Post-Floorplanning Power/Ground Ring Synthesis for Multiple-Supply-Voltage Designs

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Outline

• Introduction
• Problem Formulation
• Algorithm
• Experiment Results
• Conclusion
Voltage Island & Power Ring

- Multiple-supply voltage (MSV) design
  - Power rings enclose the voltage islands
  - Each voltage island has its individual power ring

- MSV complicates the power-ring synthesis
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Problem Formulation

• Inputs:
  – An MSV floorplan

• Objective:
  – Identify the voltage islands
  – Find the power ring of each voltage island
  – Minimize the number of corners in the power rings
IR Drop and Corners in Power Rings

- The fewer corners in power rings, the less IR drop in power rings

# of corners = 4
IR drop = 4.49 e-02

# of corners = 8
IR drop = 11.94 e-02
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• Introduction
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• Algorithm
  – Voltage-Island Identification
  – Voltage-Island Boundary Search
  – Power-Ring Corner Patching
• Experiment Results
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Voltage-Island Identification

• A voltage island consists of several circuit blocks
  – Operate at the same supply voltage
  – Are adjacent to at least one circuit block in the island

• Check the adjacencies block by block

five voltage islands
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Straightforward Approaches, but……

- **Straightforward, but incorrect approaches**
  - **Edge-overlap approach**
    - If the edges overlap no other edges, they are assumed to be the contour edges
    - Cannot distinguish these lightly shaded segments
  - **Line-sweeping approach**
    - Determine if an edge is a contour segment when the scanning line sweeps the edge
    - Hardly indicates which parts are outer boundaries
Properties of Contour Sequence

- **Counterclockwise** trace vertical and horizontal contour segments
  - From the segment **with the smallest x and y coordinates**

![Diagram](image)

- $S_x^* = <x_1, x_2, x_3, x_4, x_5, x_1>$
- $S_y^* = <y_1, y_2, y_3, y_4, y_5, y_1>$

**Increasing**

**Decreasing**

Vertical segments

Horizontal segments
Properties of Contour Sequence

- If tracing does **NOT** start the segment with the smallest x and y coordinates
  - The sequences are still composed of alternate increasing and decreasing subsequences
  - **BUT**, may **NOT** start and end in increasing and decreasing subsequences, respectively

```
S_x = <x_2, x_3, x_4, x_5, x_1, x_2>

S_x^* = <x_1, x_2, x_3, x_4, x_5, x_1>
```

Both of \(<x_2, x_3>\) and \(<x_1, x_2>\) are increasing subsequences

vertical segments
Vertical and Horizontal Inversions

- Occur when sequences change from increasing to decreasing, and vice versa

\[ S_x = \langle x_2, x_3, x_4, x_5, x_1, x_2 \rangle \]

\[ S_y = \langle y_1, y_2, y_3, y_4, y_5, y_1 \rangle \]
Voltage-Island Boundary Search

<table>
<thead>
<tr>
<th>( d_\sigma )</th>
<th>( d_\sigma' )</th>
<th>no inv.</th>
<th>vertical inv.</th>
<th>horizontal inv.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RU/(RD)</td>
<td>RU/(RD)</td>
<td>DR/(UR)</td>
<td>UL/(DL)</td>
<td></td>
</tr>
<tr>
<td>LD/(LU)</td>
<td>LD/(LU)</td>
<td>UL/(DL)</td>
<td>DR/(UR)</td>
<td></td>
</tr>
<tr>
<td>UL/(UR)</td>
<td>UL/(UR)</td>
<td>LD/(RD)</td>
<td>RU/(LU)</td>
<td></td>
</tr>
<tr>
<td>DR(DL)</td>
<td>DR(DL)</td>
<td>RU/(LU)</td>
<td>LD/(RD)</td>
<td></td>
</tr>
</tbody>
</table>

- point \( \sigma \)
- point \( \sigma' \)

- inversion
- searched contour
Correctness of Voltage-Island Boundary Search

1. Start at the correct beginning
   • Start at the point with the smallest y coordinate
   • Set the beginning direction pair to RU

2. Prove that the succeeding point must exist
   • It must exist in the directions indicated by the direction pair

3. Make a correct inversion detection
   • Correctly detect inversions if they exist
   • Correctly change the direction pair
Summary
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• Introduction
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  – Voltage-Island Identification
  – Voltage-Island Boundary Search
  – **Power-Ring Corner Patching**
• Experiment Results
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Power-Ring Refinement

• Make power rings more regular for IR-drop reduction
• Use whitespace for power-ring refinement
Power-Ring Corner Classification

- **Double joints**
  - *Individually* extend vertical and horizontal contour segments
  - A double joint is enclosed by *one* extended and *three* original segments

Here is a double joint while extending vertical segments

Here is no double joint while extending horizontal segments
Power-Ring Corner Classification

- Single joints
  - Simultaneously extend vertical and horizontal contour segments
  - A single joint is enclosed by two extended and two original segments

NOTE: This is a double joint
Complete Whitespace for a Corner

• The whitespace can fill the corner

Complete whitespaces for the double/single joints

No complete whitespace for this single joint
Power-Ring Corner-Patching Flow

- Patch *double joints*
  - Update contours
  - Any adjustable *double joints*?
    - YES
    - NO

- Patch *single joints*
  - Update contours
  - Any adjustable *single joints*?
    - YES
    - NO

Done
Optimality of Power-Ring Corner Patching

• Filling single joints will not induce double joints
  – The corner-patching flow is correct

• Power-ring corner patching optimizes (minimizes) the # of corners in power rings
  – There is no complete whitespace left
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IR Drop & # of Corners

- Corners in a power ring induce IR drop
Experimental Results – Corner Patching

- All running times are less than 0.06 second
  - 2.2 GHz CPU and 8 GB memory
Experimental Results -- Layouts

double joint

n30

single joint

n50
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Conclusion

- Proposed an algorithm for power-ring synthesis for multiple-supply-voltage design
  - Voltage-Island Identification
  - Voltage-Island Boundary Search
  - Power-Ring Corner Patching
Thank You!
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Correctness of Direction-Pair Switch

- Assume the current direction pair is RU

![Diagram showing direction pairs RU and DR with vertical inversion, and RU and UL with horizontal inversion.](image)