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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Engineers Solving Problems from ESD to Education

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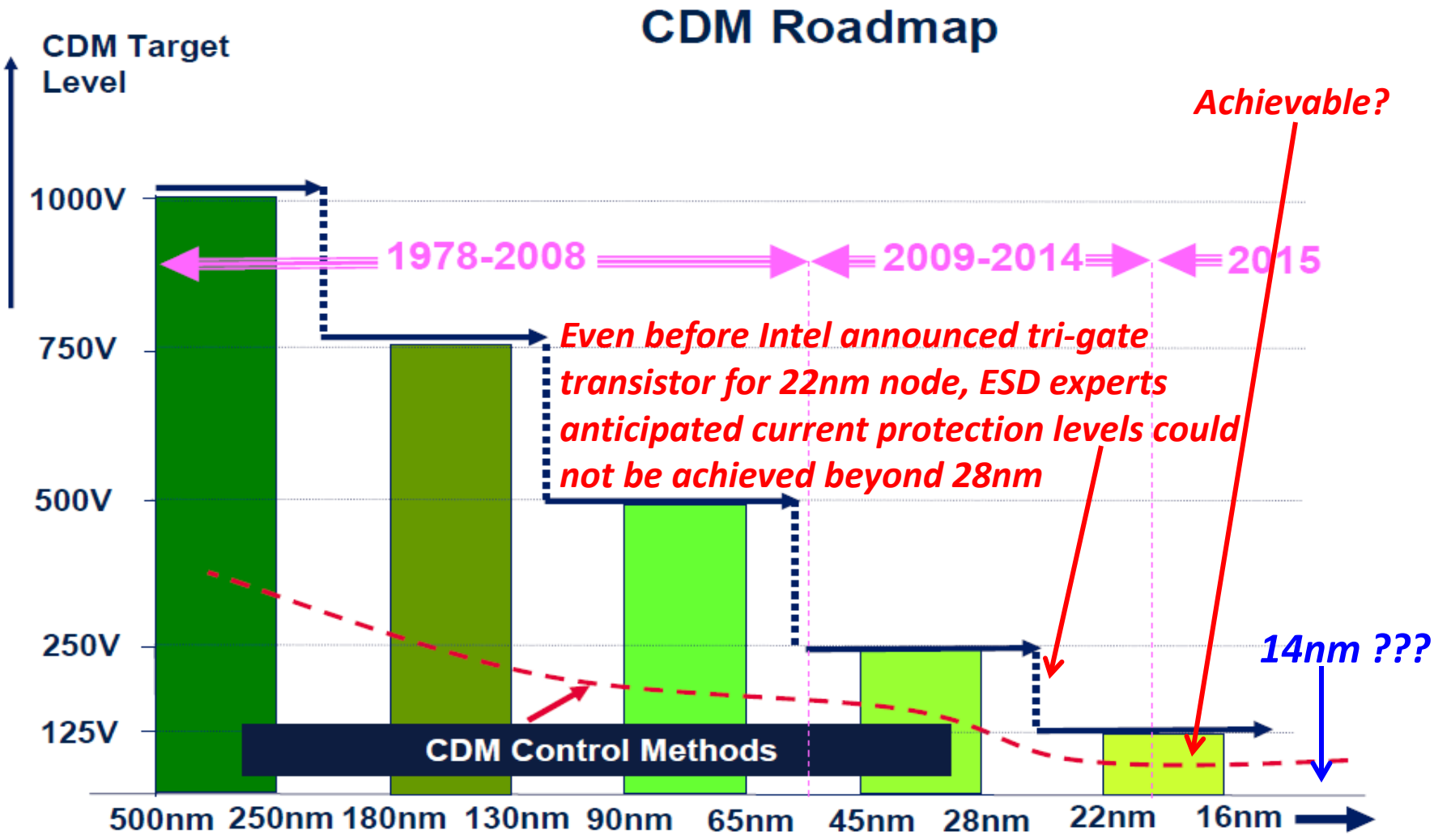
ESD: Bottleneck for IC Qualification and Reliability

