

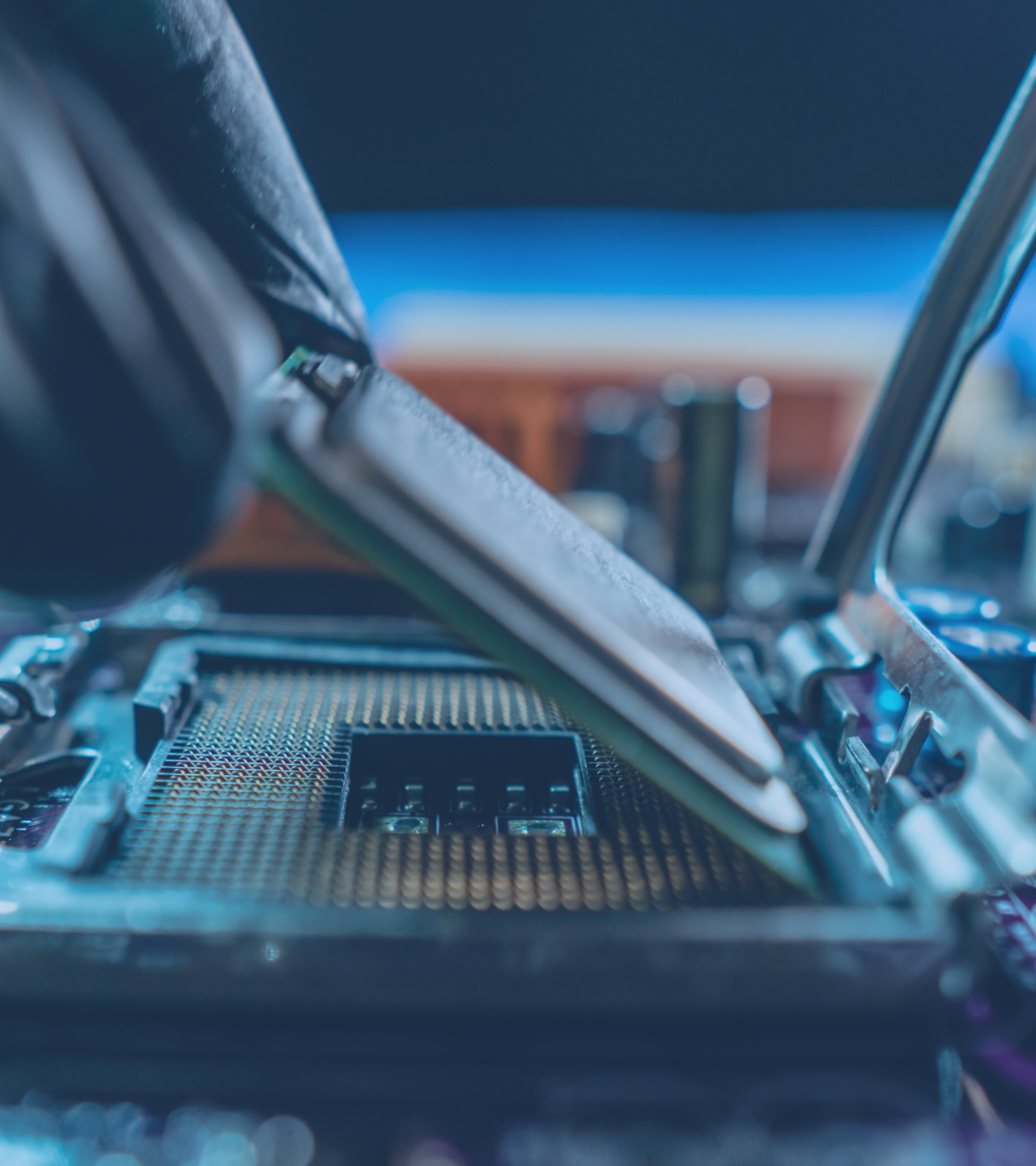
Leveraging Advanced Automation to Improve a Reverse Engineering Workflow

Chris Pawlowicz, Director of Research and Development

- TechInsights – who are we?
- Reverse Engineering Workflows
- Automated Transistor Extraction
- Netlist Search Automation
- Challenges
- Case Study
- Future Work



Presentation Agenda



About TechInsights

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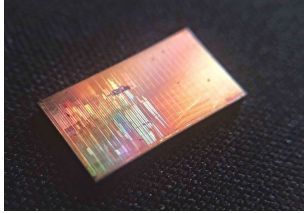
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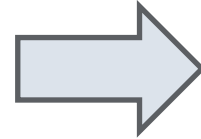
Typical Reverse Engineering Workflow



