market segments

…and how we meet it

- Growth in Mobile Computing
- Development in IoT Computing
- Emergence of Intelligent Computing
The Story of Connectivity

1965

Centralized Computing
Connecting with Centralized Data

1975

Personal Computer
Connecting with Distributed Data

1985

Networked Personal Computer
Connecting with Distributed Data & Each Other

1995

Internet and Wireless
Connecting with Each Other &
Commerce / Comms

2005

Mobile
Connecting Anywhere, Anytime

2015
The Story of Connectivity

Centralized Computing
Personal Computer
Networked Personal Computer
Internet and Wireless Personal Computer
Mobile

WHAT’S NEXT?

Transistor Growth

What Happens in an “Internet Minute”? An Explosion of Connectivity

- 2016 Internet users: 3.4B
- 2016 internet users as % of population: 46.1%
- 2016 mobile devices and connections added: 429 Million
- 2016 mobile devices and connections by 2020: 24 Billion

- 347,222 New tweets
- 2.4M Google searches
- 2.78 Million Video Views
- 51,000 apps downloaded
- 203,596 Amazon sales
- 150 Million emails sent
- 1,389 Uber Rides
- 63% mobile traffic grew from 2015 to 2016

An Explosion of Connectivity
Unprecedented Growth in Data

Every “Thing” will have a Radio

Estimates for number of “things” by 2020 range from 25B to 14T

Brontobyte
Hard drive would cover the earth 23,000 times

Zettabyte
1.3 ZB of traffic annually by 2016

Yottabyte
= 250 trillion DVDs

Exabyte

Terabyte

Petabyte

Gigabyte

Megabyte

Source: HP Information Optimization Press Conference 2012
Orchestrating the End-to-End – The next wave of Innovation

- **OBSERVE & SENSE**
  - Mobility
  - IoT
  - Automotive

- **COLLECT**
  - Wired / Wireless

- **DATA CENTERS**
  - Compute / Clouds

- **DECIDE & ACT**

- **REAL-TIME PROCESSING & RESPONSE**
  - Edge Computing

- **AGGREGATION**

- **PREDICTABILITY & RELEVANCE**

**CLIENTS**
- Automotive

**NETWORKS**
- 5G

**DATA CENTERS**
- Compute / Clouds

**REAL-TIME PROCESSING & RESPONSE**
- Edge Computing

**PREDICTABILITY & RELEVANCE**
The Engine of Connectivity Growth is Semiconductor Innovation

**More Computing Power**
Moore’s Law

**More Valuable Networks**
Metcalf’s Law

\[ V = n \cdot \log(n) \]

**More Communication Bandwidth**
Gilder’s Law

\[ \Delta B = 3 \times \Delta P \]

Source: Prof. N Venkatraman, Boston University
WHAT’S BEYOND NEXT?

SEMICONDUCTOR INDUSTRY IS AT A CROSSROAD

MOORE’S LAW IS CHALLENGED BY ACCELERATING COMPLEXITY
GLOBALFOUNDRIES CMOS Roadmap to Reshape Industry

Markets:
Servers, high performance computing and graphics, high-end smartphone, core networking

Premium Tier
Features:
High-performance, balanced-cost

High Performance Computing
- 7nm FinFET

Wireless, Battery-Powered Computing
- 12FDX™

Markets:
Low & mid-end smartphones, wireless, IoT, autonomous vehicles, mobile camera

Volume Tier
Features:
Low-power, cost-effective-performance, RF, embedded memory

- 14nm FinFET
- 28nm
- 22FDX®
- 40/55nm

the Right Technology for the Right Application™
22FDX® to Address RF/Analog Connectivity and Wireless Solutions
Superior RF/Analog for fT/fMAX, Power, Noise and Cost

The Right Technology for the Right Application™
The Semiconductor Industry Today –
Managing Complexity and Enabling Product Innovation with FDSOI

40% fewer masks
Lower mask cost
Reduced cycle time

FinFET performance & power
Superior Analog/RF
Performance on demand

Source: Based on GF internal assessments
Planar 22FD™ – Differentiated Technology
Embrace body-bias for product differentiation