- Electrostatic discharge: it's not going away
  - Triboelectric charging: a fact of nature
  - Field-induced charging in factories
- Technology trends make ICs more vulnerable
  - Feature size scaling
    - Reduced drain and gate breakdown voltages, higher interconnect resistance
  - Increased off-chip data-rates
    - Tighter limits on allowable capacitance
    - Large protection devices disallowed
  - Larger packages, more pins
    - Increased amount of stored charge, higher peak discharge current

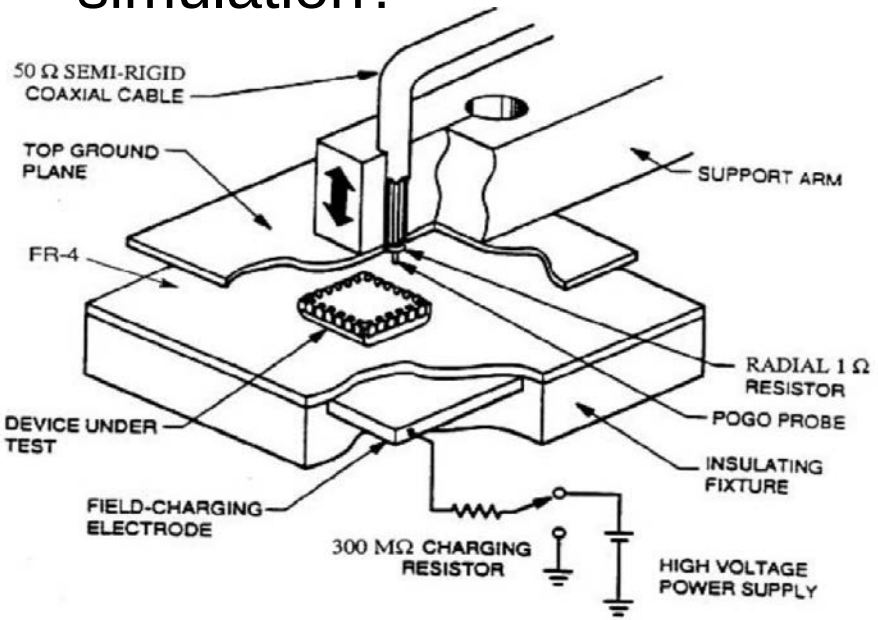
CDM-ESD Roadmap, circa 2009

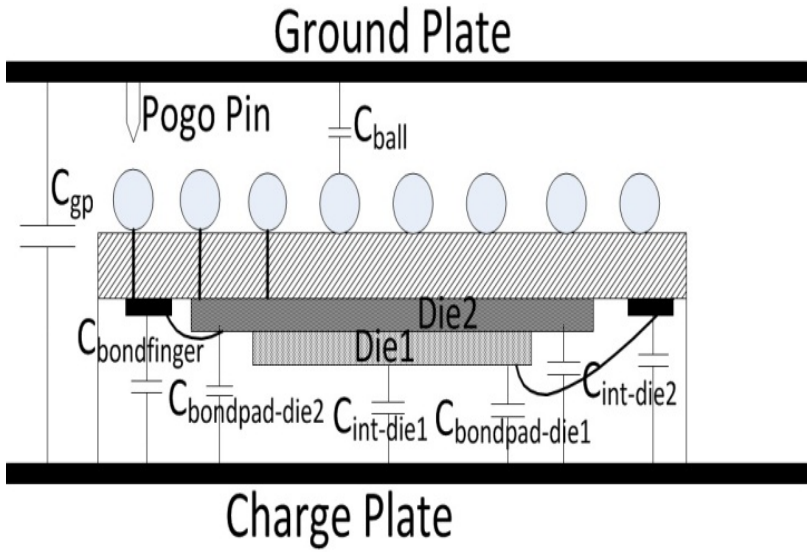


- CDM: “primary real world ESD event metric describing ESD charging and rapid discharge events in automated handling, manufacturing and assembly of IC devices” (JEDEC *JEP157*)

Simulation to the Rescue?

