# **OpenPCells**

A Technology-Indendent Layout Generator for Integrated Circuits

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#### Introduction

Technology Mapping

Code

Examples

#### **Motivation**

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

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#### Goals

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

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# **Difficulties in Layout Automation for Integrated Circuits**

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

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#### **Principles of Maintainable Circuit Layouts**

- 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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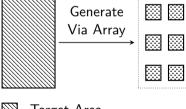
Examples

#### Vias and Contacts

Resolve via cuts with set of simple rules

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

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



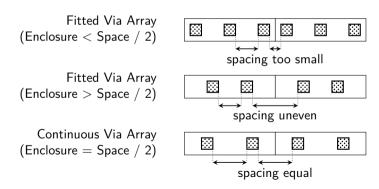
Target Area

🔯 Via Cut Layer

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#### **Continuous Vias**

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



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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

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#### **Adding Parameters**

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

#### or with a shorthand:

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#### 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)

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#### The Layout Function

- First argument is the cell buing 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
```

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#### **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?

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- 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
```

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- 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
}
```

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- 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" },
        }
    }
}
```

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- 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
}
```

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# Adding Shapes – Basic Shapes

```
-- width and height
              geometry.rectangle(cell, generics.metal(1),
                  width, height)
Rectangles:
              -- corner points (bottom left, top right)
              geometry.rectanglebltr(cell, generics.metal(1),
                  bl. tr)
              geometry.path(cell, generics.metal(1),
Paths:
                  { pt1, pt2, ..., ptN }, width)
              geometry.polygon(cell, generics.metal(1).
Polygons:
                  { pt1, pt2, ..., ptN })
```

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#### **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.)

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# **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()
```

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# **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

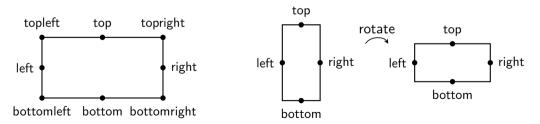
```
local cell1 = pcell.create_layout("cell1")
local cell2 = pcell.create_layout("cell2")

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

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#### **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



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# 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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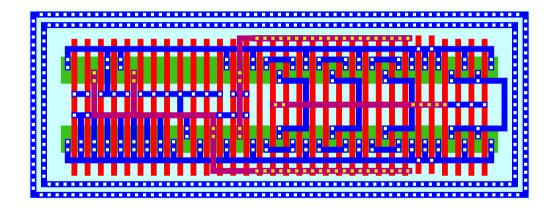
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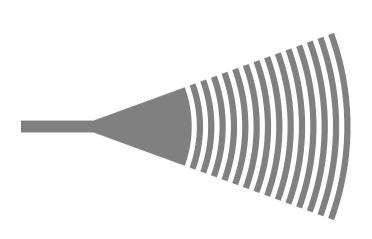
Examples

## **Current-Starved Ring Oscillator**



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# **Grated Coupler**



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