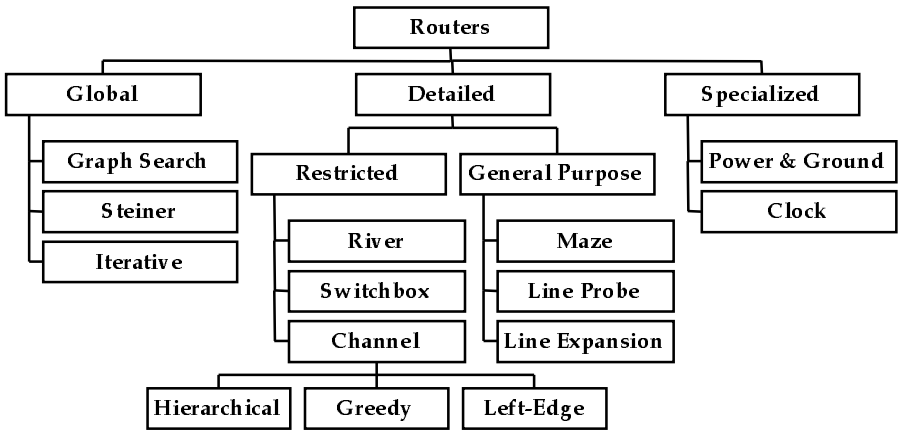
EE244: Design Technology for Integrated Circuits and Systems

Outline

Lecture 3.2

- Introduction to Routing
- Area Routers
- Channel Routing
  - Greedy
  - Left-Edge Algorithm
  - Yoshimura & Kuh
  - YACR

Taxonomy of VLSI Routers



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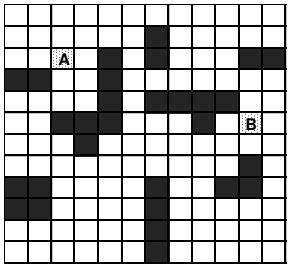
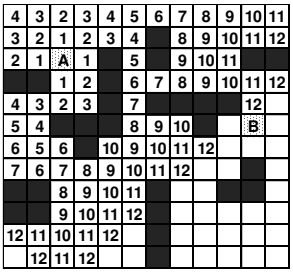
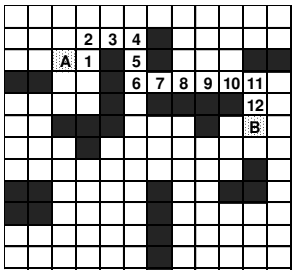
Maze Route: Lee Path Connection Algorithm



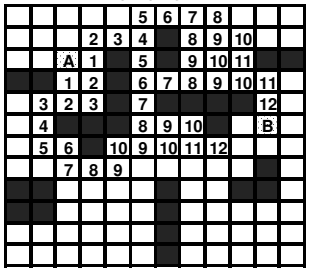
Point-to-point, single layer



Wavefront propagation

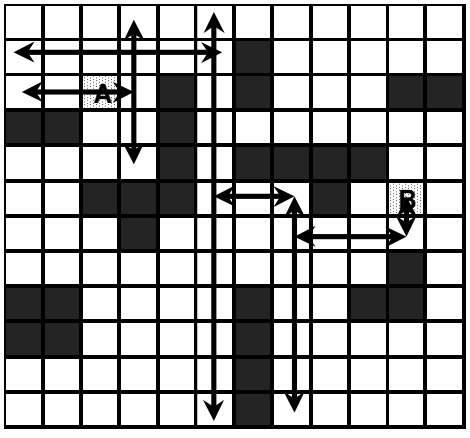


Backtracking



Prioritizing the search: A*

Line Probe: Hightower & Tabuchi



- **Also called "Ray", "Line search", "Gridless router"**
- **Usually implemented on a grid**

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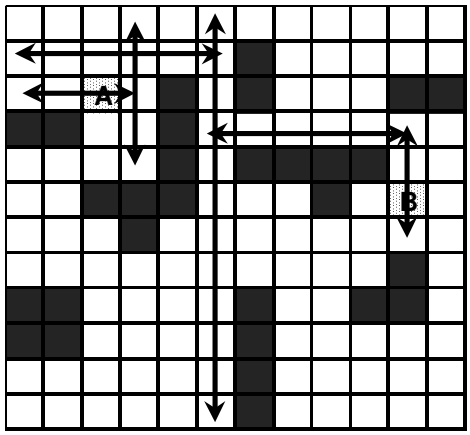
Line Search: Hightower & Tabuchi



