nanoFabrics
15-849C Lecture 2

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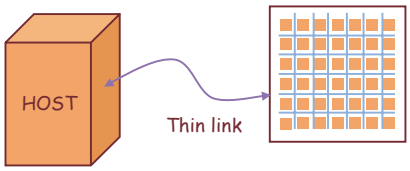
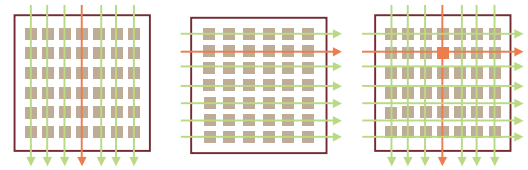
Dealing With Defects

- Need to discover the characteristics of the individual components, but
- Can't selectively stimulate or probe the components
- Download test machines



Built-In Self-Test

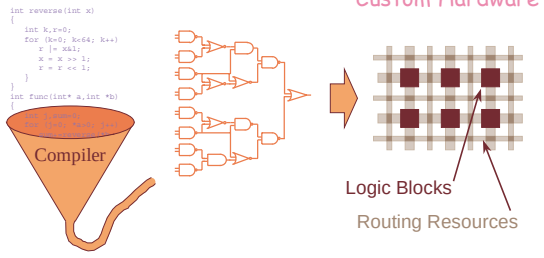


Configure testers vertically | Configure testers horizontally | Identify fault!

Configure the device to test itself!

Reconfigurable Computing

General-Purpose | Custom Hardware | General-Purpose Custom Hardware



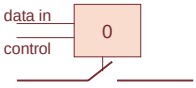
Advantages of Reconfigurable

- Flexibility of a processor
- Performance of custom hardware
- Defect Tolerant

Heart of an FPGA

The cost of the FPGA:
Increased Area-Delay Product

Universal gate = RAM



Switch controlled by a 1-bit RAM cell

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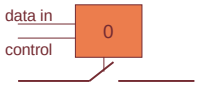
Heart of an FPGA

The cost of the FPGA:
Increased Area-Delay Product

- RAM cell

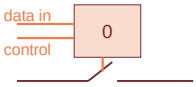


Switch controlled by a 1-bit RAM cell

Heart of an FPGA

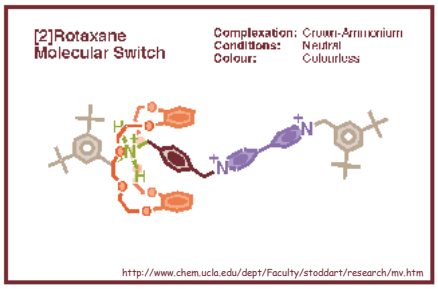
The cost of the FPGA:
Increased Area-Delay Product

- RAM cell
- Wires to program RAM cell



Switch controlled by a 1-bit RAM cell

Key Component: Reconfigurable Switch



Key Component: Reconfigurable Switch

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Key Component: Reconfigurable Switch

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Key Component: Reconfigurable Switch

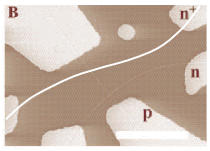
[2]Rotaxane Molecular Switch

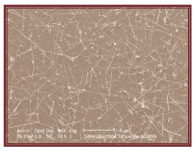
Complexation: Crown-Ammonium
Conditions: Neutral
Colour: Colourless

Reconfigurable Molecular Switch
- Holds its own configuration state
- Can be programmed with the signal wires

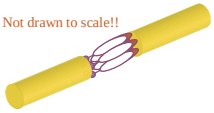
Wires

- Small ($\geq$ 2nm)
- Long ($\leq$ 3000nm)
- Excellent conductors
- Examples:
  - Carbon nanotubes
  - Silicon nanowires
  - Functional wires





Not drawn to scale!!



Chung, Yu & Heath (2000); *Cui and Lieber (2001); PSU (2000)*

Devices

- What you would expect:
  - Resistors
  - Diodes
  - Negative Differential Resistors (NDRs)
  - Transistors
  - Reconfigurable Switches
- Molecules are "easily" engineered
  - E.g., Diodes with 0.1V turn-on
  - MANY MANY possible molecules

What Can We Expect?

- $\geq 10^{10}$ gate-equivalents/cm^2
- $\leq$ 1 Watt/cm^2
- $\leq$ nanocents per gate
- $\geq 10^{11}$ ops/sec
- High defect densities

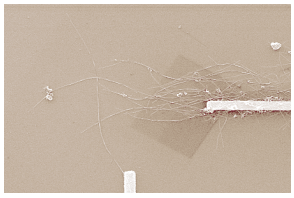
Fabrication Is Different!