- IC designs are verified prior to tape-out using simulation
- Why not also verify the on-chip ESD network using simulation?



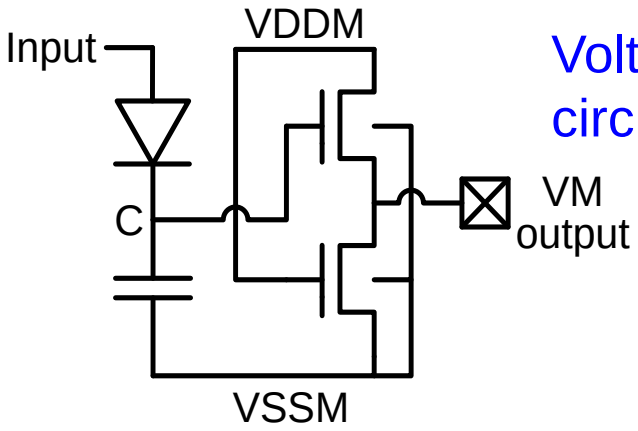


FICDM Tester (JESD22-C101E) Charge is stored everywhere!

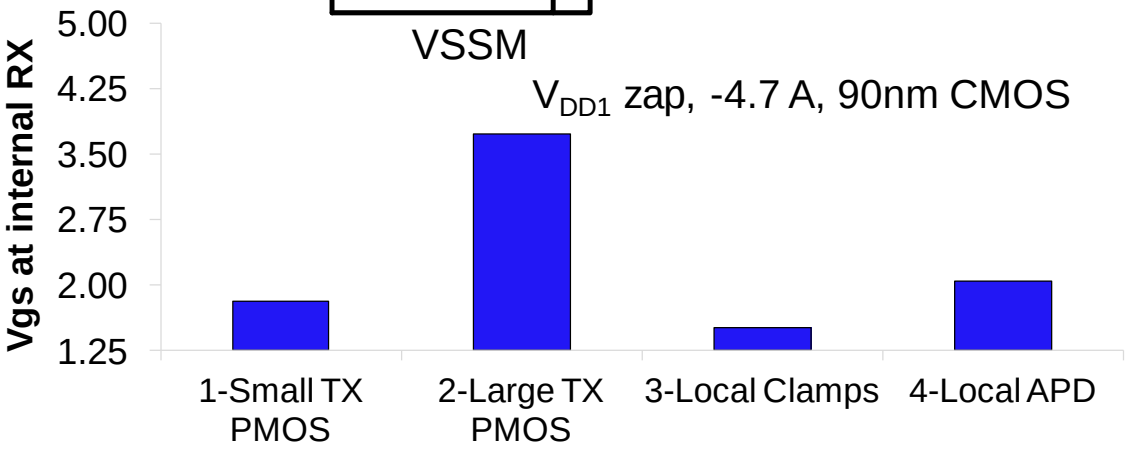
- Discharge network includes all on-chip protection devices, PDN, package traces, with decaps and other capacitors playing a role