•Note order-dependence A-B versus B-A

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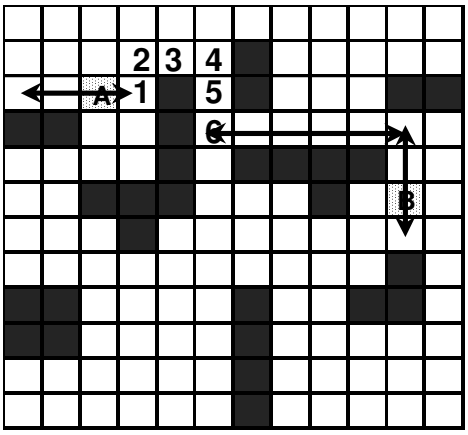
Pattern Route: Soukup



Use line-search to blockage and then revert to maze-router

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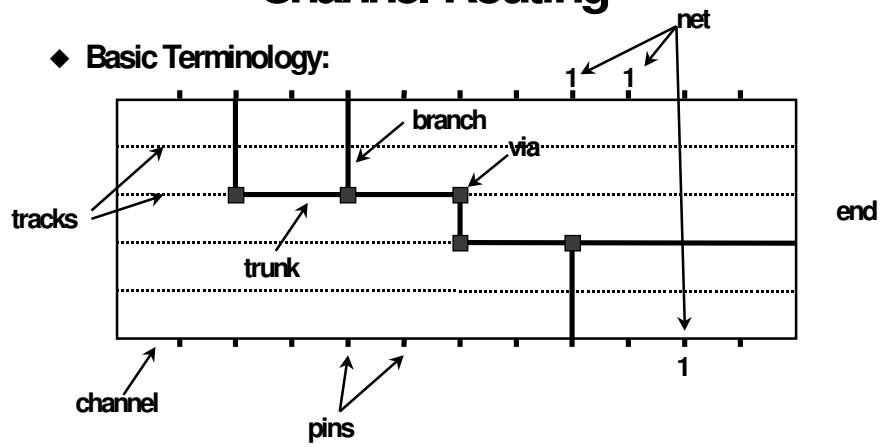
Channel Routing



- Basic Terminology:
- Fixed pin positions on top and bottom edges
- Classical channel: no nets leave channel
- Three-sided channel possible

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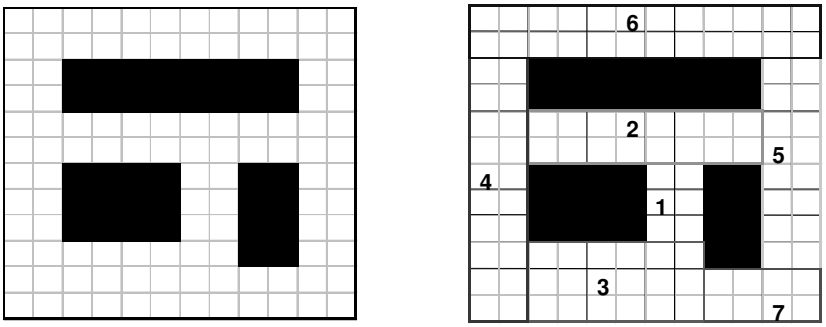
Routing Region Definition



•Use of Slicing Structure for ordering (Otten)

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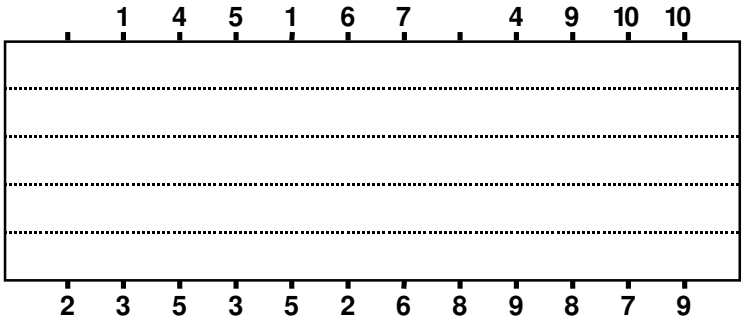
Channel Routing



- Graph representations:
  - Vertical Constraint Graph (VSG)
  - Horizontal Interval Graph (HIG)

