New Perspectives in Semiconductors
cycles, geopolitics, technologies & outlooks

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Who is TechInsights?

• World’s Largest Reverse Engineering Firm
  – Everything sized from Angstroms to Audi’s
  – Unmatched breadth knowledge of technology
  – 100’s of employees with deep engineering experience
  – Based in Ottawa, Canada
    • With private equity backing

• With a vision to build the world’s best technology information platform
  – Technology  – Market Research  – And More to Come

• Acquired VLSIresearch in 2021
  – “Because VLSI is the world’s best in market research”
    – Gavin Carter, CEO of TechInsights

• An explosive combination
  – Like Lava hitting the Sea
The Silicon Cycle
Has it moderated … or not?
Cliff Notes: The silicon cycle

• Demand side of cyclicality driven by Keynesian Acceleration Principle
  – Semiconductors follow 1st Derivative of the economy with weekly turns
  – Equipment follows 2nd Derivative

• Supply side driven by technology and lags
  – 2-3 years to build a fab
  – 2-3 years to ramp a node
    + 2-3 years to develop process & tools
  – 2-3 years to design a chip for a new node
  – Christmas driven demand cycle
What’s supply got to do with it?

The rule that large production ramps precede downturns is questionable at best.
What’s supply got to do with it?

• Supply is important, but it’s only half the equation
• Demand is other half
• Plus, technology, government, and business model shifts can change all outcomes

![Probability of Greater Demand after a Semiconductor Production Ramp](chart.jpg)

- 45% Probability of Positive Growth
- 55% Probability of Negative Growth

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What’s supply got to do with it?

The rule that large growth precedes big downturns is also questionable.
Problem with stochastic forecasting

- Cycle has always been bimodal
- Forecasters tendency to chase means
  - Especially when it comes to downturns
  - With a tendency to project out of recent trends

But if baselines are time and infrastructure dependent…
  - Chasing means is a fool’s errand
This Time it’s Different!

Every cycle is different
Recession Years: 2012-13

• Business Drivers
  – 2011 Memory Slowing

• Emergent Technology Drivers
  – 22nm node
  – HKMG and finFET
  – Fab white-space expansion model

• Triggers
  – GDP Slows
    • 2011 U.S. Debt Ceiling Crisis
    • S&P lowers U.S. credit rating
  – Foundry miss on 28nm
  – Smartphone Commoditization

<table>
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<th>Total Decline</th>
<th>Semi.</th>
<th>Elec.</th>
<th>GDP WW PPP Basis Pt Change</th>
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<tr>
<td>Semi. Equip.</td>
<td>-22%</td>
<td>-1%</td>
<td>3%</td>
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</table>

<table>
<thead>
<tr>
<th>Prior Peak Year</th>
<th>Semi.</th>
<th>Elec.</th>
<th>GDP WW PPP</th>
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</thead>
<tbody>
<tr>
<td>Semi. Equip.</td>
<td>103%</td>
<td>31%</td>
<td>19%</td>
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</table>
Recession Years: 2019

• Business Drivers
  – NAND Capacity transition

• Emergent Technology Drivers
  – HDD to SSD
  – Planar NAND to Vertical NAND

• Triggers
  – GDP Slows
  – Memory Capacity Glut
Why Growth has Risen off the 1995-2010 mesa

- **The Chip Insider**
  - *February 19, 2021:*
  - “In 2003, the first 300mm fabs were coming on line and were far more productive than 200mm. That 1997 cost number for a 200mm equated to almost $18-per-sq.cm., which was down to $8 in 2003 and hit a bottom of $5 in 2010.”

![Wafer Fab Cost vs the Semiconductor Equipment Market](chart)

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What's next?

- 200mm holiday is over
- More than Moore Capacity expansion is matching More Moore
  - Analog, Power, Chiplets
- More than Moore is no longer a friction source
- Discretes in the 90's: everything that could be integrated had been integrated

Moore than Moore Capacity
200mm Holiday Ends in 2020

Y/Y Growth


More Moore More than Moore

Nodes 11 Feb 22

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Market Outlook: Billions are no longer cool…
A only a Trillion Dollars is cool
Cliff Notes: Market Outlook

• Innovation is exponential
• Software is Hardware constrained for the foreseeable future
• Semiconductors are no longer the rust belt of technology
• Average Long Term Growth Forecast
  – 5% Electronics Market
  – 7% IC Market
  – 7% IC Equipment Market
  – 5% Silicon Demand
Long-term Semiconductor Outlook

### Decadal Trends
Where we’ll be in 10 Years
- **$283 T World GDP**
- **$1.3 T Semiconductors**
  - 9% Chip AGR
  - 0.47% IC Content
- **$0.33 T Equipment**
  - 29% Eq Content

