Programming and physical design tools for flow-based biochips

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Programming biochips: vision

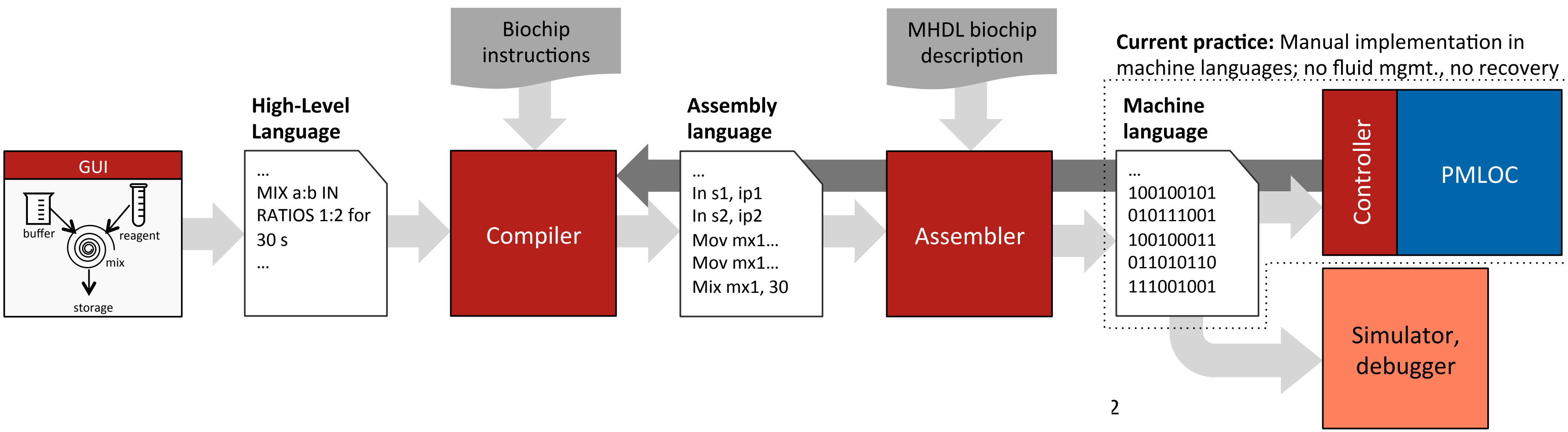
- High-level language for describing biological protocols

Original protocol

Add 100 ul of 7X Lysis Buffer (Blue) and mix by inverting the tube 4-6 times.
Proceed to step 3 within 2 minutes.

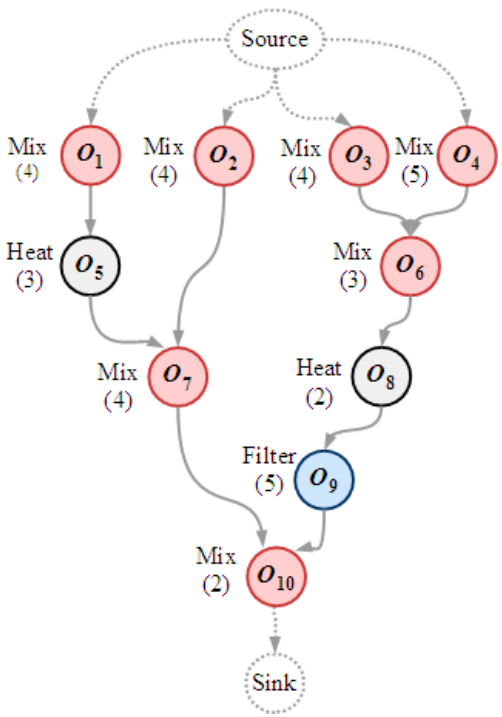
```
ASSAY Glucose START
fluid Glucose, Reagent, Sample;
fluid a, b, c, d, e;
VARResult[5];
input Glucose 50;
input Reagent;
input Sample 30;
conflict Sample FOLLOWS Glucose WASH water;
a=MIX Glucose AND Reagent IN RATIOS1 : 1
```

