New Trends and Perspectives on the Integrated Design Society

Nicky Lu, Ph.D., IEEE Fellow, NAE Member
CEO, Chairman and Founder, Etron Group
Board Chairman, GSA

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Key Driving Forces for IC Industry Growth

- **’70s**  Technology (Circuits): Pioneer or System House
- **’80s**  Manufacturing & Automation: IDM*
- **’90s**  VLSI Design: Fabless and Foundry
- **’00s**  Diversified Applications: System Chip & Cluster Model

*IDM means Integrated Device Manufacturer
Key Driving Force for IC Industry Growth

- ’70s Technology (Circuits): Pioneer or System House
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- ’90s VLSI Design: Fabless and Foundry
- ’00s Diversified Applications: System Chip & Cluster Model
- ’10s Life Effectiveness: Ubiquitous Integration of Human-Machine-ICs
- ’20s Fusion of Heart-Touching System into Life, Body, and Community: Heterogeneous Integrated Design & Architect

*IDM means Integrated Device Manufacturer
@Station of Brusselle City, Belgium
The Experience Economy*

- Experience ≡ Heart Touching
- Heart Touching Drives Service; Service Defines Products
- ICs are Cornerstones of Heart Touching Experiences

Work is Theater &
Every Business a Stage

Experiencing Riding the Cloud: Growth Opportunity for ICs

Heart-Touching Devices

Heart-Touching Services

Experience-Based Communication Networks

IC Suppliers
Business Dynamics in the Experience Economy

Leadership (Top-Down)
Support Organizations & Infrastructures:
Process & object-oriented
Business Dynamics in the Experience Economy

Life-Worth Experiences:
Joy, Wealth, Love, Peace

Resource Flow: Synchronized to Support

Heart Touching (Bottom-Up)
Experience Delivery
Channel: Human-oriented

Leadership (Top-Down)
Support Organizations & Infrastructures:
Process & object-oriented

Value Flow: Prosper and Touch Hearts

“For where your treasure is, there will your heart be also.”
- Mathew 6:21
Change Your Executive & Corporate Mindsets to Experience Success in New Economy

- Attract (the Cared): wow! the first time
- Serve (the Attracted): with heart
- Learn (the Process): with head
- Network (the Connected): in synergy
- Lead (the Assembly): by truth
- Transform (All): succeed with high-value products & platforms which can deliver Heart-Touching experiences
Moore’s Law*: Homogeneous Integration

- The number of transistors per square-inch doubles each 18 months

*Golden Moore: Co-founder of Intel, 1965
Meet Mr. Norte
One day he had an inspiration
He came up with a unique innovation
Other people liked it a lot
So he manufactured more side by side
Driving across wide landscapes, burning energy, causing noise...sweating a lot
But the houses were so far apart
It took him a long time to get from one side to the other side.
Another man visited Norte’s girlfriend in the meantime

Ms. User
So going from side to side was a setback
Norte came up with another innovation again
A stacked tower was the answer
Layers on top would be faster and more productive

Performance optimized,
Form factor shrunk,
Energy saved,
And GREEN!
Finally, this Heart-Touching Architect, Mr. Norte, and his beloved, Ms. User, lived happily ever after in 3D Towers!
Heterogeneous Integration* (HI) is Happening

- New System Chip Architecture: mD-IC (multi-Dimensional Die Integration Chip); m = 2, 2.5, 3, 4...

*e.g. RF or Power, Analog or Cache over SoC, Memory + Logic*

*After Nicky Lu, ISSCC 2004 Plenary Talk*
More HIs are Coming

- HI (mD-IC) ≡ Moore’s Law + 3D ICs + More than Moore + Novel Functions Created by Non-Silicon Contents
  - Inspire More Inventions & Innovations
  - Generate Higher Value
  - Create Diversified System Products
Trimodal I/O Interconnects for a 3D Chip Stack Using a Silicon Carrier*

*Copper TSV

*After Professor Jim Meindl, ISSCC 2010 Plenary Session
New Measurements in mD-IC Era

Moore’s Law
- More transistors in a 2D die area
- Monolithic Integration (MI) by using planar technologies in a single die
- 2X in 12 to 24 months
- 45-year progress will continue for another 2 decades

(G. Moore, Electronics 1965 & ISSCC 2003 Plenary Talk)

3D IC - Lu’s Metrics
- More functions per unit volume in a smaller footprint
- Heterogeneous Integration (HI) by using multi-dimensional stacked-die technologies
- Multiple-X every year?*
- Emerging as Application-driven, started in the 21st century and continuing

*Ho-Ming Tang (ASE) and Nicky Lu observed a linear increase in the number of devices divided by the cube root of total package dimensions on an exponential axis vs. time.