Starting sample



Sample Preparation



Imaging

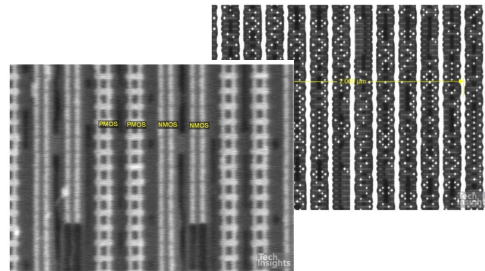
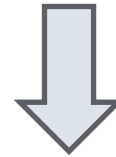
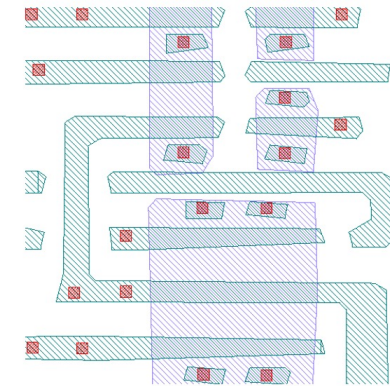
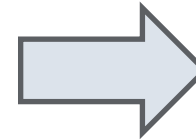
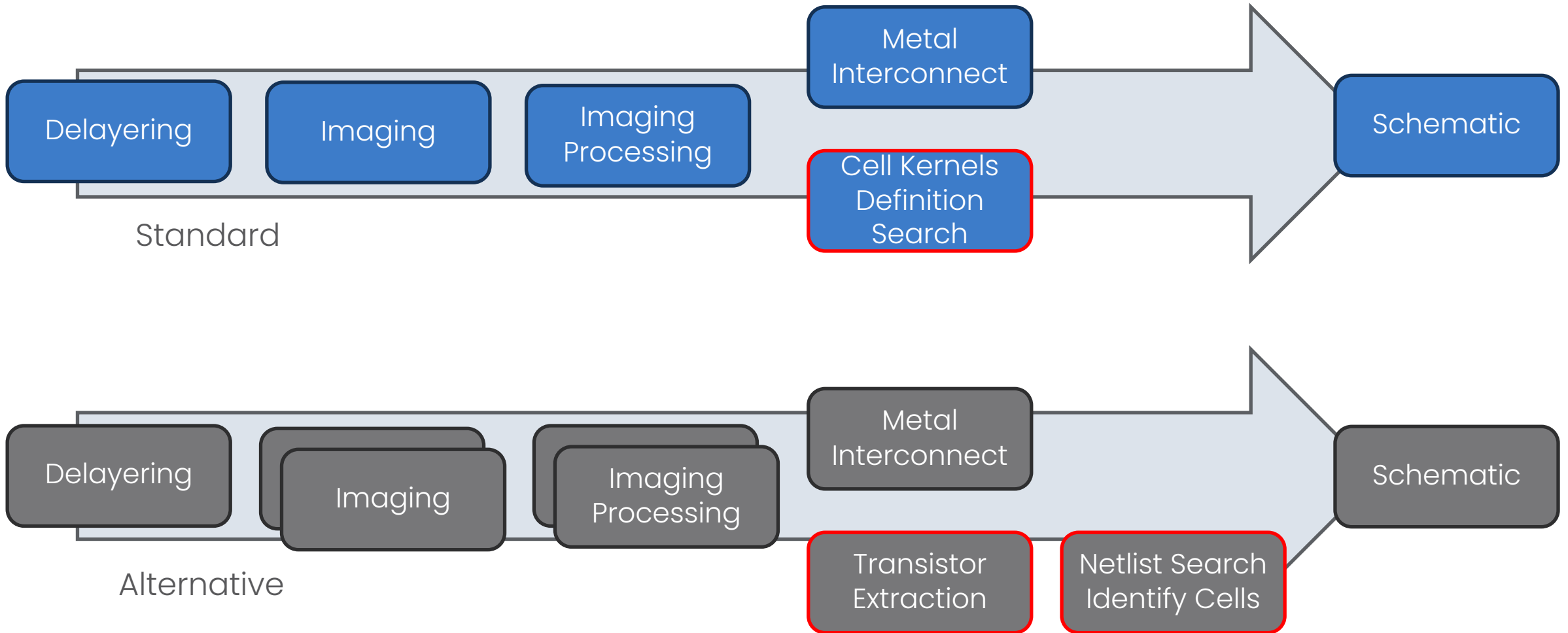


Image Processing



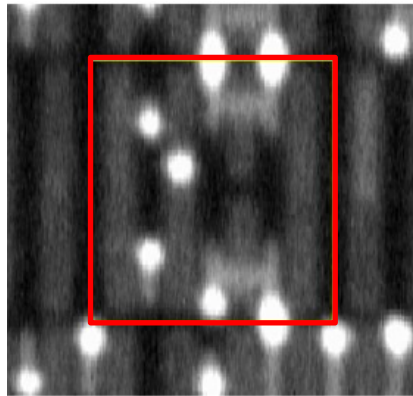
Component Identification
Schematic Organization