- Programming tools: compiler, assembler, debugger, simulator

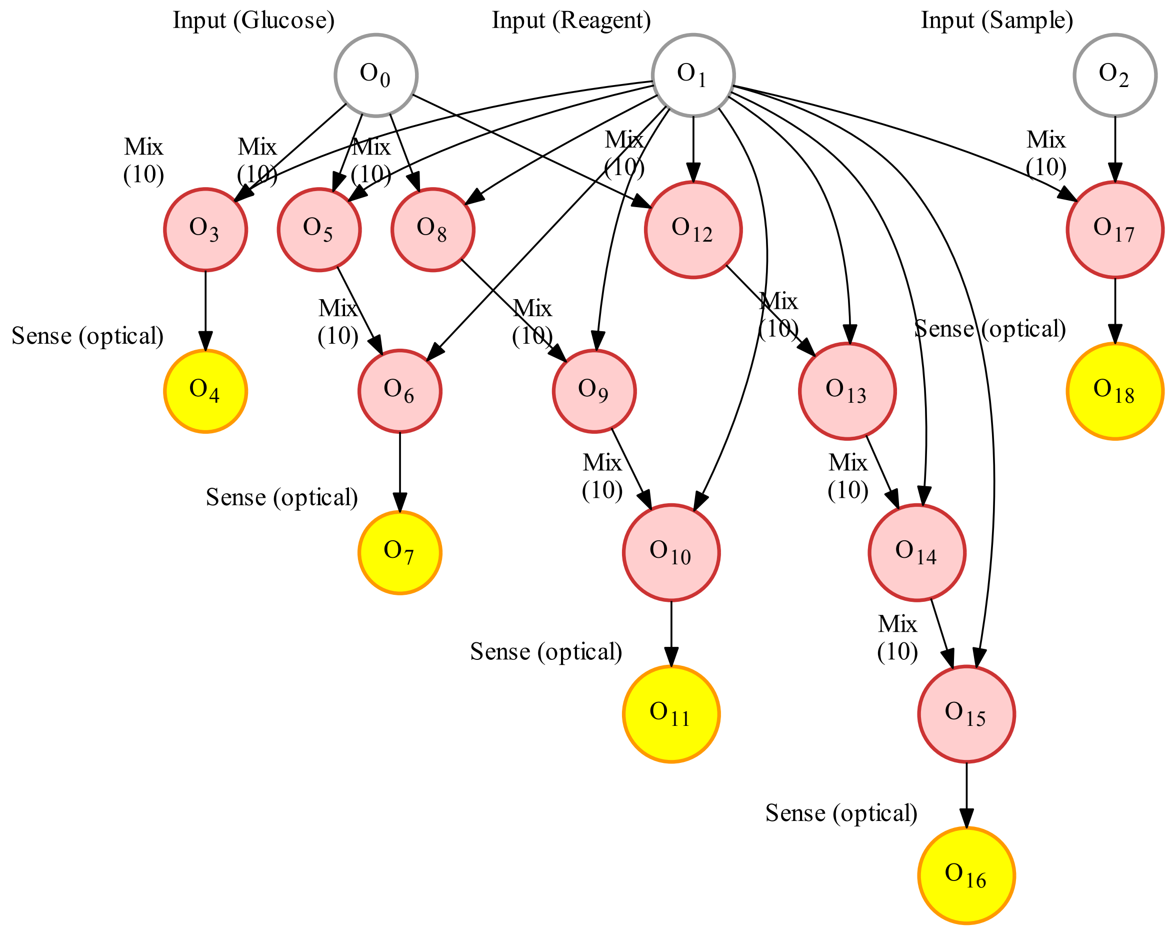


From HLLs to graph models

- We model a biochemical application as a graph

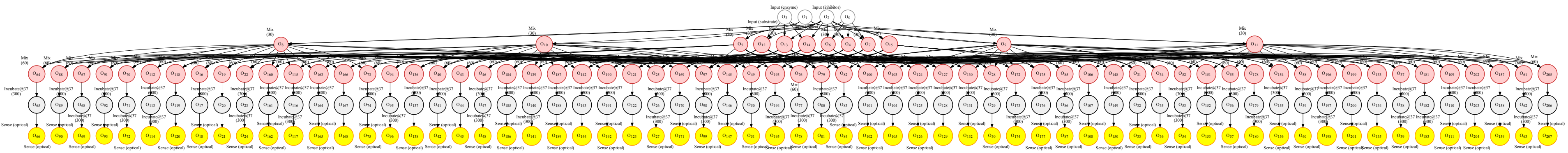


- Compiler: translates the protocol written in the HLL into the graph, doing mixing optimization