(Nicky Lu, ISSCC 2004 Plenary Talk)
Industry Business Structures are Varied in the Experience Economy (I)

Vertical Integration
IDM (Integrated Device Manufacturer)

Horizontal Segmentation
Fabless & Foundry

CVVI?!
Industry Business Structures are Varied in the Experience Economy (II)

- Clustered Virtual Vertical Integration (CVVI)
  - Co-Development by Companies
  - Integrated Knowledge Domains
  - Profit and Loss Sharing
  - Heart-Touching Experiences

- Versus Vertical & Horizontal Integration

After Nicky Lu, ISSCC 2004 Plenary Talk
Etron’s Product Portfolio

- Heart-Touching Customer Solutions: RAM & SerDes Chips, Platforms, Software, Multi-Dimensional Die Stacking Designs, etc.
- Known-Good-Die Memories (KGDM) of Premier Quality

Application Buffer DRAM

System Chips
- USB3.0 Host Controller
- USB3.0 Device Controller
- Webcam Controller

SRAM
- Pseudo SRAM
- Low Power SRAM

- Wide-Bandwidth DDR I/II
- Known-Good-Die DRAM
- Enduring SDRAM
- Low Power & Mobile DRAM
Etron Product Synergy is Aligned with Experience-Driven Mindsets

- Biological Processing is an Increasingly Important Analogy for Inspiring New Technologies

Buffer Memory & USB3.0 Flash Controller: Storing Experiences

Webcam Controllers: Capturing Experiences

Memory ↔ Logic

USB3.0 & High Speed Serial Links: Connecting Experiences
Etron KGDM Prevailing in 3D-IC

- Etron Started KGD Volume Shipments in 2000, and has Since Received the Intel Supplier Award and Many Other Accolades, and Shipped over 620 Million Units

- Monthly KGD Shipments Exceed 10 Million Units and Continue to Grow

- Applications Served by Etron’s KGD Solutions:
  - Multimedia/baseband chip in Cellular Phones, Digital Cameras, GPS Devices, PDAs, MP3s, Mobile TVs
  - TVs/Displays, Projectors, Rearview Monitors, Surveillance
  - Printers, HDDs, ODDs, Blu-ray DVDs, Graphics
  - Flash Combos
  - STBs
Growth Barriers for the IC Industry - Return on Investment Issues

- **Can a $300B Industry Sustain Building Future $10B Angstrom Fabs?**
  - Annual announced Capex has exceeded $45B in 2011
  - How much is the Industry's profit required to cover continuous Capex investments?
  - It’s hard for most Fabless to share the risk that Foundries have committed to take

- **How Many Times Can a Company Afford Each >$100M Design Failure?**
  - A few bugs can scrap a design investment
  - A few field-application or reliability failures can cause >2X penalties
  - Unexpected customer changes can force design termination

- **More Product Introductions have Suffered and Fallen off Cliffs**
  - Clones, copycats, overcompetition, last-minute changes in customers/suppliers...
  - Speculative patent litigation without solid grounds hurts productivity
  - Products do not have high value nor stay long enough to achieve returns
Do ICs Need a Renaissance?
Where is the new da Vinci?

- A painter, sculptor, musician, scientist, mathematician, anatomist, geologist, writer, cartographer, botanist, engineer, inventor, but
- The Broadest and Deepest Architect and Designer!

The most beautiful Lady & the most handsome body
Define mD-ICs Based on Vector Description I

Vector Axis Contents
- Axis Y0: Transistor, diode, etc.
- Axis Y1: IC die in silicon, GaAs, InP, etc.
- Axis Y2: Silicon Carriers, Active/Passive Interposer, etc.
- Axis Y3: A die-tower (Multiple Dies Stacked Vertically)
- Axis Y4: Multiple die-towers (Laterally Positioned)
- Axis Y5: Embedded active/passive in multi-layers substrates, superlattice, etc.
- Axis Y6: Optical/magnetic component
- Axis Y7: Bio sensor, life device, living electronics, etc.
- Axis Y8: Energy storage device, battery, etc.
- …Axis Y100 ~ Axis Y∞

For Example, mD = 2.5D* = Y1 + Y2 (+ Y0)
Define mD-ICs Based on Vector Description II