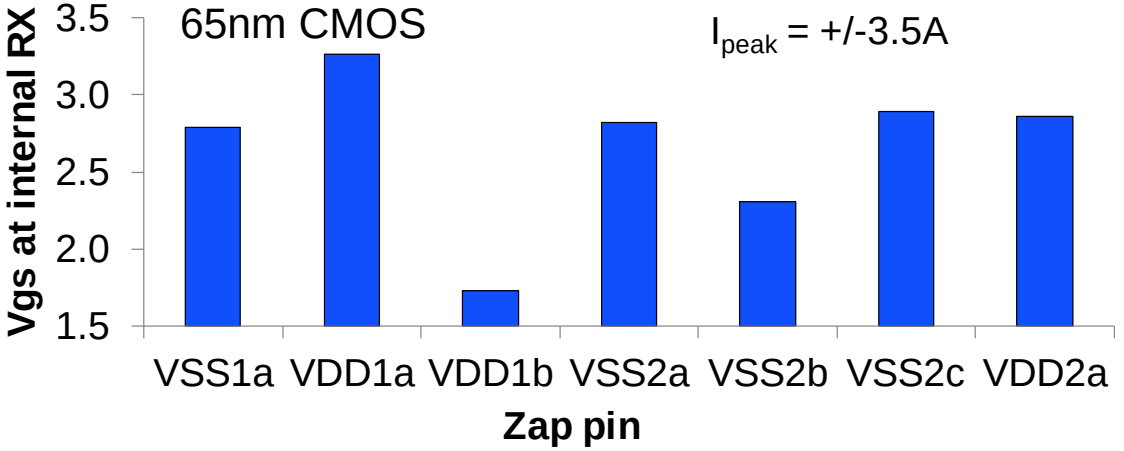
Making CDM Simulation Work

- Full component event, yet must limit size of model
  - To avoid sacrificing accuracy, must understand where and why IC failures occur; experimental studies are key
- Our contributions
  - Developed wafer-level CDM testers and techniques for probing waveforms on internal nodes of IC
  - On-chip voltage monitor: not erased by ESD I_{sub}, long retention time