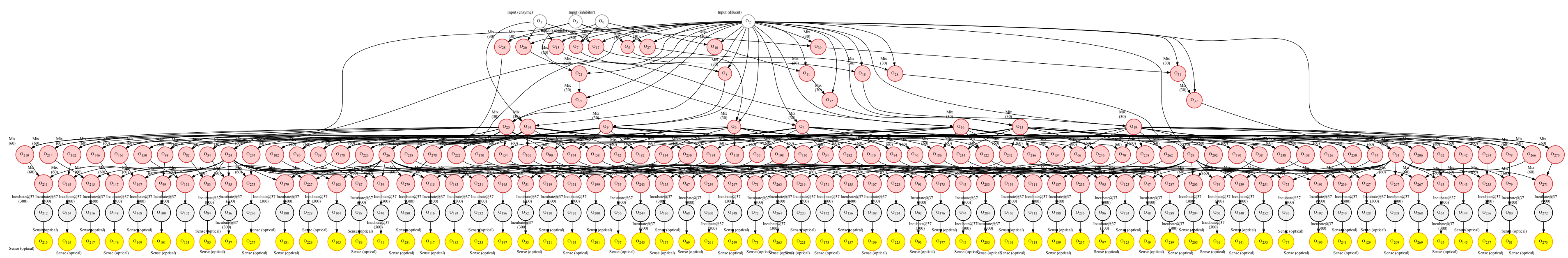


The graph model for an enzyme test

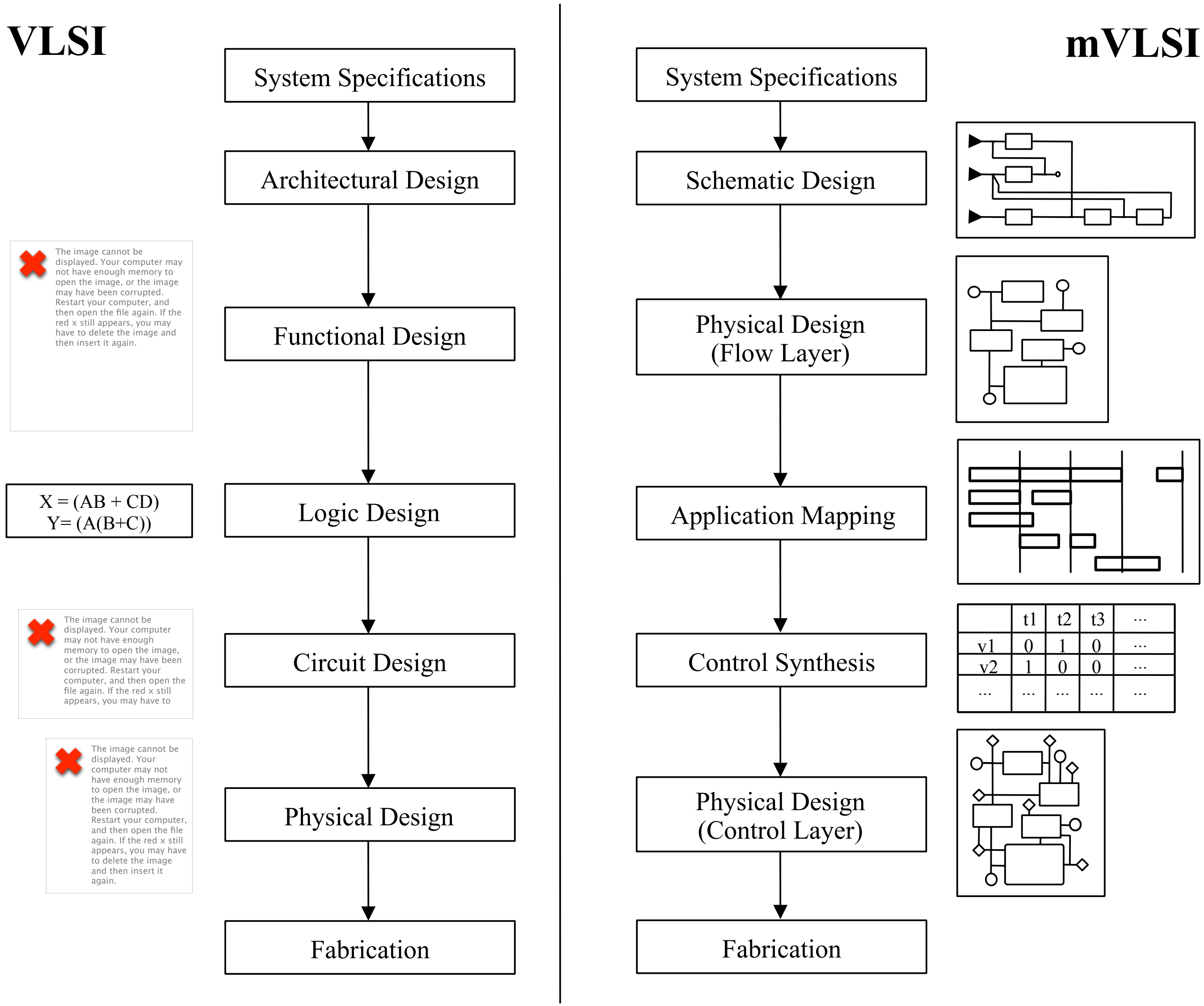
- Considering a **variable** mixer module



- Considering a **1:1 mixer module**; mixing is optimized

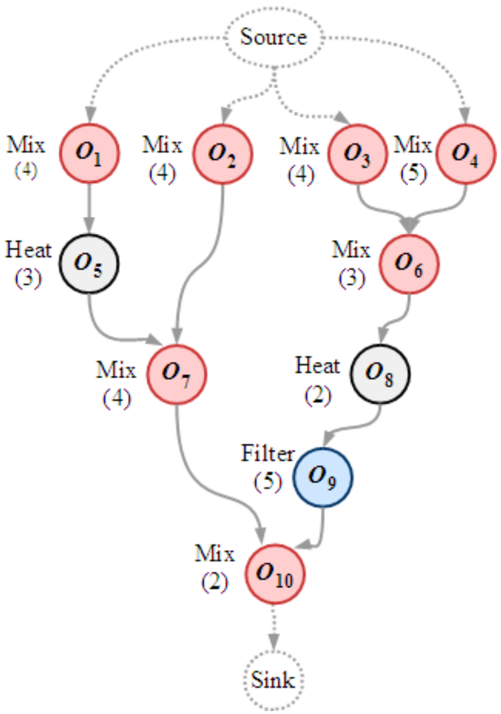


Physical design: VLSI vs mVLSI

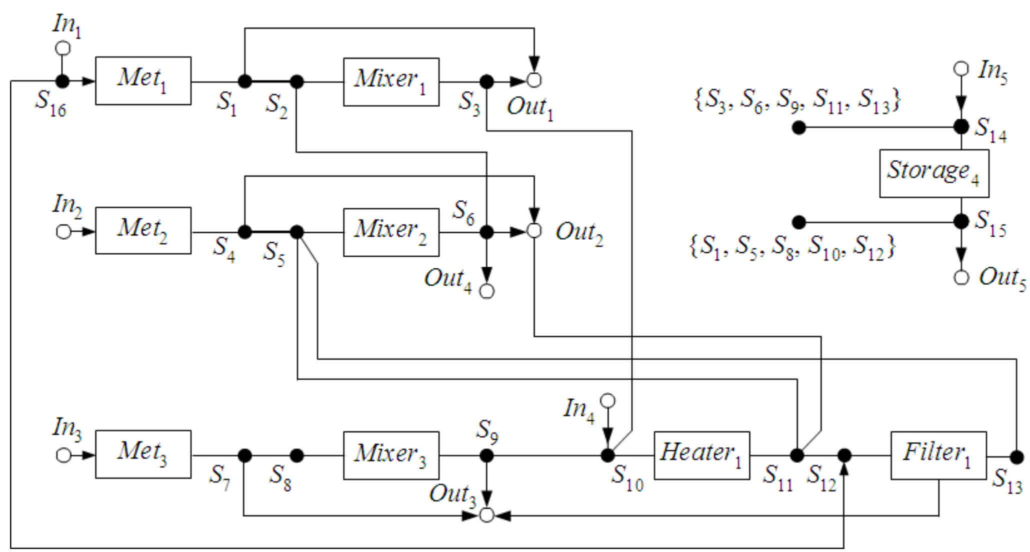


Allocation and schematic design

- How many components, and how to interconnect them?

