

OpenPCells

A Technology-Indendent Layout Generator for Integrated Circuits

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Introduction

Technology Mapping

Code

Examples

- Design re-use quite poor in analog design
- Still many repetitive tasks, especially in layout
- Designs usually subject to restrictive non-disclosure agreements

- Enable design re-use
- Provide reference implementations of common circuits
- Port complex systems to other technology nodes
- Share circuits with other researchers/companies/...

- Integrated circuits are complex
- Many, many, many different ways to do the same thing
- Even more design rules, especially in modern technology nodes

1. Simplify the schematic
2. Simplify the schematic
3. Simplify the schematic
4. DRY in layout (don't repeat yourself)
 - ▶ Draw everything only once (instances, vias, etc.)
 - ▶ Make extensive use of symmetry, only draw half/quarter/... layouts
 - ▶ Find minimum common representation of sub-blocks (e.g. transistors without implants)
 - ▶ Hard to do and can result in very steep instance hierarchies
 - ▶ More special cases make this even harder

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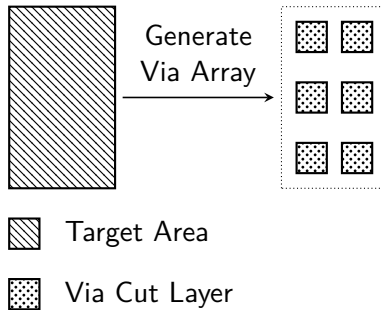
Examples

Vias and Contacts

- Resolve via cuts with set of simple rules

- Fit via: $R = \left\lfloor \frac{W + S_{\min} - 2 \cdot E_{\min}}{C + S_{\min}} \right\rfloor$

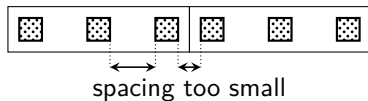
- Continuous via: $R = \left\lfloor \frac{W + S_{\min} - 2 \cdot E_{\min}}{C + S_{\min}} \right\rfloor$



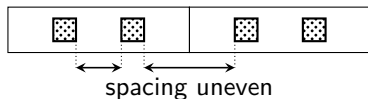
Continuous Vias

- Simple cut fitting not suitable in some applications (for example merging/aligning guard rings)
- Specialized via translation ensures equal spacing

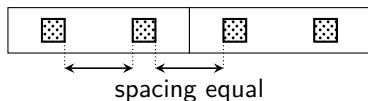
Fitted Via Array
(Enclosure < Space / 2)



Fitted Via Array
(Enclosure > Space / 2)



Continuous Via Array
(Enclosure = Space / 2)



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Basic Cell Code

```
function parameters()  
    -- parameter definitions go here  
end  
  
function layout(cell, _P, env)  
    -- layout descriptions go here  
end  
  
function config()  
    -- special stuff  
end
```

- Cells are described by defining public (global) functions
- Every cell *must* define `layout()`
- `parameters()` defines the parameters of the cell (and some minor other things)
- A cell without any parameters always represents the same layout
- In rare cases, `config()` is used, but this is only required for special cells

Adding Parameters

```
function parameters()  
    pcell.add_parameter("width", 100)  
    pcell.add_parameter("height", 100)  
end
```

or with a shorthand:

```
function parameters()  
    pcell.add_parameters({  
        { "width", 100 },  
        { "height", 100 } -- <--- uses varargs function call,  
    })                    -- no comma after last argument  
end
```

Parameters – Allowed Values

- Per default, numeric parameters can take any values
- Allowed parameters can be limited to `even` or `odd` values, intervals (`interval`) or explicit sets (`set`)

```
function parameters()  
  pcell.add_parameters({  
    { "width", 100, posvals = even() },  
    { "height", 100, posvals = interval(1, inf) },  
    { "rep", 2, posvals = set(2, 4, 8, 16) }  
  })  
end
```

The Layout Function

- First argument is the cell being built (it is created by the calling code)
- The first argument is in theory optional, but a cell without a cell argument makes no sense
- Second (optional) argument is the table holding all parameters with their current value (default or user-given values)
- Third (optional) argument is the environment, similar to parameters but concerns values that are defined by cell higher up in the hierarchy

```
function layout(cell, _P, env)  
end
```

Adding Shapes

- Basic shapes are added with the `geometry` module
- All `geometry` functions take the cell as first argument
- The layer as second argument
- Shape parameters (for example width and height for a rectangle) as remaining parameters
- All sizes are in nanometers (only integers allowed)

```
function layout(cell)
    geometry.rectangle(cell, layer, 100, 100)
end
```

But what do we put into the layer?