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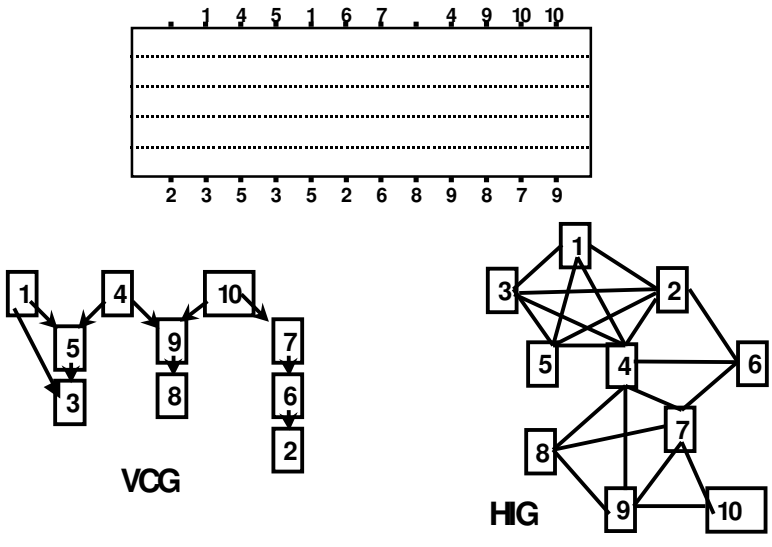
Channel Routing



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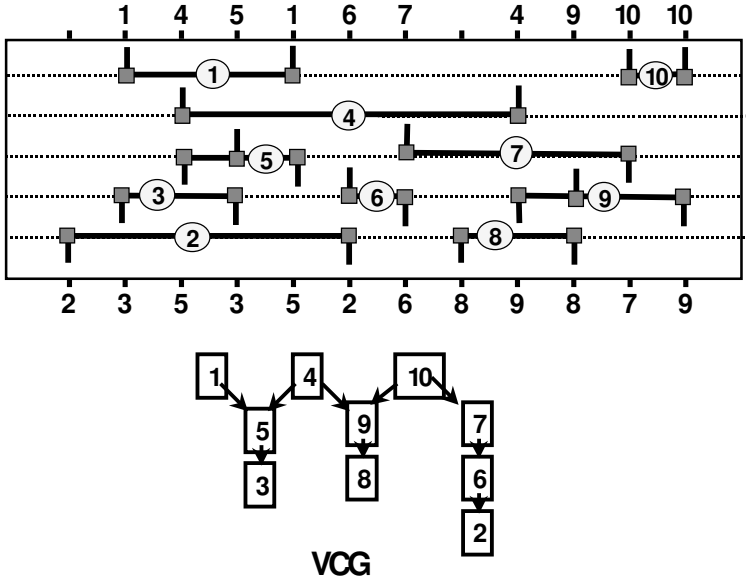
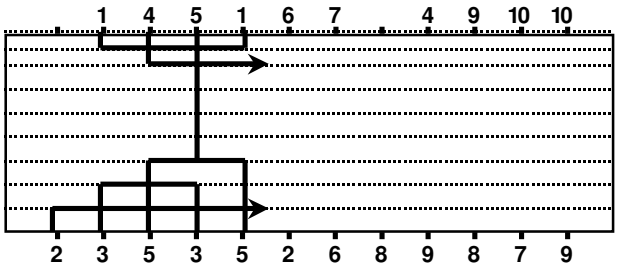
Vertical Constraint Graph



Greedy Router: Rivest & Fiduccia



- **Proceed column by column (left to right)**
- **Make connections to all pins in that column**
- **Free up tracks by collapsing as many tracks as possible to collapse nets**
- **Shrink range of rows occupied by a net by using doglegs**
- **If a pin cannot enter a channel, add a track**
- **O(pins) time**

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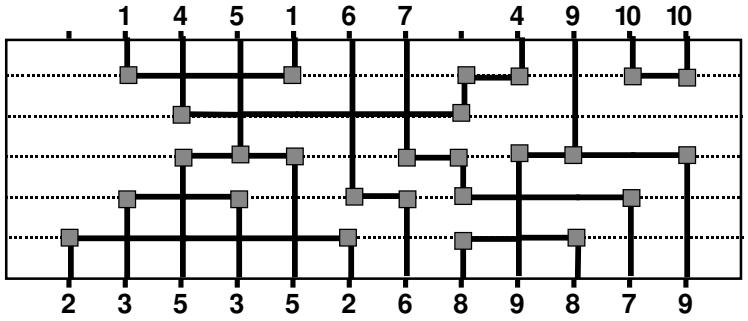
Greedy Router