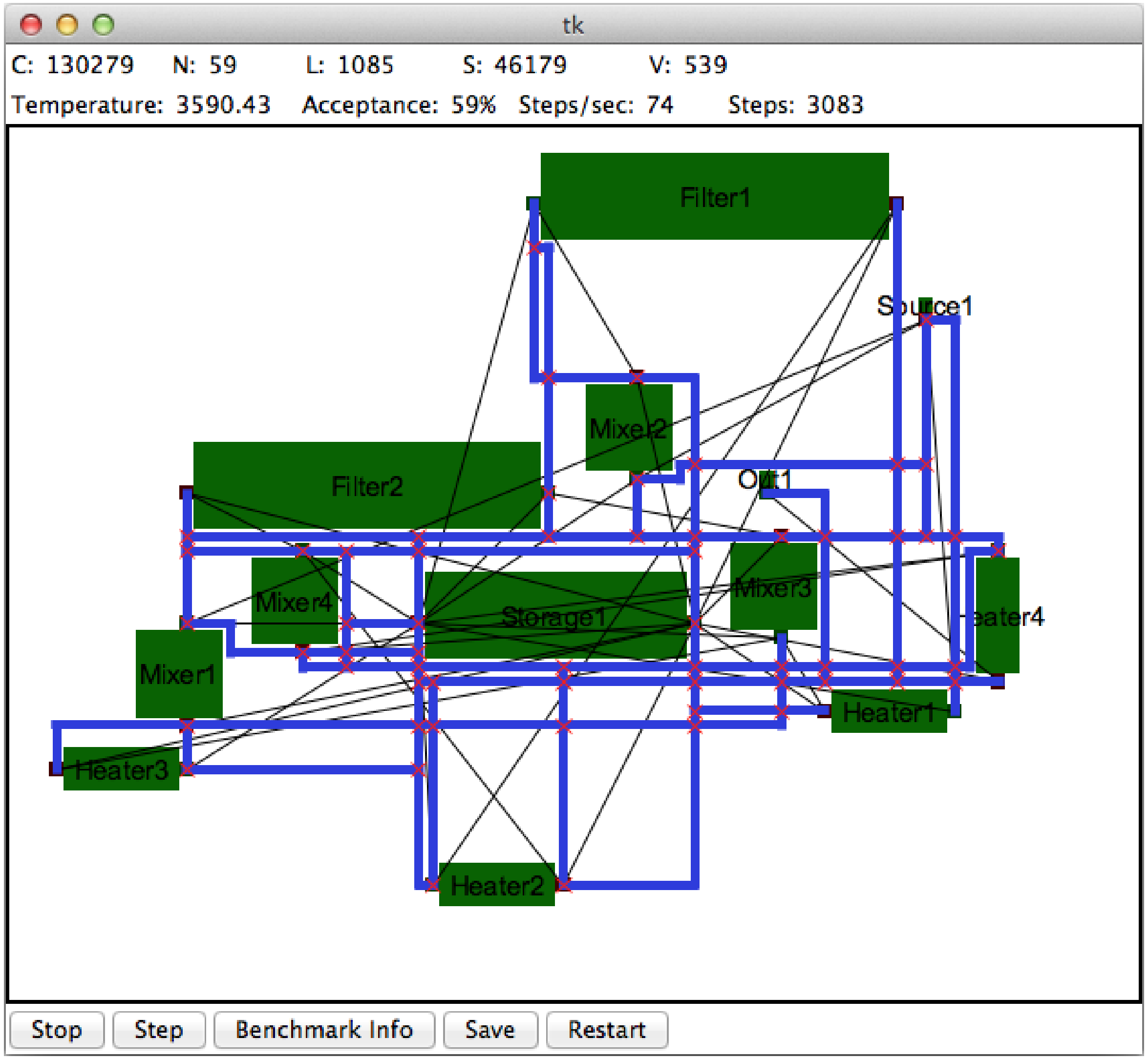


Mixer	3
Heater	2
Filter	1



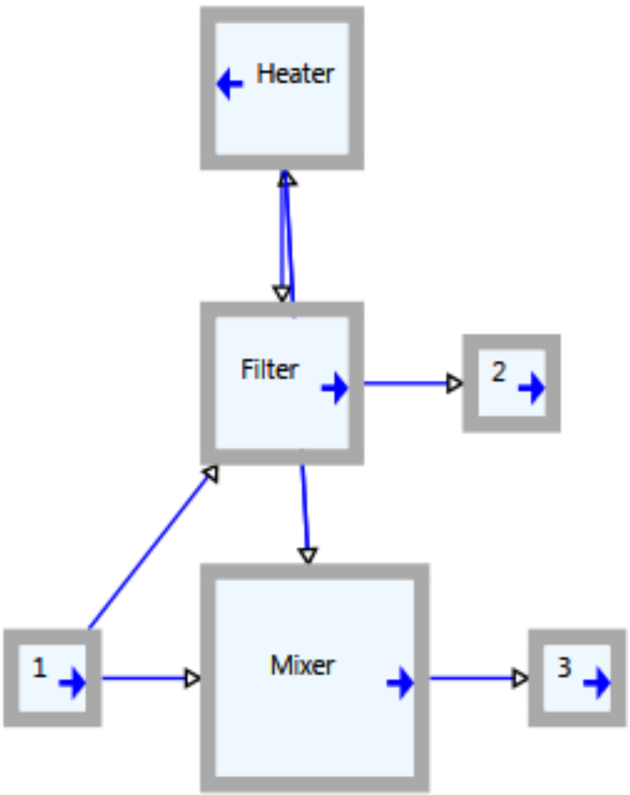
- Input/ output ports
- Storage units
- Fluidic constraints