### Decadal Trends
Where we’ll be in 10 Years
- 27 BSI Silicon
- **$48 RPSI**
  - 1% RPSI AGR
- 105 new GFES
  - 100% more fabs needed
SmartAuto: the new Queen of the Market

SmartPhones are no longer the growth driver

The Auto Industry is Reinventing itself Again with ADAS & Electrification

- EV ~ 7 X ICE Chip Content
- EV ~ 10X Growth Potential

Auto is the NBT displacing the out-of-breath Smartphone
Chip Innovation Engine Relentlessly Drives Opportunity

Macroeconomic
- AI-everywhere
- AR/VR
- Auto SDV, ADAS
- IoT, SSD
- Computational Medicine
- Data Center as a Profit Center
- Cloud Factory 4.0
- 3D Printing, Etching
- Quantum Computing

Semiconductors
- Law of PPACt
- Heterogeneous Integration
- GAA, GaN, CNT, 2D
- Compound Semi, DRAM, PCRAM, RRAM
- Nanosheets, DCTO
- AI-in-design

Equipment & Materials
- Multi-beam litho/inspection
- EUV revolution, Optical DW, Hi/NA-EUV
- Al-in-fab, CNT 2D, HAR ALE Q-ALE
- Advanced Assembly, EPE\LER, Hi/LoK, Curvilinear Masks
- Hi/NA-EUV, ALD, DSA, Dry Resist
- Materials System Engineering, Riblets
- Materials Enabled Scaling, Selective-dep/etch
- NGInterconnect
Chip Innovation Engine made possible by us…

DRAM 3D DRAM GAA-enabled Copper Low R Metal
DDR_{N+1}
ALD EPE\LER EUV revolution DCTO
HAR Gap Fill Co capping AL-in-fab
Selective-dep/etch NGMs Hi-Mobility Channel TSV
LoK Dielectric HKMG
Advanced Doping
Advanced Interface Engineering

NAND V-Limit: H-Scaling Low-Dishing CMP
ALE\_NG RRAM Hybrid W2W Bonding NPU xPU
PCRAM Hole-Thinning 3DNAND Hi-Modulus ON
CrossPoint DCTO NGM-Hard Mask
2D Nanosheets
CMOS Over/Under Array Zig-Zag Staircase
HAR Gap Fill
Advanced Interface Engineering
Optimized Implant/Anneal

LAP Logic, Analog & Power
EUV Hi-NA-EUV
Law of PPACT GaN TSV
Al-in-fab Curvilinear Masks
Heterogeneous Integration GAA
Materials Enabled Scaling hyper-NA-EUV
GAA\_enabled eDRAM
3D Logic NGM-Hard Mask
Chiplets CNT 2D
Dry Resist Compound Semi
Selective-dep/etch Advanced Interface Engineering
Near-Term Semiconductor Outlook

2023 Forecast: 581 $B  -6%
2022 618 $B  5%

Semiconductor Growth Forecast

Weeky Semiconductor Sales Growth

Updated: 21-Feb-23
IC Sales Growth: Overheated or Underheated?

Annual IC Sales Growth: Weekly Moving Averages

- Peak: 21 Sep 07
- +63% Peak: 26 Feb 10
- +13% Peak: 11 Jul 14
- +34% Peak: 22 Dec 17
- +34% Peak: 4 Feb 22
- -32% Bottom: 23 Jan 09
- -12% Bottom: 23 Mar 12
- -8% Bottom: 18 Mar 16
- -18% Bottom: 31 May 19

- Great Recession
- Sendai Earthquake
- The Great Bubble
- COVID
- Inventory Glut

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Trendlines to 2030

Path to a Trillion Dollars

Weekly IC Sales in $B (log Scale)

Great Recession
Sendai Earthquake
2018 Memory Bubble
Great Chip Shortage
COVID-19

$1T
$0.5T

2010 2015 2020 2025 2030

IC Sales 13 Week MA
IC Sales 52 Week MA
Poly. (IC Sales 13 Week MA)
Poly. (IC Sales 52 Week MA)

Semiconductor Analytics

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TechInsights’ IC Supply/Demand held in Tight conditions. IDM, OSAT, and Analog & Power all loosened this week. IDM went to Loose from Balanced, OSAT to Tight from Shortage, and Analog & Power moved from Tight to Balanced. The remaining segments stayed the same.
Electronics’ Retail Prices are trending down
What about Semiconductor Utilization?

- All sectors falling
  - Wafer Fab
  - Test
  - Packaging
- Off >10% peak levels
What about Planned Fab Capacity?

• Current plans add
  – ~25% of Current
  – 2.5x Average
What about Semiconductor Inventory?

- The Inventory-to-Billings Ratio is…
  - in an expansionary range
  - Above critical levels

- Customer complaints about extreme shortages were a sign of multiple bookings
Concerns

A Double Dip
Concerns

Inflation
Concerns

Hoarding
Thank You

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