- **Three Parameters Control Algorithm:**
  - **Initial_Channel_Width, Minimum_Jog_length, Steady_Net_Constant**
- **Rule-Based Approach**
  - **Rule 1: Make feasible top and bottom connections in minimal manner**
  - **Rule 2: Free up as many tracks as possible by collapsing split nets**
  - **Rule 3: Add jogs to minimize distance between split nets (but no shorter than minimum_jog_length)**
  - **Rule 4: Add jogs where possible to raise rising nets and lower falling nets**
  - **Rule 5: Widen channel if needed to make top or bottom connections. Add tracks in the middle of the channel**
  - **Rule 6: Extend the channel to a new column to complete unconnected net segments.**

Greedy Routing Example



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Left-Edge Algorithm (LEA)

(Hashimoto & Stevens)

- Process horizontal tracks in order from top to bottom of channel and assign nets to tracks at each stage (assuming no cyclic constraints in VCG)
  - For track *i*, choose the "left-most net" of those who have no ancestors in the VCG
  - Repeat process until no additional nets can be assigned to the track
  - Move to track *i+1*
- Guarantees a solution since there are no cyclic constraints permitted in VCG
- In example, VCG permits (1,4,10) in first track, but only (1,10), (4,10) based on HIG; choose (1,10)

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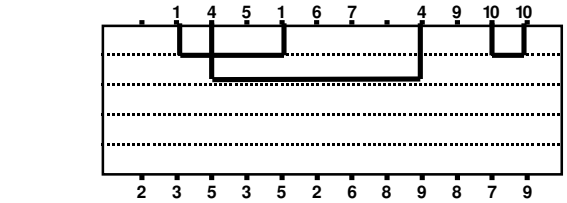
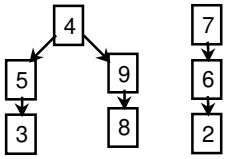
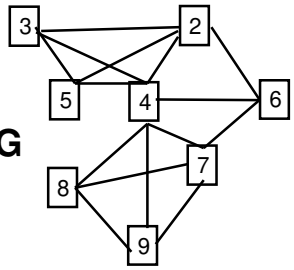
Left-Edge Algorithm (LEA)

(Hashimoto & Stevens)





VCG



HIG

- Choose 4 or 7; choose 4 since left-most

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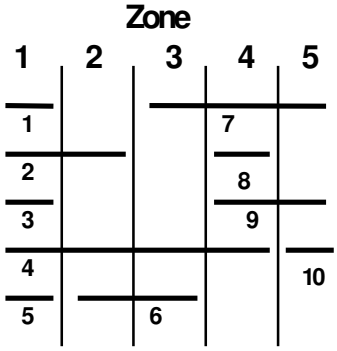
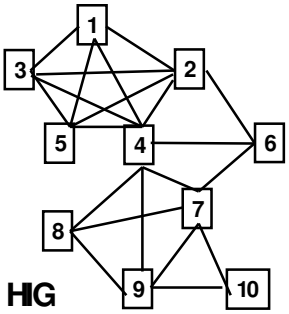
"Merging of Nets"
(Yoshimura & Kuh)

- On the assumption of no cyclic constraints, nets that can be placed on the same track can be merged in the VCG, simplifying the VCG.





Merging of Nets

- Definition: Let *i* and *j* be nets for which the following holds:
  - (a) *i* and *j* are not adjacent in the HIG
  - (b) There is no direct path between *i* and *j* in the VCG

  Then these nets can be assigned to the same track and hence they can be merged in the VCG
- Merging Operation:
  - (1) Combine nodes *i* and *j* into node *i•j* in VCG
  - (2) Update zone representation such that *i•j* occupies zones of *i* and *j* and all zones in between