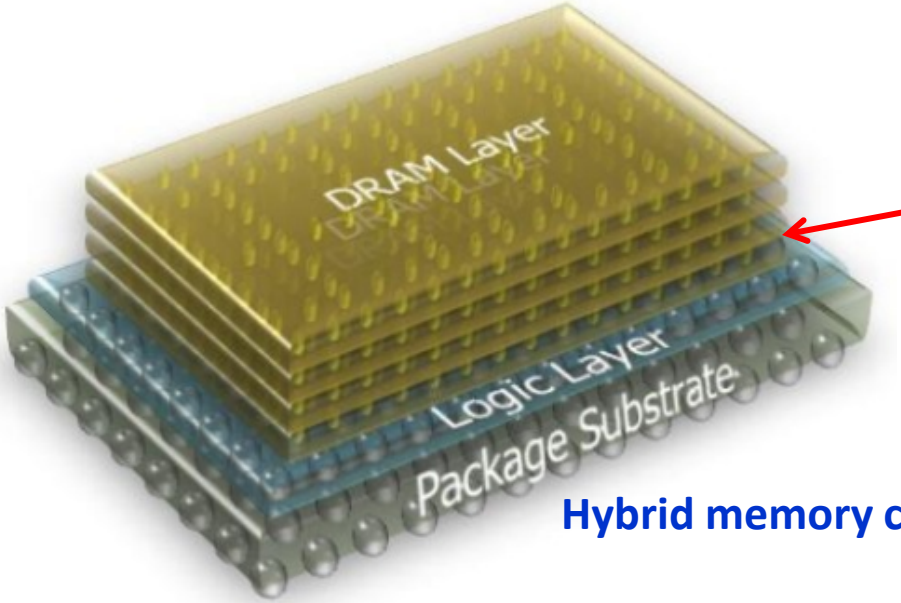


Voltage monitor circuit

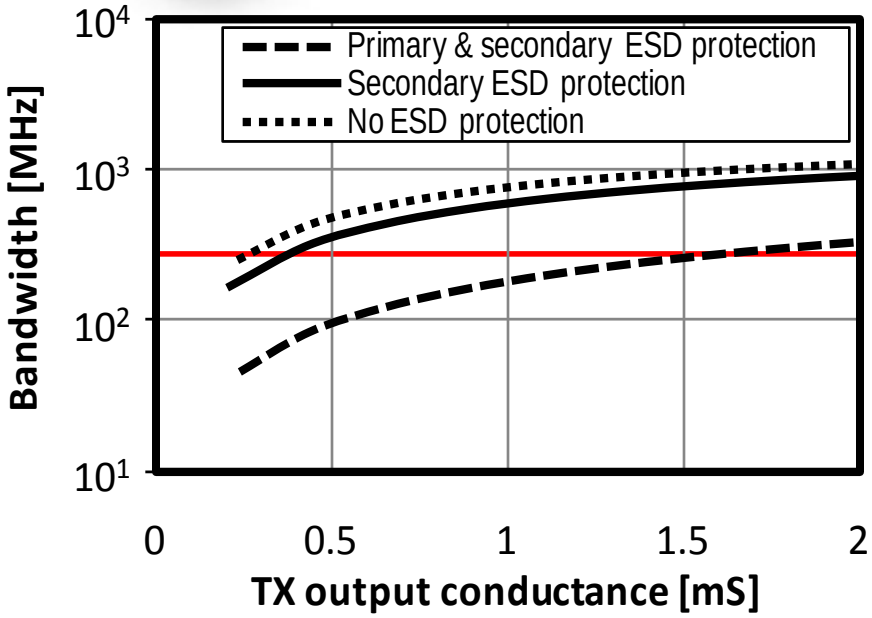




New Technologies, New Challenges



Hybrid memory cube



- Is ESD protection needed at inter-die interfaces?
- Reduces power benefits of 3D integration
- (Our) analysis: small voltage clamp provides sufficient protection if dies connect to a common ground bus
- Addresses ESD qualification, what about 3D assembly?
- Are rail clamps needed on all die or just bottom?

Full Employment

- My graduate students
  - Contribute to solving a very important problem
  - Study electromagnetics, circuit design, semiconductor device physics, technical writing
  - **Are highly sought after by employers**
- Can we conclude that, despite 7.9% unemployment (USA, Nov. 2012), there are jobs available for people with the right education?

Political Rhetoric

And fifth, we will champion SMALL businesses, America's engine of job growth. That means reducing taxes on business, not raising them. It means simplifying and modernizing the regulations that hurt small business the most.

Candidate Romney's 5-point plan for the economy

Is this begging the question? Are there too few jobs right now??

Engineering Job Vacancies in the U.S.

- “For the second year in a row, engineer is the hardest job to fill in America.”
  - T. Weiss, “The 10 hardest jobs to fill in America,” *Forbes.com*, June 3, 2009.
- “If you’ve got the skills, she’s got the job”
  - T. Friedman, *New York Times,* Nov. 17, 2012.
  - Sheet metal company seeking welders, but applicants “did not understand metallurgy, modern cleaning and brushing techniques and how different metals and gases, pressures and temperatures had to be combined”
  - “Welding is now a STEM job.”

Too Few Engineers

- Facts and figures
  - In 2009, only 5% of bachelor's degrees were awarded for study in engineering (Nat'l Ctr. Education Stats.)
  - Must add engineering to the K-12 curriculum (NAE)
    - Increased awareness of engineering and the work of engineers
    - Interest in pursuing engineering as a career
- Engineers must take an active role in developing the curriculum
- We understand that *engineering is the creative application of science and mathematics for the benefit of humankind*
- We can show children what it is we do, and ensure they receive technically accurate information
- Engaging children in <u>meaningful</u> design projects is key

Industry Example: Microsoft

- N. Wingfield, “Fostering tech talent in schools,” *New York Times,* Sept. 30, 2012
- “Likely to be 150,000 computing jobs opening up each year through 2020 [ACM]” but “fewer than 40,000 American students received bachelor’s degrees in computer science during 2010”
- “110 engineers from high-tech companies” in “Microsoft program aimed at getting high school students hooked on computer science, so they go on to pursue careers in the field”
  - Participants commit to teaching a high school computer science class for a full school year
- “Volunteers have little teaching experience”
- Don’t know how to “manage unruly teenagers”
- Make mistakes such as preparing lengthy powerpoint presentations

University Example: UIUC

- Train graduate students to do engineering outreach
- Post-graduation, they will be well equipped to participate in and even lead outreach programs
- Instruction
  - Lesson plans, assessment, educational psychology of middle school students, diversity and inclusion, grant proposal writing
- Practicum: each Friday in the same middle school classroom
  - Present a real-world problem and challenge students to solve it via design; lesson plan vetted in advance by an experienced middle school science teacher
  - Four weeks per project