Workflows



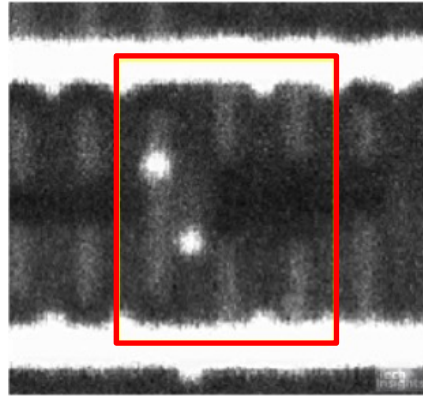
Cell Kernel Definition

Inverter 7nm

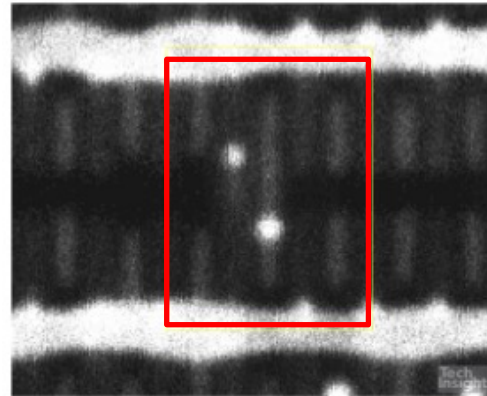


Screenshot of Cell at CT/VC

Inverter 5nm



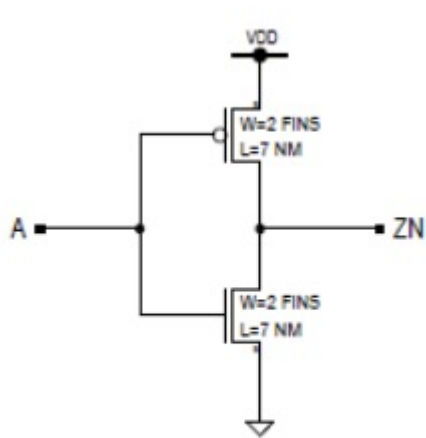
Screenshot of Cell at CT/VC



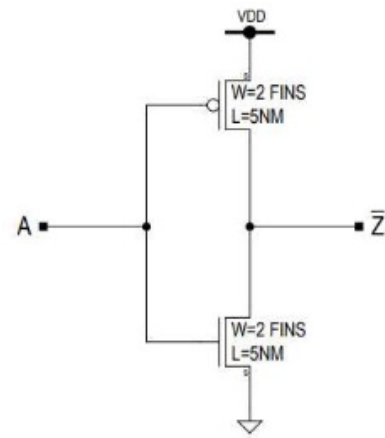
Screenshot of Cell at CT/VC

Image Correlation Search

Up to 8 orientations
 Rotation (0, 90, 180, 270)
 Mirror (X,Y)
 Scaling



Schematic

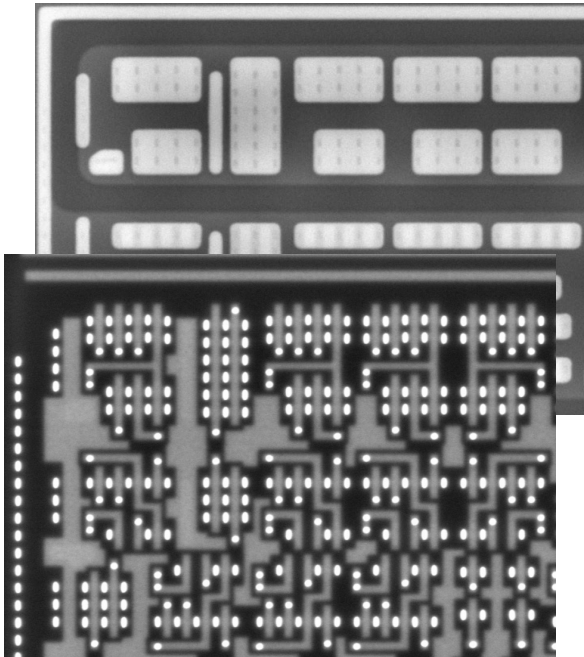


Netlist

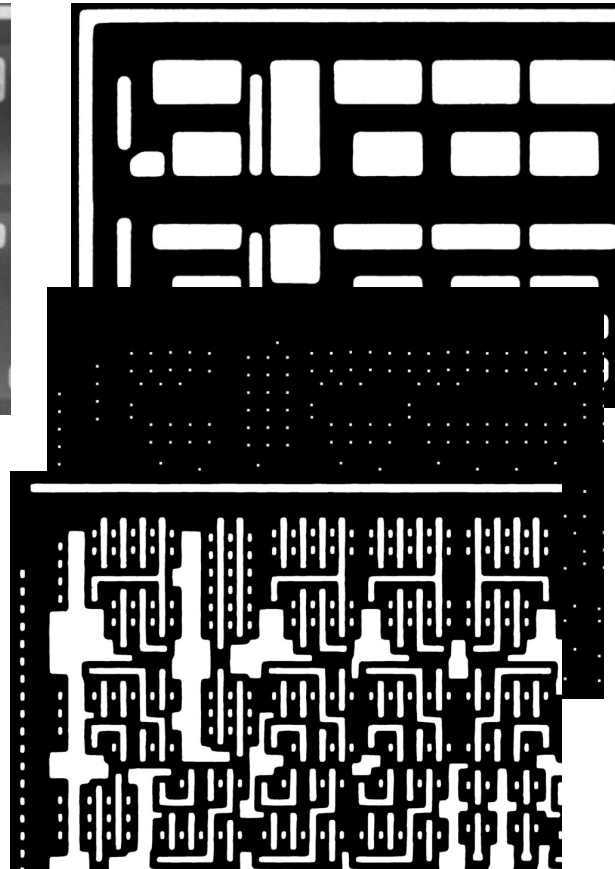
```
V 51
K 336293793500 NOT
Y 0
D 0 0 1660 1250
Z 10