For Example, mD = 4D = Y2 + Y3 (3D) + Y4

- Vector Axis Contents
  - Axis Y0: Transistor, diode, etc.
  - Axis Y1: IC die in silicon, GaAs, InP, etc.
  - Axis Y2: Silicon Carriers, Active/Passive Interposer, etc.
  - Axis Y3: A die-tower (Multiple Dies Stacked Vertically)
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  - Axis Y5: Embedded active/passive in multi-layers substrates, superlattice, etc.
  - Axis Y6: Optical/magnetic component
  - Axis Y7: Bio sensor, life device, living electronics, etc.
  - Axis Y8: Energy storage device, battery, etc.
  - ...Axis Y100 ~ Axis Y∞
An Example of Heterogeneous Integrated Architecture

New Technology Frontier: DNA Synthesis

- Moving From Cutting-and-Pasting DNA to Programming DNA
- Carlson’s Curve Shows Exponential Growth that Exceeds Moore’s Law
- Analogous to Computer Science and Electrical Engineering, Humans are Breaking New Ground in Programming DNA

Source: The Economist, 2006
Living Electronics are Possible: Biological Memory and Counters in Living Cells

- Single Invertase Memory Module Encodes Memory in DNA Orientation
  
  ![Diagram of DNA orientation with invertase and read points](Image)

  GATTACA  
  CTAATGT

  OFF or ZERO  
  ON or ONE

- Single Invertase Memory Modules Enable Counter Circuits in Living Cells

  123456789

After Professor Timothy Lu, MIT (Source: Science 2009)
Define mD-ICs Based on Vector Description III

For Example,
\[ mD = 8D = Y3 + Y6 + Y7 + Y8 \]

- **Vector Axis Contents**
  - Axis Y0: Transistor, diode, etc.
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  - ...Axis Y100 ~ Axis Y∞

**Substrates**
- LED
- Solar cell/Battery function
- Optical function
- Bio function
The Integrated Designer & Architect Profession Born in the HI (mD-IC) Era

- "mD-IC Architect" Designs HI like Playing with LEGOos*
- The Best Architectures are Inspired by Heart-Touching Experiences, like da Vinci
- Today, Integrated Circuits Designers’ GDP < Semiconductor Products’ GDP
- IC Industry < Silicon Industry, but…

* The LEGO Group was founded in 1932
New Dream Paradigm for the Integrated Design Industry

- From Manufacturer to Designer to Heart-Touching Architect
- Today, IC Industry < Silicon Industry, but Tomorrow, Integrated Design & Architect (IDA) Industry Based on IC Industry > Silicon Industry
The New Uplifting Skills: CANDLES

- **Content**: Heart touching
- **Architect**: Lead by innovation & versatility
- **Network**: Open to connect in harmony
- **Dream**: Let creativity soar like an eagle
- **Life**: Care for living beings and the environment

**Effectuate:**
Design and realization (through “ISSCC - Integrated System, Software, Circuit, Chip” and more, e.g., Bio- & Battery-devices)

**Service:**
Be instruments to restore joy, wealth, love, and peace on earth
Key Messages

- Turning Executive Mindsets, Corporate Culture, and Business Strategies in the Face of the Emerging Experience Economy
- Driving Forces of the IC Industry Pushing toward Life Effectiveness & Fusion
- Upcoming Heterogeneous Integration is Generating Tremendous Opportunities for Integrated Designers and the Silicon Industry, while Creating Higher Values with Non-Silicon Technical Contents
- Business Model Evolving to CVVI (Clustered Virtual Vertical Integration) and IDA (Integrated Design & Architecture) Society
- Silicon-Only Product Revenue Can Hardly Support Huge Angstrom Fab and SoC Chip Investments, but HI and IDA will Boost Total Revenue to Support IC Industry Growth
- My Testimonial: Transforming Etron to New High Value-Added IDA Business Model that will Persist from the 2010s towards the 2030s
- Professional Skills Extending from Today’s Chip Design to ISSCC (Integrated System Software Circuit and Chip) and then CANDLES!
Etron is Very Open to Collaboration via Either Vertical Integration or Horizontal Engagement

- In the Coming Heterogeneous Integration Era, Etron Welcomes Collaboration with Companies under the CVVI Model
Thanks to Dr. TC Lee, Dr. John Chang (Etron), Dr. Cheng-Wen Wu, Dr. John Lau (ITRI), Dr. Ho-Ming Tang (ASE), and You, GSA Audience

Featured
Mr. Norte and Etron