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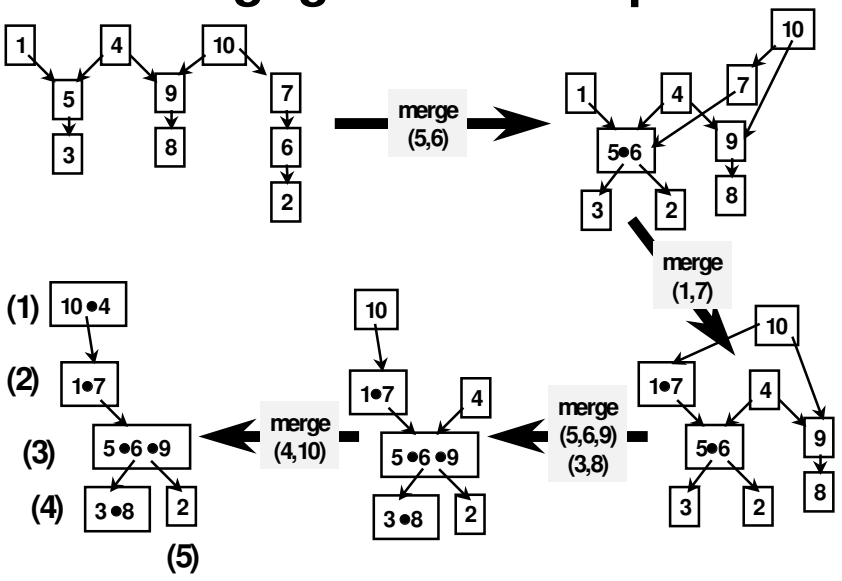
Merging of Nets: Example



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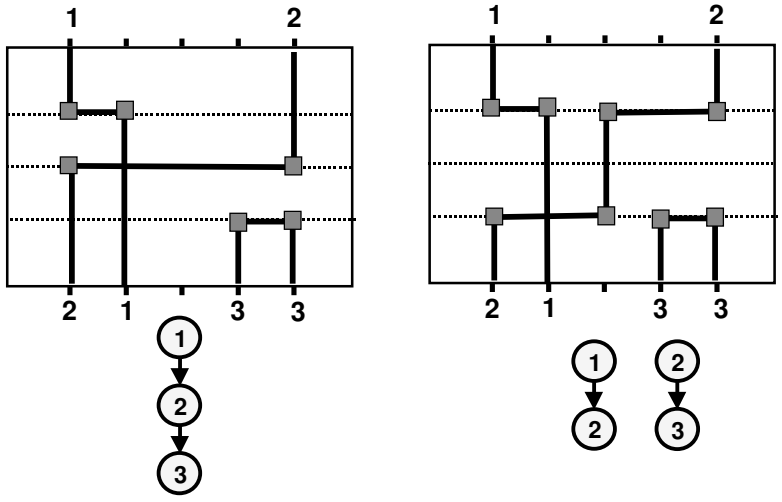
Introducing Doglegs



Finding the optimal locations for doglegs is an NP-Complete problem

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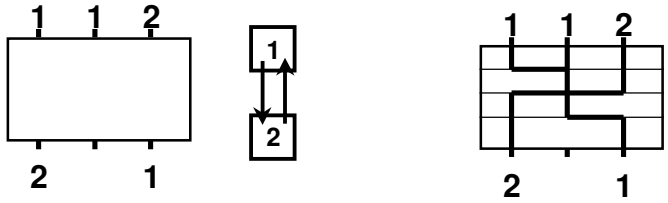
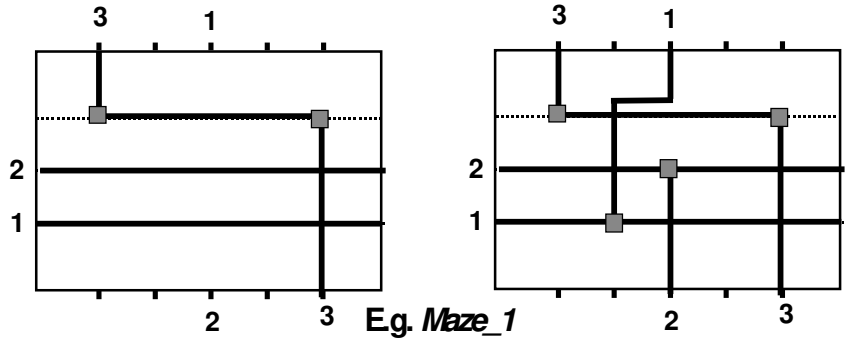
Cyclic Constraints

- VCG may contain a "cyclic constraint" and therefore cannot be routed with algorithms above
- The use of "doglegs" (a net using two or more tracks) will permit breaking these constraints



YACR: Pattern Routing



E.g. *Maze_1*

- Performs normal LEA, track assignment for nets that do not violate vertical constraints
- Connect remaining trunks using "maze router" (actually pattern router)
- Three patterns: Maze_1 (route under), Maze_2 (one dogleg), Maze_3 (two doglegs)
- If patterns fail, add track
- Will add end columns, if needed, to resolve otherwise impossible cyclic constraints in VCG

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