ROUTING

- The task of routing is an important one for IC as well as board-level design.

- In both cases, once we have a design in which all modules/gates (or ICs in the case of board-level design), we need to wire the pins of these elements.

- Algorithms for IC or board-level routing are similar, but constraints vary:
  - In IC routing, the number of routing layers is fixed and determined by the fabrication technology. The critical aspect is completion - the ability to route all nets.
  - In board-level routing, the number of routing layers are variable. The figure of merit of a router is the number of layers it requires to complete all routes (lower the better).
  - Wire widths and spacing for IC routing is determined by the fabrication technology. Values are smaller for lower metal layers. For board-level routing, these quantities do not vary across metal layers.
• Typically, routing consists of two phases - global routing and detailed routing. In global routing, we do “rough” routes based on estimates of congestion of the routing region. In detailed routing, the final routes are performed.

• We will talk about detailed routing in this unit.
PROBLEM STATEMENT

• The area routing problem can be defined as follows:
  Given $m$ available metal layers, and $n$ signal nets
  (each of which comprises a set of electrically equivalent pins)
  find an interconnection between the pins
  of each signal net, subject to
  
  — arbitrary sized obstacles present on each layer $i$.
  — individual pins of each signal net present on possibly different metal layers.
  — various geometric and electrical constraints
  — minimizing the sum of the length of wires and/or vias in the routed design.

• Geometric constraints specify minimum spacing and widths of conductors, electrical constraints may be imposed to ensure immunity to cross-talk, heat dissipation characteristics of the design, etc.

• Optimum solutions are infeasible due to the large number of nets in the design.

• The typical detailed routing approach routes one net at a time, using some predetermined ordering of nets. If prior routes block the last route, we have to rip-up and reroute offending nets.
CLASSIFICATION

- Routing techniques are classified broadly based on whether they are gridded or gridless.

- Gridded routers route any wire along a predetermined square grid, while gridless routers are flexible in this regard. Gridded routing makes the problem simpler, but inflexible. For instance, if we have a long net, we may want to route it with a wire of width $1.4\times$ the grid, which is not permissible.

![Routing Techniques Diagram]

**Routing Techniques**

- **Gridded**
  - Lee
  - Lee’s Extensions
  - Others
- **Gridless**
  - Line Search
  - Tile Expansion
  - Hybrid and Pattern Based
- **Sequential Techniques**
- **Hierarchical**
- **Rip-up and Reroute**
- **Routing Accelerators**
  - SIMD
  - MIMD
GRIDDED ROUTERS

• The classic gridded router is the Maze router. It is simple and effective.

• Lee’s maze router (1961) is the simplest gridded router. For a routing grid of size $n \times n$, this algorithm has quadratic memory and time complexity.

• It has the ability to find the shortest route for a net (if one exists).

• In the example below, an $X$ denotes an obstruction, $S$ and $D$ denote the source and destination of the net, and numbers denote grid points reachable from the source in as many steps of maze expansion.

• Lee’s algorithm expands a front around the source pin, creating the set of points reachable from the source in $i$ steps.

• When this front touches the destination pin, we have a route.

• Because of its high complexity, a maze router is often used as a back-up router. We usually utilize faster routers (which can’t guarantee the ability to
find a route if it exists), and in case the faster router fails, we resort to maze routing.

- Modifications based on the original maze router are developed even today.
GRIDLESS ROUTERS

• The classic gridless router is Hightower’s line searching router (1969).

• This technique alternately grows one line segment (from source and destination points), until two growing sub-nets meet.

• At each expansion step, the current segment is expanded until it hits an obstruction. An escape point is created, from which a perpendicular segment is constructed, continuing the search as before.

• This technique cannot guarantee finding a route if one exists.
HYBRID ROUTERS

- Pattern routing (1978) is another efficient technique.

- In such a router, a route is constructed by using a small set of pre-defined route shapes (patterns), with parameterizable segment lengths.

- Patterns are classified by the number of bends (vias) they utilize.

- The router searches for a route with the least number of bends.

- This type of router was defined in a gridded setting, but is equally applicable in a gridless setting.

- Some possible patterns are shown below. Note that for each of these patterns, the length of a wire before it bends is parameterized.