i 11249
I 8052 SI_LIB:GND 1 815 530 0 1 '
C 8046 1 1 0
I 8056 SI_LIB:PWR 1 805 775 0 1 '
C 8026 2 2 0
I 8054 SI_LIB:OUT 1 940 665 0 1 '
L 980 665 24 0 2 0 1 0 QN
C 8029 4 1 0
I 8053 SI_LIB:IN 1 695 665 0 1 '
L 685 665 24 0 8 0 1 0 A
C 8031 3 1 0
I 8047 SI_LIB:NMOS 1 785 575 0 1 '
A 786 625 18 0 3 3 REFDES=MN?
A 810 605 18 0 3 1 W=WN
A 810 590 18 0 3 1 L=LN
C 8046 2 1 0
C 8031 6 2 0
C 8029 1 3 0
T 8048 ST ITR-PMOS 1 785 605 0 1 '
```


Automated Transistor Extraction - Planar

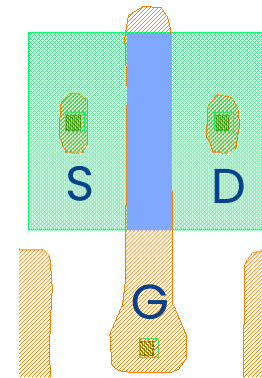
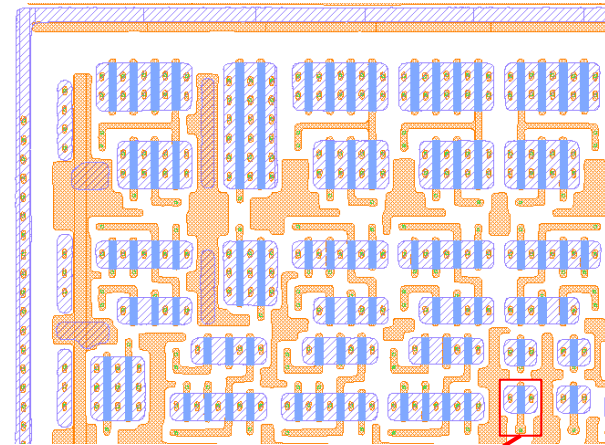
SEM images