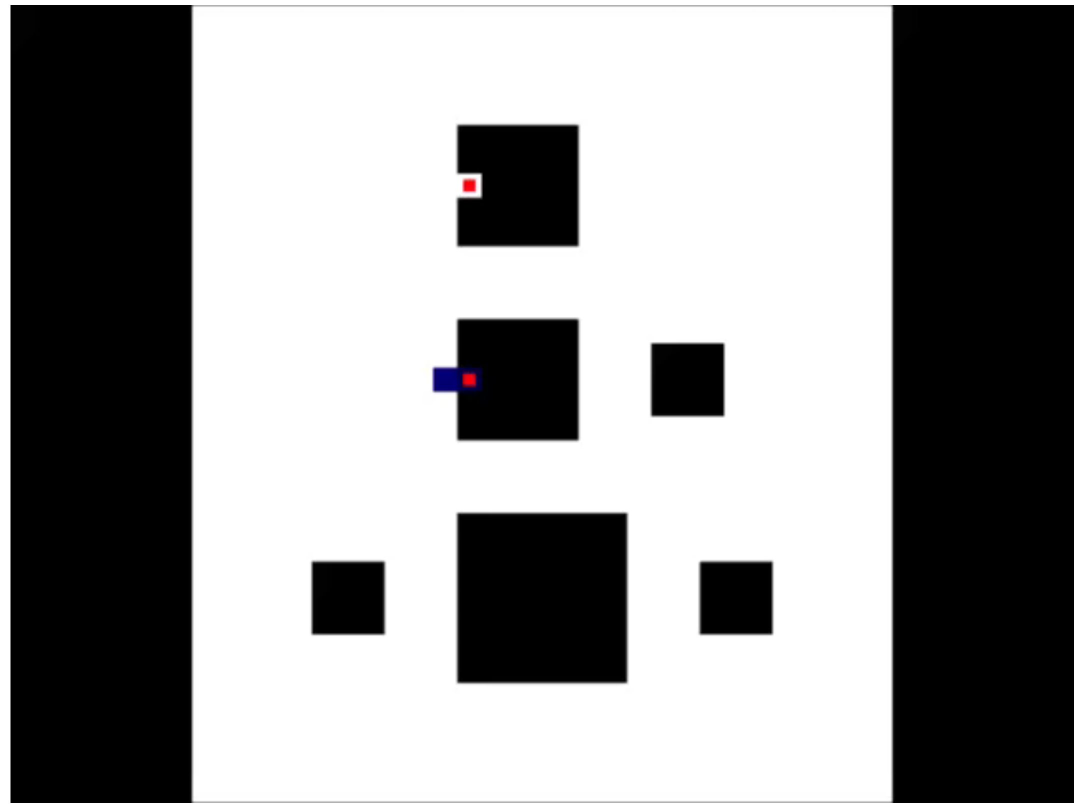
Flow layer placement



Flow-channel routing

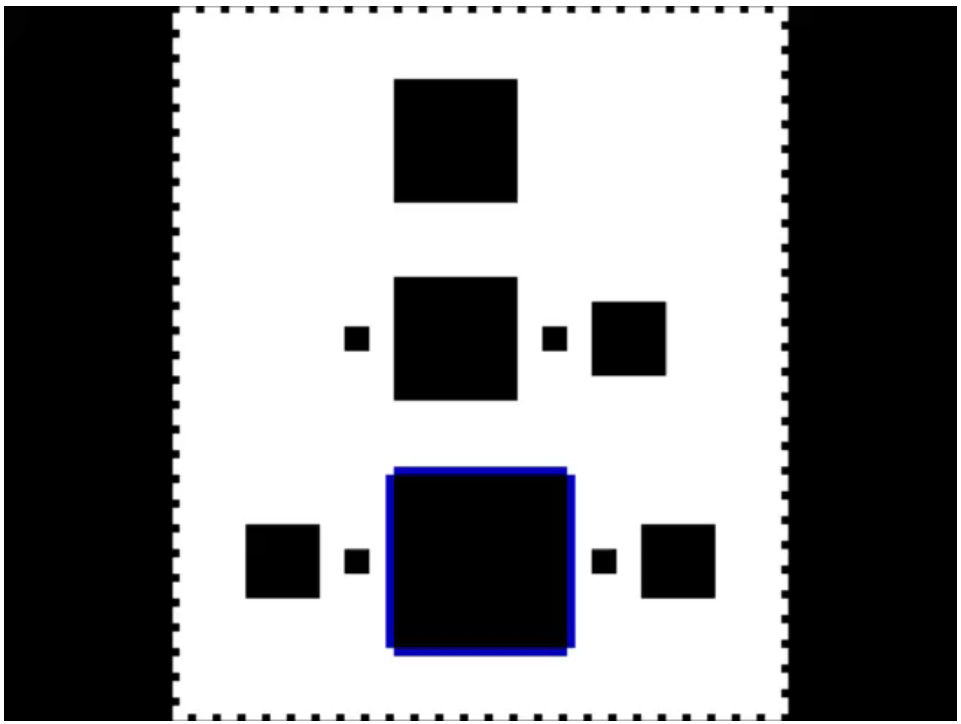
- Algorithms
  - Lee, Hadlock, Soukoup



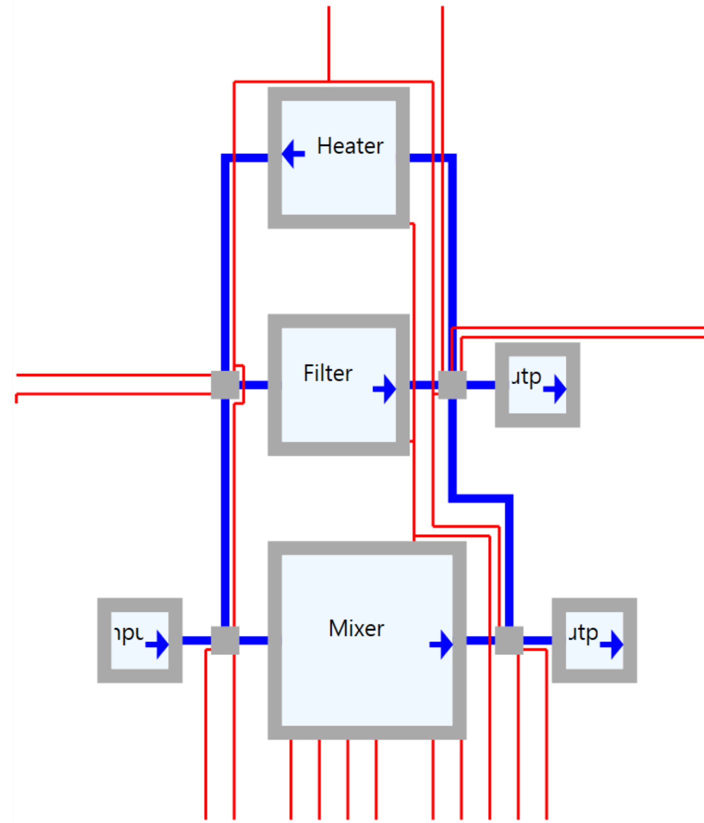


Control layer routing

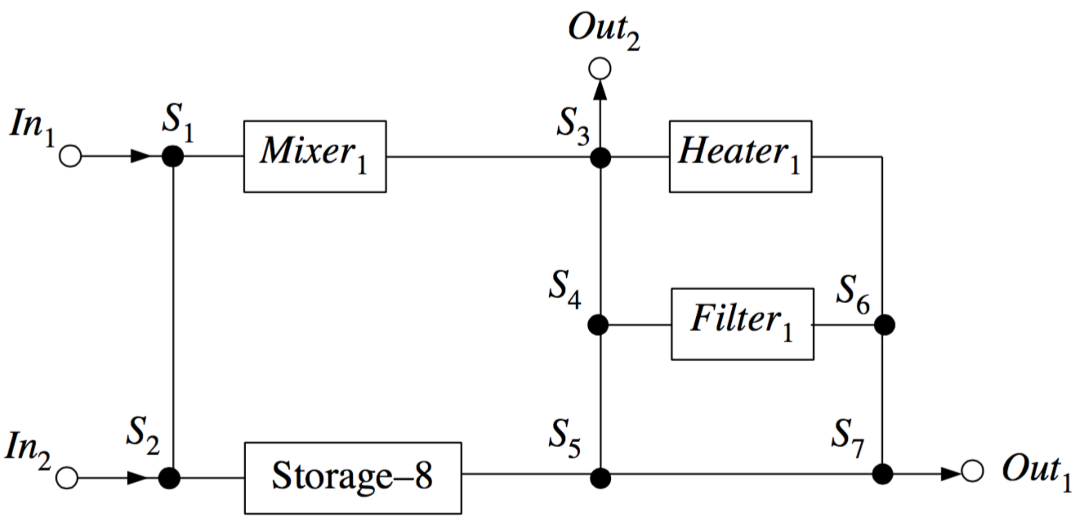
- Algorithms
  - Lee-Steiner: Route from component to nearest air inlet; rip-up and reroute
  - PathFinder