Digression: Generic Layers

- Shapes need to have layer information
- Can't put in specific technology layers (for example metal 1)
- Can't put in layers for the specific format (for example GDSII)
- Need a system to represent chip layers technology-independent and format-independent
- This is achieved by using *generic* layers

```
function layout(cell)
    geometry.rectangle(cell, generics.metal(1), 100, 100)
end
```


Digression: Generic Layers

- Metals indexed by a number (1 being at the bottom of the metal stack, closest to the bulk wafer)
- Generic layers for gates, active regions, implants, threshold voltage markings, oxide thickness
- Generics layers are translated into specific technology-bound layers
- Mapping described in layermap file with simple syntax
- Layermap has to be created for every technology node

Layermap example with only one layer (gate):

```
return {  
    gate = { layer = { gds = { layer = 6, purpose = 0 } } },  
    -- more layers here  
}
```

Digression: Generic Layers

- The technology layermap can define various export types (output formats)
- Most important is currently gds (GDSII)

More complex layermap example with only one layer (gate):

```
return {  
  gate = {  
    name = "poly",  
    layer = {  
      gds = { layer = 6, purpose = 0 },  
      SKILL = { layer = "poly", purpose = "drawing" },  
      svg = { style = "gate", order = 3, color = "ff0000" },  
    },  
  },  
}
```

Digression: Generic Layers

- Unused layers can be marked as empty
- For example, non-SOI (silicon-on-insulator) technology nodes don't need a buried-oxide break (soiopen)

```
return {  
    soiopen = {}, -- will be skipped  
}
```

Adding Shapes – Basic Shapes

Rectangles:

```
-- width and height
geometry.rectangle(cell, generics.metal(1),
    width, height)
-- corner points (bottom left, top right)
geometry.rectanglebltr(cell, generics.metal(1),
    bl, tr)
```

Paths:

```
geometry.path(cell, generics.metal(1),
    { pt1, pt2, ..., ptN }, width)
```

Polygons:

```
geometry.polygon(cell, generics.metal(1),
    { pt1, pt2, ..., ptN })
```

Cell Hierarchies

- Often-used cells more efficiently represented by hierarchies (re-use)
- Put sub-layouts in objects with `object.create()` or re-use existing cells with `pcell.create_layout()`
- Create a reference handle with `pcell.add_cell_reference(ref, name)`
- Use `object.add_child()` to instantiate this reference
- The (light/proxy) object returned by `object.add_child()` can be use as a regular object (transformed, aligned, etc.)

```
function layout(cell)
  local child_reference = pcell.create_layout("libname/subname")
  local child_name = pcell.add_cell_reference(child_reference,
    "child")
  local child = cell:add_child(child_name)
  child:move_anchor("left")
end
```

Object Translations and Transformations

- Cells can be transformed (rotated, flipped, ...) and translated in x and y
- Vital for building complex hierarchies with many different sub-cells
- Implementation handles this efficiently by using transformation matrices

```
local cell = object.create()  
-- add some shapes  
cell:translate(100, 100) -- takes x and y  
cell:rotate_90_left()  
cell:mirror_at_xaxis()
```

Object Anchors for Relative Placement

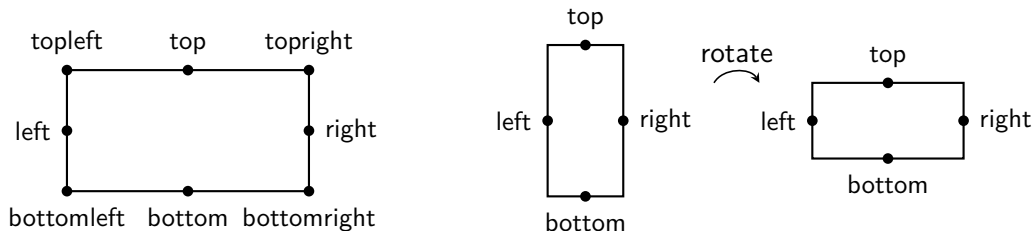
- Cells can define arbitrary *anchors* (points with a name)
- Can be used to position cells (`object.move_anchor`) or to query positions within cells (`object.get_anchor`)
- With both methods, cells can be placed relatively to each other

```
local cell1 = pcell.create_layout("cell1")
local cell2 = pcell.create_layout("cell2")

cell1:move_anchor("output", cell2:get_anchor("input"))
```

Object Alignment Boxes

- Define an object's main boundary (rectangular)
- Align with other similar objects (for example digital standard cells)
- Define eight special anchors
- Provide standardized means of object positioning
- Alignment boxes are transformed (rotated, mirrored, flipped), but the position of the special anchors is updated to reflect this



Relative Placements Everywhere

- Relative placement should be chosen wherever possible
- Absolute coordinates are usually only needed in fundamental/basic cells like transistors
- With relative placements (using alignment boxes), the cells “know” their own size
- This enables changes deeper in the hierarchy to propagate *up*
- Done correctly, child cells can be fixed/adapted without having to change the top cell

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Current-Starved Ring Oscillator

