Physical Synthesis:
The Good, the Bad, and the Ugly

Charles Alpert
Manager, Design Productivity Group
IBM Austin Research Laboratory
The Nuisance Factor
Decisions with High Nuisance Factors
Low Nuisance Factors
The Nuisance Curve of Decision Making

- High Nuisance
- Low Nuisance

Payoff point
Feel good point
What about these Nuisance Curves?

- Good Decision
- Bad Decision
- Ugly Decision
Why Do We Still Do Custom Design?
Why Do We Still Do Custom Design?
Why Do We Still Do Custom Design?
The Story of Xiang Yu
Too Many Doors for Design
The Birth of Physical Synthesis

Manual Flow

- Placement
- Gate Sizing
- Buffering
- Timing Analysis
- Re-synthesis

Physical Synthesis

- Legalization
Physical Synthesis Comes of Age

Back then

Placement

Timing

Synthesis

Legalization

Today

Routing

Power

Clocks

Layer Opt

Placement

Timing

Synthesis

Legalization
Constructive Versus Polishing
Example Physical Synthesis Flow

- Global Placement
- Electrical Correction
- Legalization
- Timing Analysis
- Critical Path Opt.
- Compression

- Timing Analysis
- Net Weighting
- Area Recovery
- Detailed Placement
- Electrical Correction
- Critical Path Opt.
- Compression
More Mature Physical Synthesis Flow

Which Toys are the Best Value?

- Global placement
- Cell movement
- Pin swapping
- Detailed placement
- Cloning
- Vt assignment
- Layer assignment
- Routability analysis / recovery
Good: Global Placement
Good: Global Placement
Force Directed Placement
Potentially Big Congestion Reduction
Big Block Placement: Good, Bad, Ugly?

Hand Placed Blocks

Automatic Block Placement
Handling Pipeline Paths: Ugly

- High net weight
- Feasible Region
- Higher net weight
Example Four Cycle Path
What about Buffering?
What about Buffering?
Interference From Other Logic
Interference From Other Logic
Interaction of Optimization and Legalization
The Purpose of Legalization
An Ugly Legalization Problem
A Closer Look
Does a Cell Fit?
Good: Optimization of Flat Design
Bad: Hierarchical Design
Getting Across Town
Fat Metal Wires Are Freeway Overpasses
What is Wire (Interconnect) Synthesis?
What Does Wire Synthesis Really Mean?
What Does Wire Synthesis Really Mean?
Buffering Restricts Global Routing
The Academics: Wire Synthesis in the 1990s

Optimal Wire Shape

Simultaneous Buffering and Wire Tapering
Was Wire Tapering Worthwhile?

- Routers could not handle these structures well if at all.
- Even with simultaneous buffering, results close to tapering.
- Theoretical formula: 3.5% difference in optimal cases.
1990s Uniform Wire Sizing in Optimization
Performing Layer Assignment

4x
2x
1x
Slew Based Wire Synthesis

Slew constraint still cannot be met.

Slew constraint cannot be met, so bump up to higher layer.
Delay – Based Wire Synthesis (X = 5 ps)
Layer Assignment in Physical Synthesis

- Global Placement
- Electrical Correction
- Legalization
- Timing Analysis
- Critical PathOpts
- Compression
- Layer Recovery

Slew WS

Delay WS (X=5 ps)

Delay WS (X=20 ps)
Ugly $\rightarrow$ Bad, But Not Yet Good
Power Management

- Circuit techniques (power gating, voltage islands)
- Primary algorithmic technique: vt assignment

<table>
<thead>
<tr>
<th>Library</th>
<th>Relative Delay</th>
<th>Relative Leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>High vt</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Regular vt</td>
<td>0.8</td>
<td>3</td>
</tr>
<tr>
<td>Low vt</td>
<td>0.6</td>
<td>25</td>
</tr>
</tbody>
</table>
Vt Assignment Strategies

Start with all high vt
- Run physical synthesis
- Local, incremental vt assignment

Start with all low vt
- Run physical synthesis
- Perform vt recovery

On the border between good and bad
The Future?

Today

Routing  Power
Clocks  Layer Opt
Placement
Timing  Synthesis
Legalization

Floorplanning
Yield  Statistical
Routing  Power
Clocks  Layer Opt
Placement
Timing  Synthesis
Legalization
Why Do We Still Do Custom Design?
The Power of Our Friends
Grass Roots Change
Grass Roots Change
Grass Roots Change
Grass Roots Change
You see, in this world there's two kinds of people, my friend: Those with loaded guns and those who dig. You dig.

- Blondie

You see, in this world there's two kinds of people, my friend: Those in charge of the design tools and methodology and those who design. You design.