Previous Programs

- Science outreach training for graduate students
  - Practicum at Boys and Girls Club (2011), middle school (2012)
  - Did not focus on design and engineering
- Introduction to engineering for 5th graders
  - Featured topics were relevant to my group's research
    - Microelectronics, Waves, Static Electricity, Heat
  - Demos and discussions designed to show students how we use math and science to do useful things
  - Early awareness of engineering as a career is important; motivate students to take elective math and science courses in high school
    - Not truly elective for students who wish to matriculate in a 4-year engineering undergraduate program
- Workshops for teachers

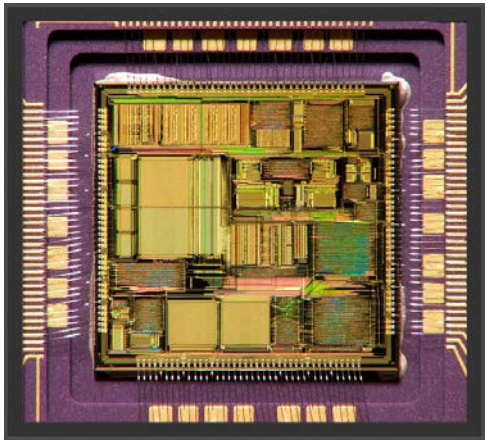
Talking to the Layperson

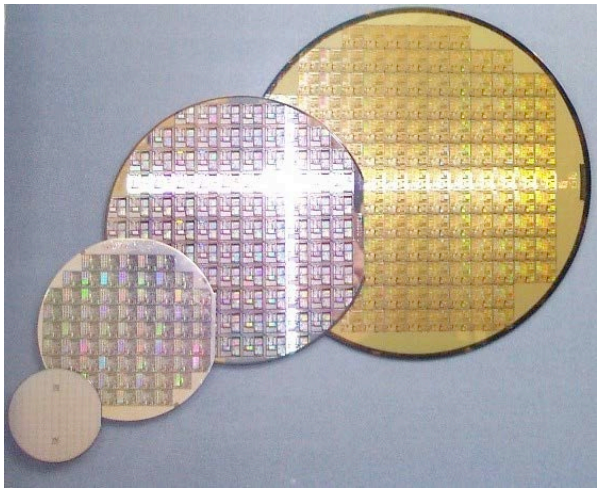
- Do you know how to show someone who doesn't have a Ph.D. in EE what it is you are working on?
- Know the audience's science background
- Emphasize hands-on active learning over lectures
- Let's look at some material we used to familiarize kids with our research

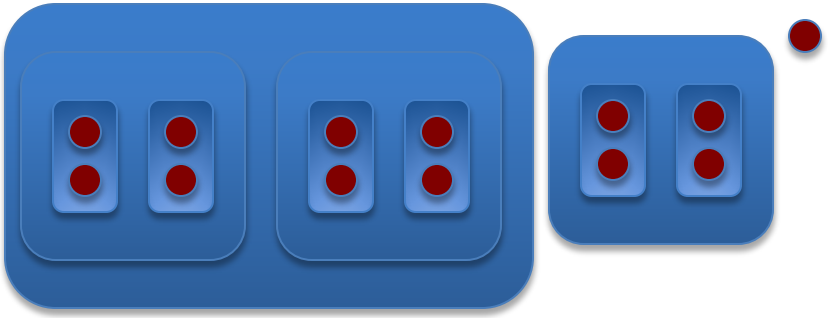
What the Kids Knew Before

- The Nature of Matter: electrons, protons, neutrons
- Electricity and simple circuits

What They Learned Anew: Microelectronics







8	4	2	1
2^3	2^2	2^1	2^0
1	1	0	1

New Learning: ESD

Positive: Lowest electron affinity

Dry Human Skin
Leather
Glass
Human Hair
Nylon
Wool
Fur
Silk
Paper
Cotton
Wood
Hard rubber
Polyester
Styrofoam
Saran Wrap
Polyurethane
Polyethylene (scotch tape)
PVC
Teflon

Triboelectric charging

Negative: Highest electron affinity

Demos: Electrophorus & Leyden Jar