Segmented images



Extracted gates

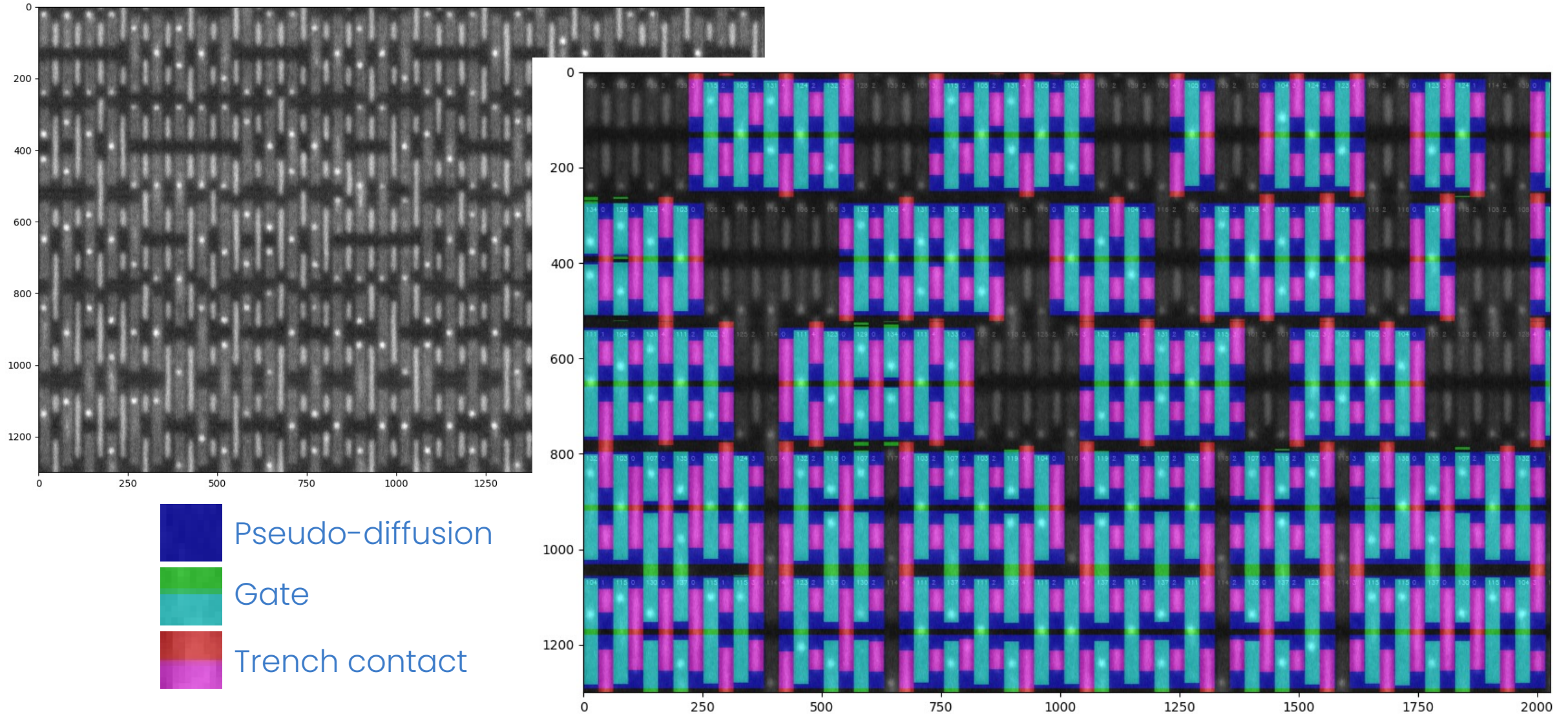


Transistor: Source-Gate-Drain

Transistor netlist

```
"transistors": [  
{  
  "T": [86550, 57933],  
  "DIM": [28, 206], ← Length,  
  Width  
  "S": {"XY": [86588, 57908]},  
  "G": {"XY": [86614, 57946]},  
  "D": {"XY": [86588, 57984]}  
},  
.....
```

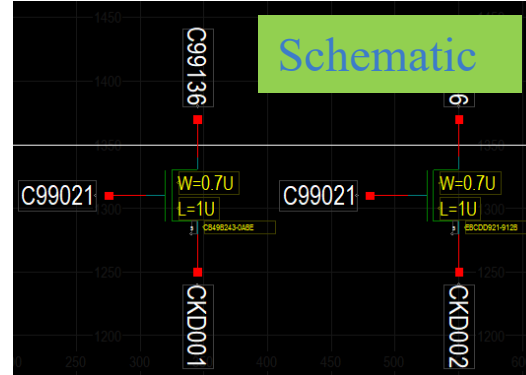
Automated Transistor Extraction - FinFET



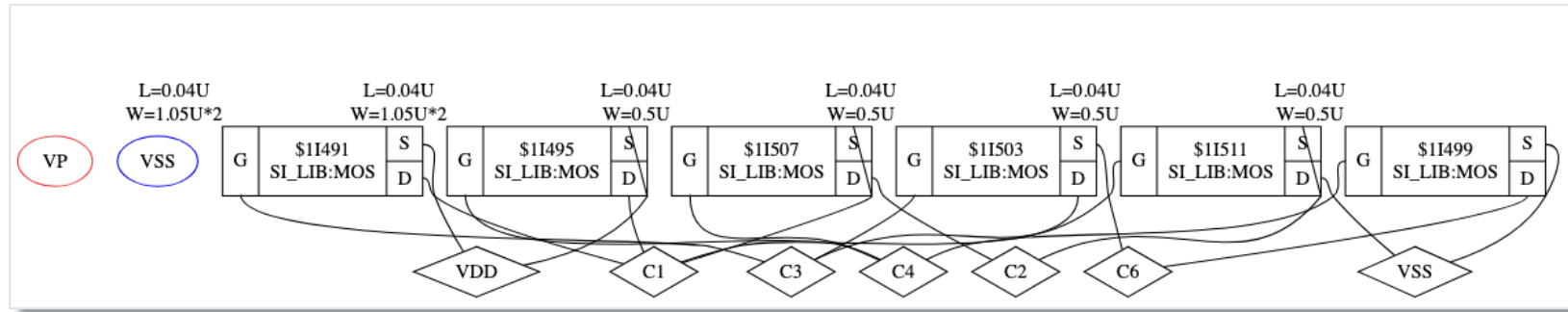
Netlist Search Automation – Search Area

```
...  
I 8298 SI_LIB:MOS 1 2390 1280 0 1  
A 2390 1280 18 0 9 0 ATE_DEV=ID411221B.DEV  
A 2390 1280 18 0 9 0 ATE_DEV_DB=61B.DEV_DB  
A 2390 1280 18 0 9 0 DATETIME=05 APR 2023 16:31:08  
A 2390 1280 18 0 9 0 GRID=B  
A 2420 1300 18 0 2 1 L=0.6U  
A 2390 1280 18 0 9 0 USERNAME=LR'  
A 2420 1320 18 0 2 1 W=0.1U*2  
A 2435 1285 10 0 2 3 X={9B9D3C96-5DA0-45E6-BA80-  
9E116CEB6876}  
A 2390 1280 18 0 9 0 XY=496373 -94228  
C 8296 11 0  
...
```