22FDX™ Platform

- Energy efficient Turbo mode w/o reliability impact
- Adaptive Low-power and high-performance mode
- Standby mode leakage reduction
- Reduce cores/save area & cost
- Post-silicon tuning/trimming
- Increased dynamic range for RF
What Customers are Saying About FD-SOI

**Top business reasons to use FD-SOI**
- Product differentiation
- Shorter design cycle
- More design margin
- Robust, simpler design for AMS

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**Top technical reasons to use FD-SOI**
- Low Power
- Back-bias
- Analog (RF) / matching / gain

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### What Customers are Saying About FD-SOI

<table>
<thead>
<tr>
<th>Factor</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto: Reliability</td>
<td>10%</td>
</tr>
<tr>
<td>Auto: More stable thermally</td>
<td>10%</td>
</tr>
<tr>
<td>Analog: better RF / MXSL integration</td>
<td>15%</td>
</tr>
<tr>
<td>Analog: better gain</td>
<td>10%</td>
</tr>
<tr>
<td>Analog: better matching</td>
<td>10%</td>
</tr>
<tr>
<td>Lower defectivity</td>
<td>10%</td>
</tr>
<tr>
<td>Performance</td>
<td>5%</td>
</tr>
<tr>
<td>Manufacturability</td>
<td>5%</td>
</tr>
<tr>
<td>Being fully depleted</td>
<td>5%</td>
</tr>
<tr>
<td>Better radiation hardness</td>
<td>5%</td>
</tr>
<tr>
<td>RF</td>
<td>5%</td>
</tr>
<tr>
<td>Lower variation</td>
<td>5%</td>
</tr>
<tr>
<td>Lower leakage / parasitics</td>
<td>10%</td>
</tr>
<tr>
<td>ULV Io Vdd-Vmin</td>
<td>10%</td>
</tr>
<tr>
<td>BB gives more V variables</td>
<td>15%</td>
</tr>
<tr>
<td>Body biasing</td>
<td>15%</td>
</tr>
</tbody>
</table>

*Source: VLSI Research 2016; FD-SOI / 22FDX Customer Survey*
GF's 22FDX is the most radical departure from the main stream but also likely delivers the best density, RF and power performance."

– SemiWiki.com, April 2017

The 22nm node is now becoming one of the biggest battlegrounds in semiconductors

22FDX is clearly leading in Performance, Power, Area and Maturity
FD-SOI Will Become Standard for the Volume Tier

- Camera
- Computer Graphics
- NLP
- AR / VR
- Natural Interfaces for Input
- Real-time data processing
- Connectivity

Source: Companies, conference reports, IC Insights
FDX™ for Mobility

Application Tiers
- Low-Mid: On 22FDX® up-to 1.8GHz Quad-Core A53 (2.1GHz w/ body-bias)
- High: On 12FDX up-to 2.1GHz Octa-core (2.4GHz w/ body-bias)

Technology Capabilities
- 70% lower power than 28nm Poly/SiON
- 40-50% lower power for RF Tx/Rx than 28LPS
- Memory: Standby Leakage: ~6.5x lower, Dynamic Power ~2x lower
- Multiple Low-end smartphone libraries on 22FDX
- PMIC and RF integration

Value
- 22FDX has ideal PPAC for low-mid tier Mobility Baseband + AP, Embedded 4G transceiver integration & 5G mmWave Design
- 12FDX shows 10nm FinFET performance at 50% better power efficiency than 16/14FF
FDX™ for IoT

Application Tiers

- 22FDX® can cover 300 MHz to 1 GHz and above for ARM cores

Technology Capabilities (Available / In-development)

- Lower dynamic and leakage power vs. 40nm
  - Logic: 80% lower total power; operation down to 0.4v
  - Memory: 1pA/cell standby & 0.28v retention voltage
- High performance (RF) LDMOS for integrated PA and switch
- Connectivity: BLE/15.4, Wi-Fi, Cellular LTE Cat M/NB-IoT
- Body-Bias driven power management
- eMRAM for non-volatile memory