- Electronic nanotechnology separates:
  - Manufacturing of devices
  - Fabrication of the circuit
- Manufacture wires and devices
- Somehow glue them together

Assembly, Assembly, Assembly

Parallel Wires

- Can align wires
- Can mix types of wires
- Not precise



UCLA (2000); PSU(2000)

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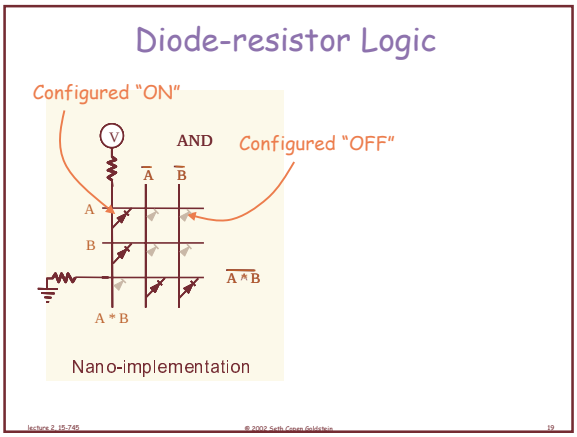

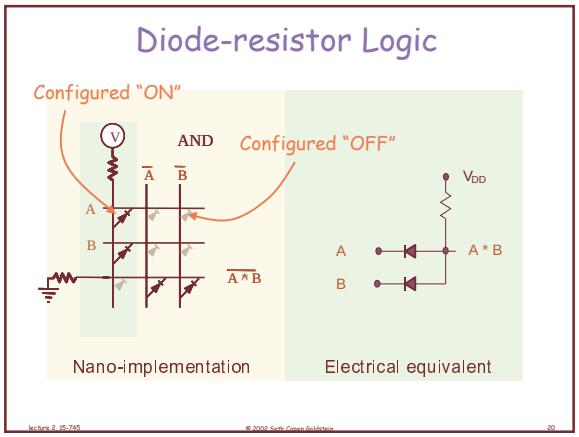

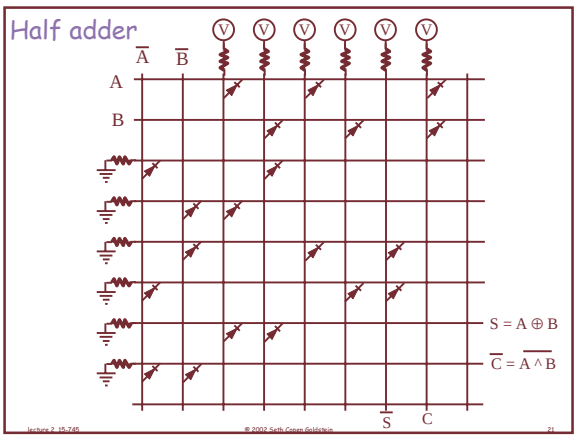

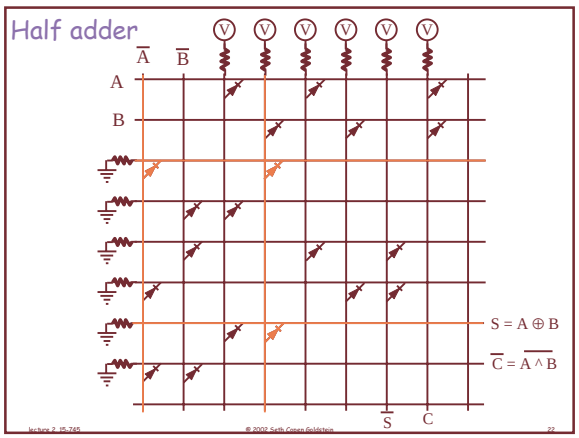

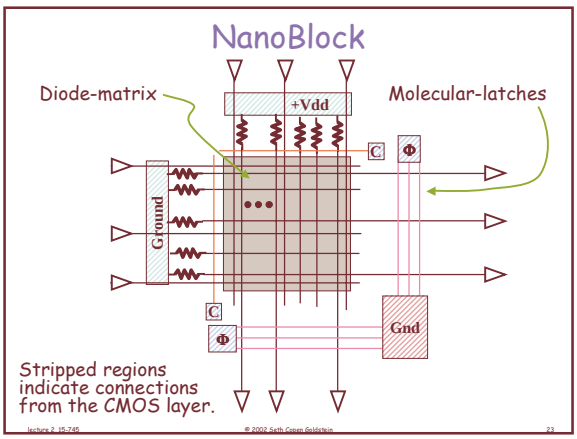

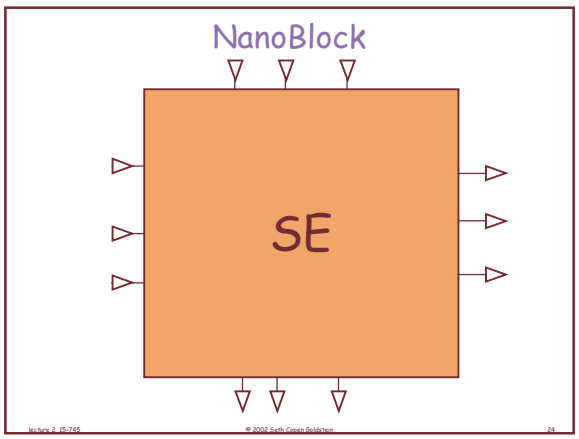

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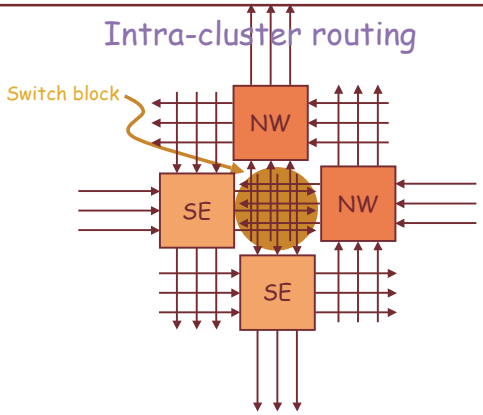