Netlist



Transistors



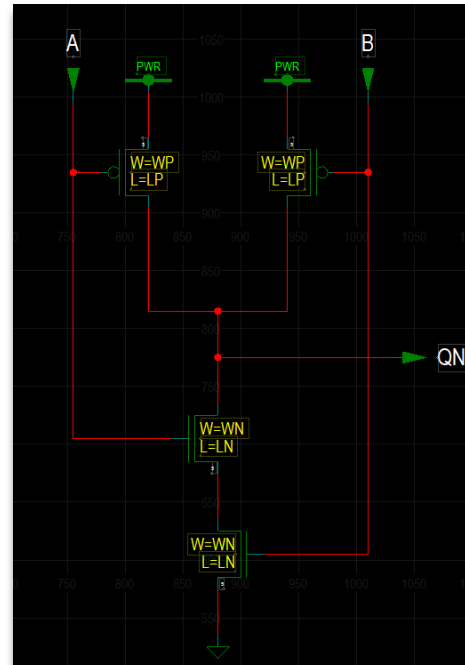
Graph (edges and nodes)

Netlist Search Automation – Search Template

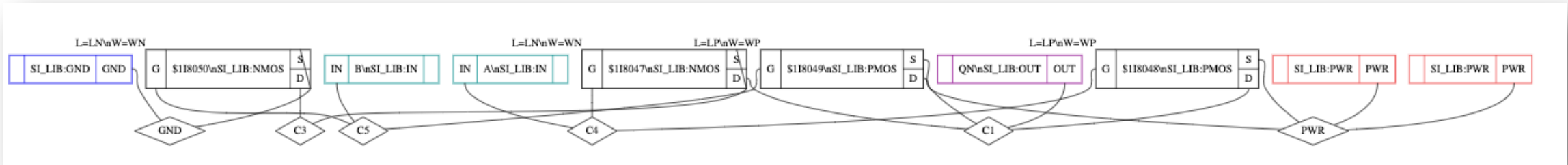
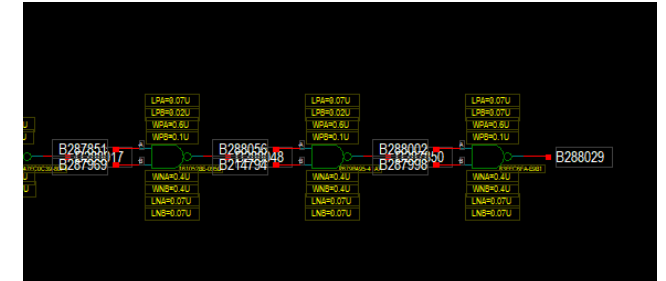
Template: NAND2 gate.

```
graph nand2_1 {
  ...
  I8054 [shape=record, layer=io, color=cyan4, label="{<P1I8054>
  IN}]{A\nSI_LIB:IN}{{}}"];
  I8055 [shape=record, layer=power_high, color=brown2,
  label="{}}{SI_LIB:PWR}{{<P2I8055> PWR}}"];
  I8056 [shape=record, layer=power_high, color=brown2,
  label="{}}{SI_LIB:PWR}{{<P2I8056> PWR}}"];
  C1 [layer=signal, shape=diamond];
  I8048:P1I8048--C1
  I8054:P1I8054--C1
  ...
}
```

Netlist



Schematic



Search Approach

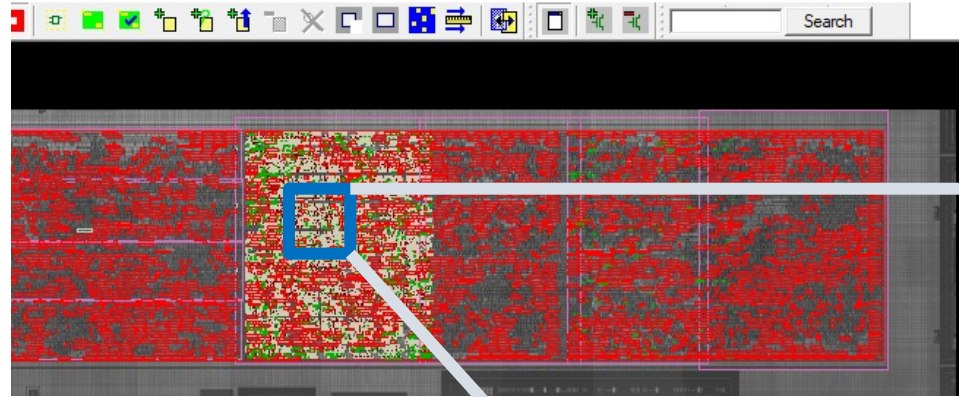
- Crawl search space, marking off components when found
- Collapse parallel/series
- Search order big to small
- Special rules for high fanout nets