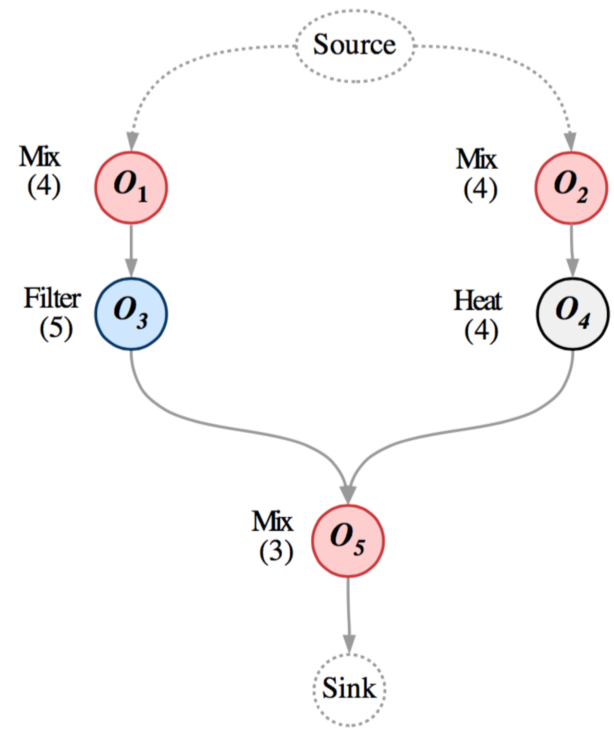
Lee-Steiner's algorithm



Design for fault-tolerance: motivation example

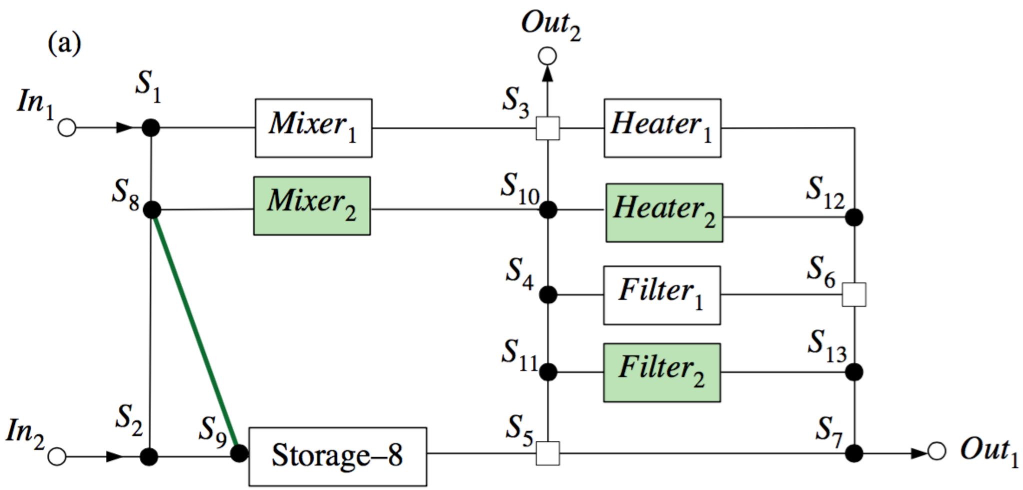


Architecture without fault-tolerance

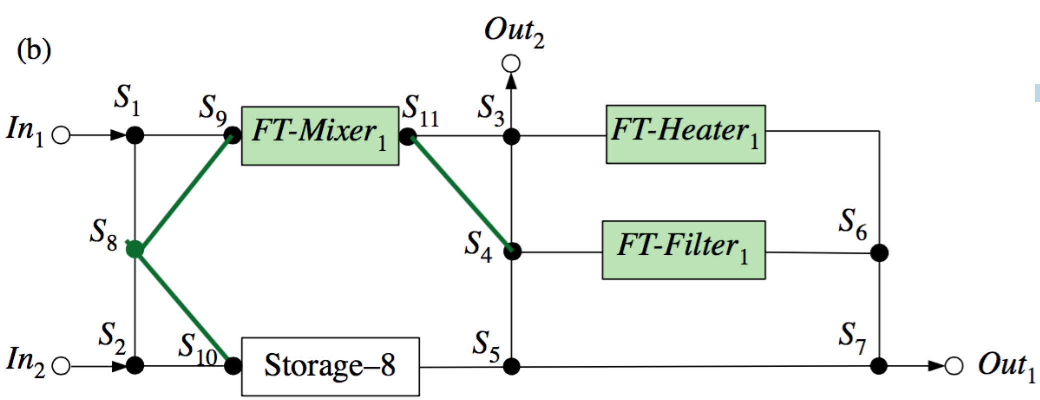


Application