Value

22FDX is a great fit for wireless, battery-powered connected IoT clients that require ULP/ULL and performance-on-demand processing with integrated RF and embedded memory
FDX™ for 5G Transceiver + mmWave Radar

RF CMOS Application Tiers
- Sub 6GHz: Connectivity (BLE, Wi-Fi, Zigbee), Cellular (3G, 4G LTE, 5G)
- mmWave 77GHz: ADAS Radar, 5G

Technology Capabilities
- Enables new RF architectures w/ 35-50% die shrink (compared to 28poly) for LTE, WIFI and other wireless applications <6GHz
- Integrated mmWave PA with 15dBm PSAT via SOI-stacking
- Highest ft/fmax for 5G/mmWave
- Lowest power consumption for 5G mmWave handset single chip solution

Value
For sub-6GHz, 22FDX® offers
- Near 14FinFET performance but at much lower cost
- Higher gain, higher speed and lower power than 28nm, 40nm
World-class GF in-house RF IC / mixed-signal design team
FDX™ for Automotive

Application Tiers
- ADAS (Vision), Infotainment (IVI), Body Electronics MCU, mmWave Radar
- Automotive Grade 3, 2 and 1 rated

Technology Capabilities
- ADAS (Vision): Low Power (<5W), Processing < 1.2GHz, Auto Grade 2/1
- IVI: ~1GHz performance, Auto Grade 3/2
- MCU: MHz to < 1 GHz, 22FDX® + eMRAM + SRAM, Auto Grade 2/1
- mmWave: Key 22FDX mmWave advantage over 40 and 28nm
- Higher Pout on SoC for mid to long range radar single chip solutions
- @77GHz 10dBm <Pout <18dBm
- Stable Pout performance at 150°C (Grade 1)

Value
- 22FDX® offers a lower-power, performance-on-demand positioning for ADAS (Vision) capabilities for Autonomous driving Levels 1 to 3
- Is extremely well-suited for Local MCU, MCU32 with medium density NVM
- 22FDX mmWave is a key advantage for Automotive Radar System’s fT / fMAX
Feb. 2017 – First Silicon for ADAS Computer Vision SoC on 22FDX®

Advanced driver assistance system (ADAS) computer vision SoC developed for European THINGS2DO project with working first silicon fabricated on GLOBALFOUNDRIES’ 22nm FD-SOI Platform.

Collaborators:
Dream chip, ARM, Cadence, Arteris, INVECAS, GLOBALFOUNDRIES

Targeted use-cases:
- 360 degree Top View Camera
- Digital Mirroring
- Video Analytics – Object/Pedestrian Detection

Chip Carrier (SOM) – Chip and two LPDDR-Memories

Dreamchip Development board with socket for Chip Carrier
“Highly differentiated ultra low power 22FDX from GLOBALFOUNDRIES is the optimal technology for our FPGAs”

– Shen Lei
VP, Technology Engineering and QA
Shanghai Fudan Microelectronics Group Company Limited

“The Consumer and IoT markets are areas of significant importance for Sigma Designs, and we are always working cutting-edge products to meet the power and leakage envelopes. We see the GLOBALFOUNDRIES 22nm FD-SOI technology and software-controlled Body Bias in our designs as a necessary differentiator that will deliver to the market requirements for our products and customers”

– Thinh Tran
CEO and Chairman BOD, SIGMA DESIGNS

“For our last two automotive ADAS Multi-Purpose SoC tape outs, we have successfully used GF’s 22nm FD-SOI technology to boost performance. Besides new features such as Forward Body Bias (FBB), the support from the GF team was key for us to choose 22FDX. The technology is an excellent fit for today’s exciting new automotive designs with vision processing.”

– Dr. Jens Benndorf
Managing Director, COO
Dream Chip Technologies GmbH
What is “Beyond Next”?  

Technology and Business model Innovation will **Enable Moore’s Law**  

Semiconductor Industry Growth will Continue by Enabling **Connectivity Innovations**  

The Semiconductor Industry will continue to **Drive GWP***  

*Subi Kengeri on Techno-economics – ConFab 2014
Thank You

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