Challenges

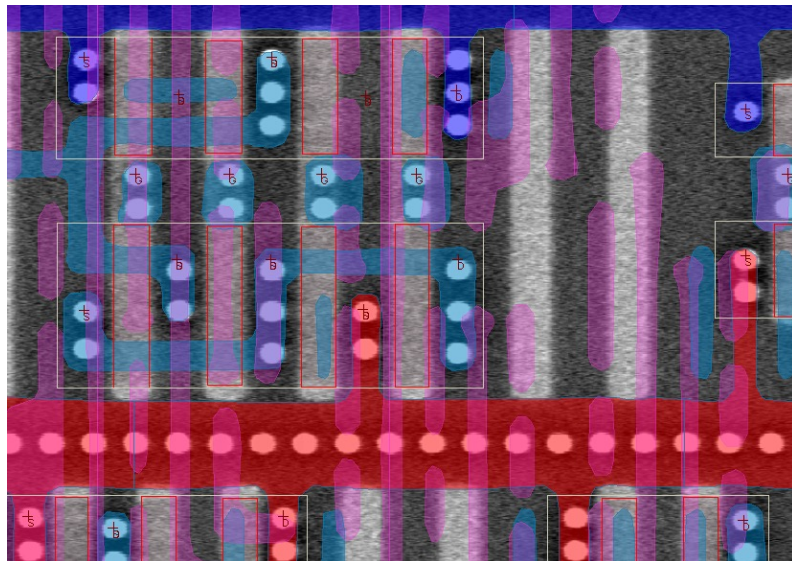
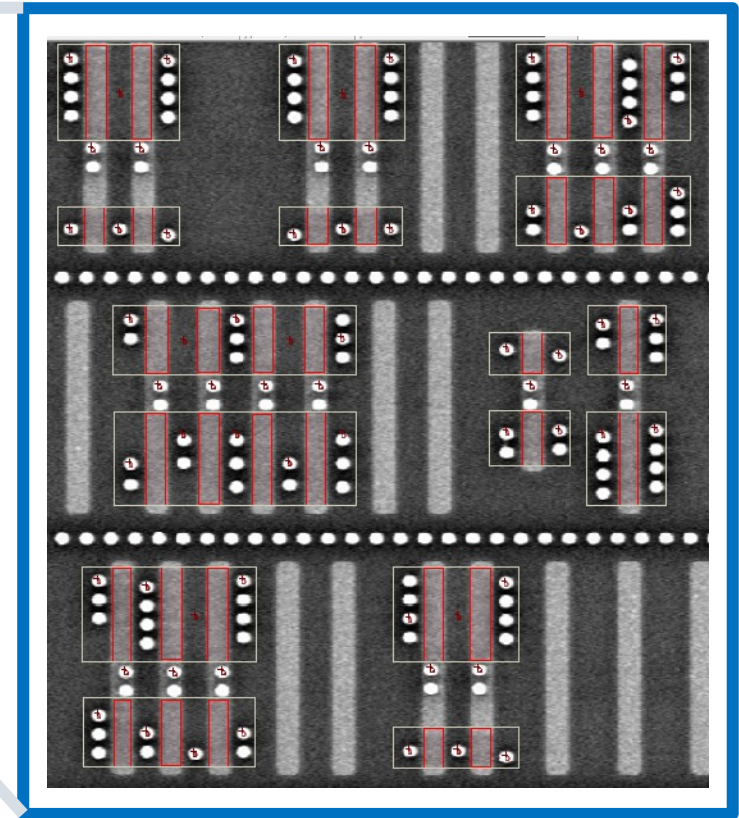
- Requires additional imaging/segmentation/accuracy
- Power domains
- High fanout signals
- Analog circuits
- Guard rings
- Compute power