Straightforward vs. optimized redundancy



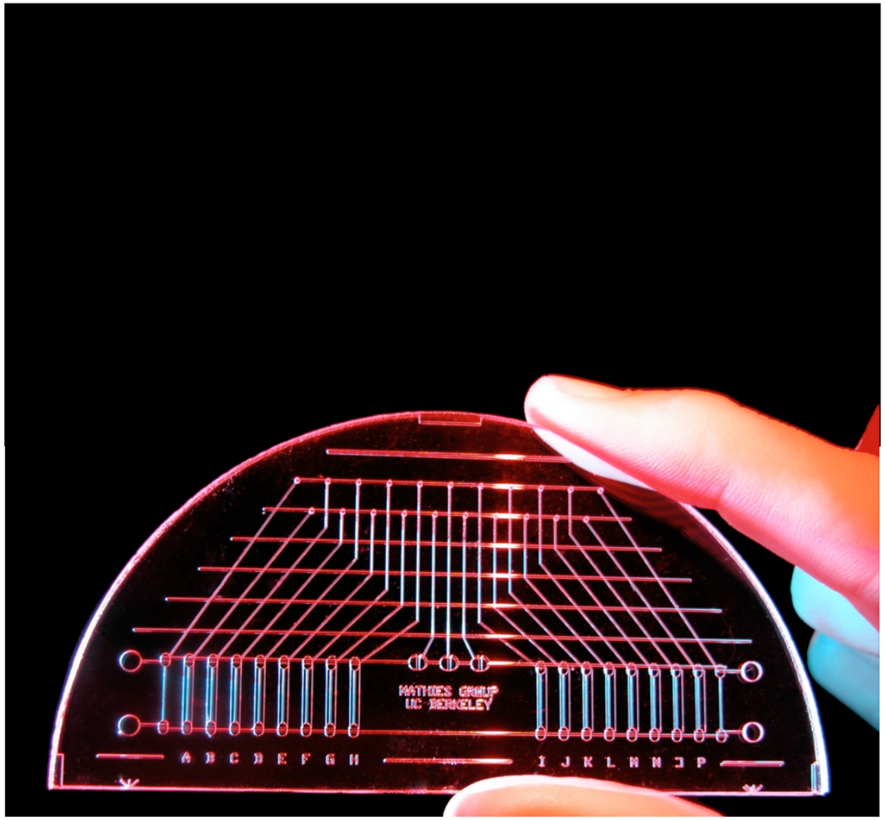
- Straightforward solution: redundancy not optimized; architecture cost: 129

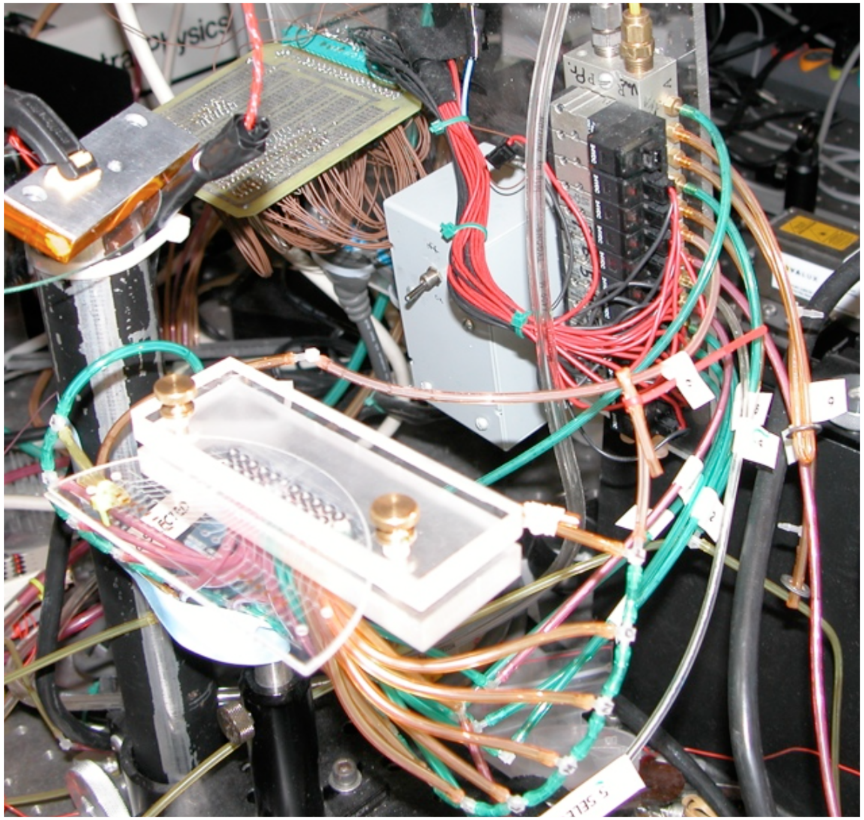


- Optimized solution the introduction of redundancy is optimized; architecture cost: 96