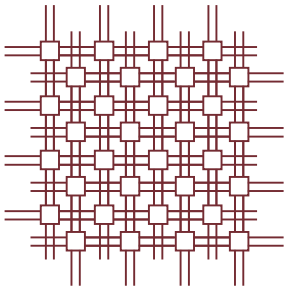
Intra-cluster routing

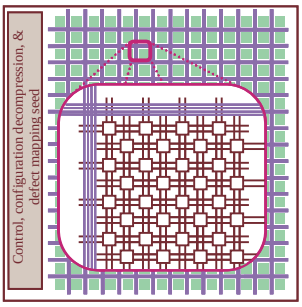


Cluster of NanoBlocks



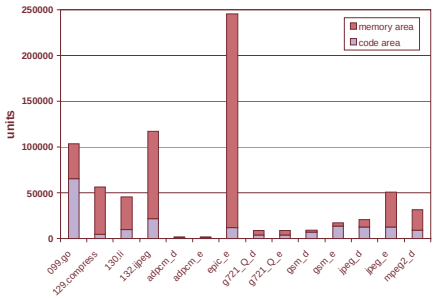
The NanoFabric

- Nanoscale layer put **deterministically** on top of CMOS
- Highly regular
- ~10^8 long lines
- ~10^6 clusters
  - Cluster has 128 blocks

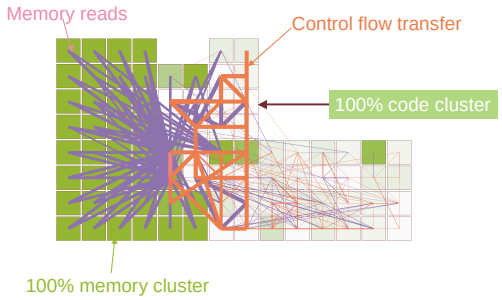


Area

(10^6 units/cm^2 available)



Typical Program Graph (g721_e)



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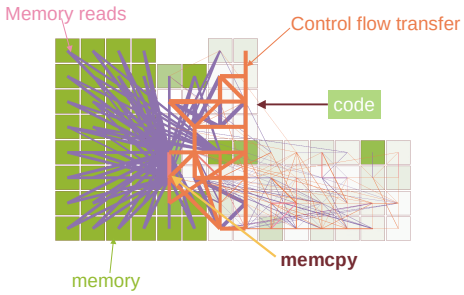
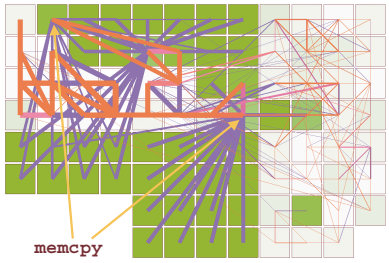


Program Graph After Inlining `memcpy`



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