Case Study

Large digital block



Automatically extracted transistors



Automatically recognized gates

Netlist Search on Large Digital

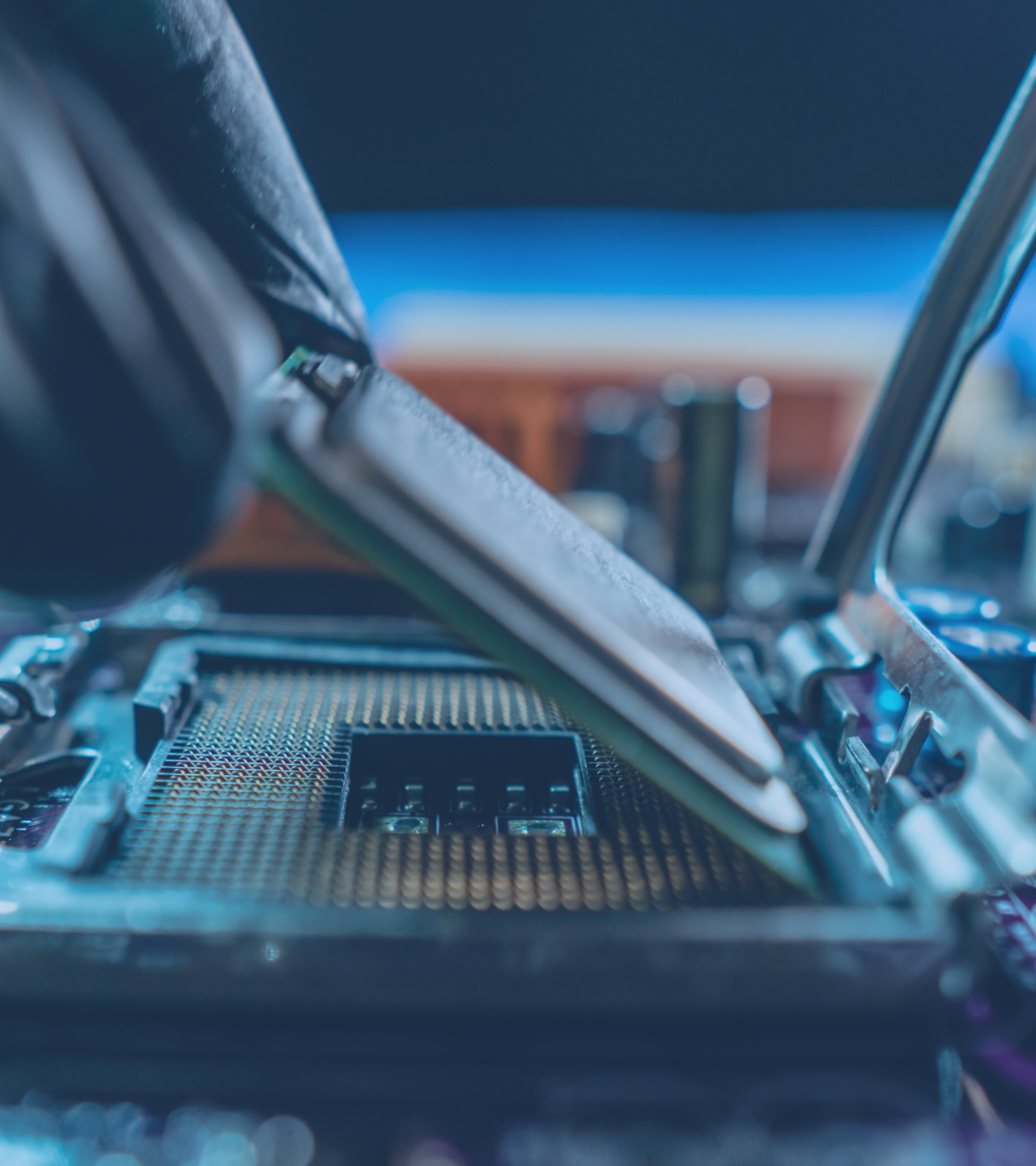
A search for “off-the-shelf” standard logic cells

In 5 minutes, we found 12,970 logic cells, accounting for 64% of the total number of transistors originally extracted.

```
Found 1 instances of CHIPWORKS_LIB:MX22__INV, claiming 14 search space instances.
Found 336 instances of CHIPWORKS_LIB:BUF, claiming 1344 search space instances.
Found 1096 instances of CHIPWORKS_LIB:NAND2, claiming 4384 search space instances.
Found 897 instances of CHIPWORKS_LIB:BUF2, claiming 3588 search space instances.
Found 121 instances of CHIPWORKS_LIB:TRINOT13, claiming 484 search space instances.
Found 242 instances of CHIPWORKS_LIB:INV2, claiming 968 search space instances.
Found 764 instances of CHIPWORKS_LIB:NOR2, claiming 3056 search space instances.
Found 9 instances of CHIPWORKS_LIB:MX22__TG, claiming 72 search space instances.
Found 131 instances of CHIPWORKS_LIB:TRINOT23, claiming 524 search space instances.
Found 21 instances of CHIPWORKS_LIB:TRINOT14, claiming 84 search space instances.
Found 3 instances of CHIPWORKS_LIB:TRINOT24, claiming 12 search space instances.
Found 4 instances of CHIPWORKS_LIB:XNOR2__TG, claiming 32 search space instances.
Found 13 instances of CHIPWORKS_LIB:MXA21__TG, claiming 78 search space instances.
Found 1 instances of CHIPWORKS_LIB:PULLDN, claiming 2 search space instances.
Found 2338 instances of CHIPWORKS_LIB:INV, claiming 4676 search space instances.
Found 1 instances of CHIPWORKS_LIB:PULLUP, claiming 2 search space instances.
Found 666 instances of CHIPWORKS_LIB:TRIGATE, claiming 1292 search space instances.
Total claimed search space instances: 64368.
Total # instances found: 12970.
```

Future Work

- Power Domains
- FinFET
- Fuzzy Search



Thank You!

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