The need for on-chip control

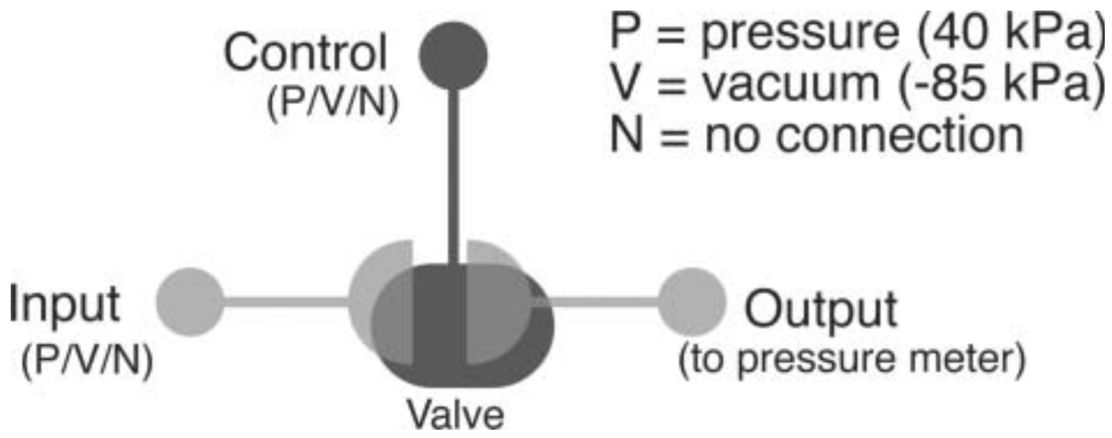
- Slide from Prof. William Grover



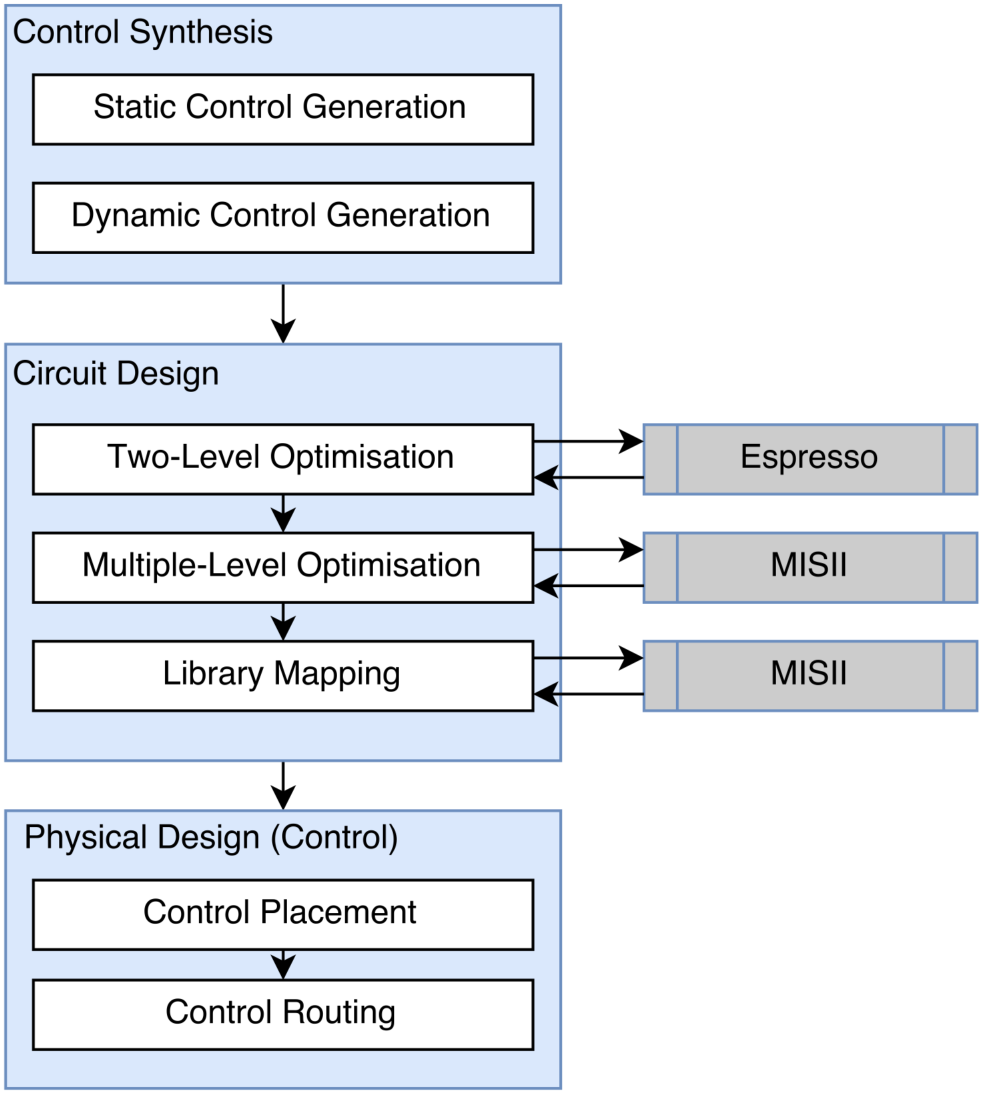


On-chip control

Rule	Maintained at input/kPa	Maintained at control/kPa	Measured at output/kPa
PP	40	40	0
PV	40	-85	40
PN	40	0	40
VP	-85	40	0
VV	-85	-85	-83
VN	-85	0	0



Control circuit synthesis…



..and its physical design