AFTU

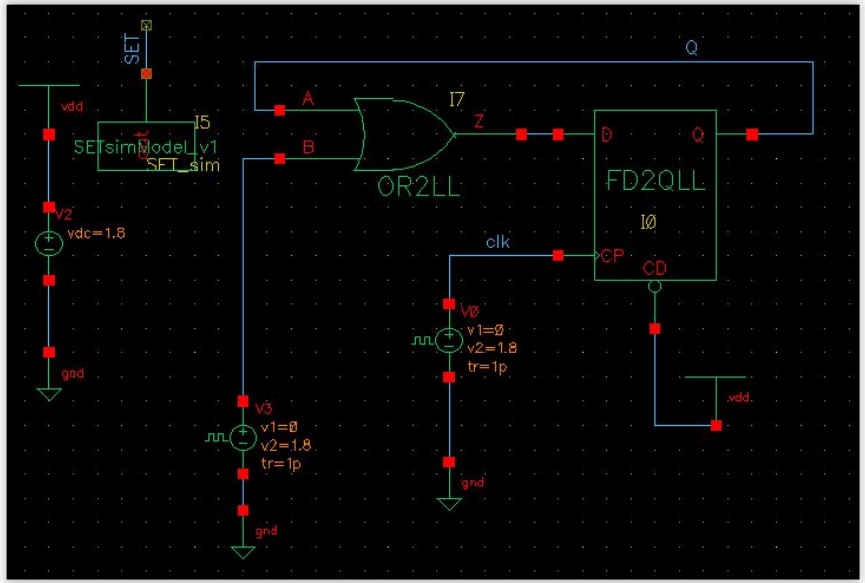
Analog FTU Hardware Debugging System

What is AFTU?

The Analog FTU Hardware Debugging System is a tool to evaluate the SEE sensitivity of analog/mixed signal circuits at transistor level

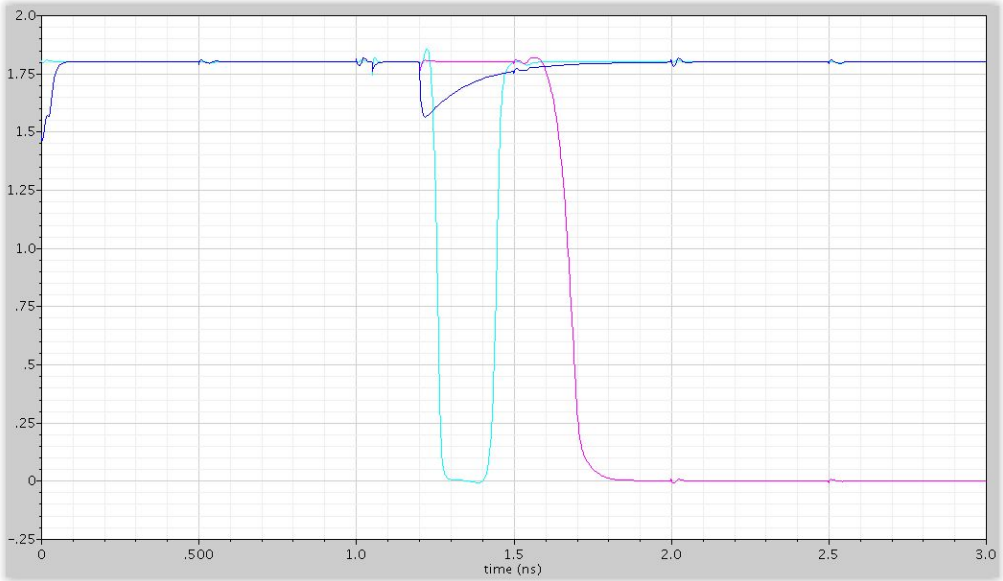
How does it Work?

AFTU takes a Spectre design...



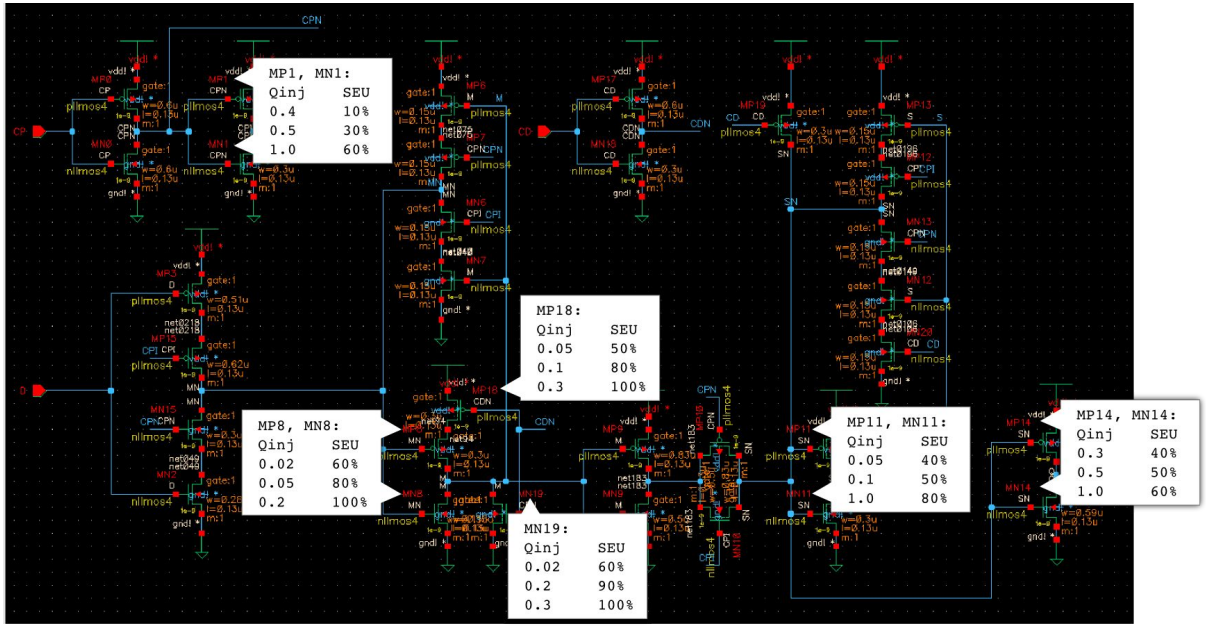
How does it Work?

...emulates radiation conditions...

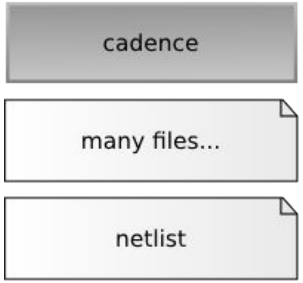


How does it Work?

... and evaluates vulnerabilities



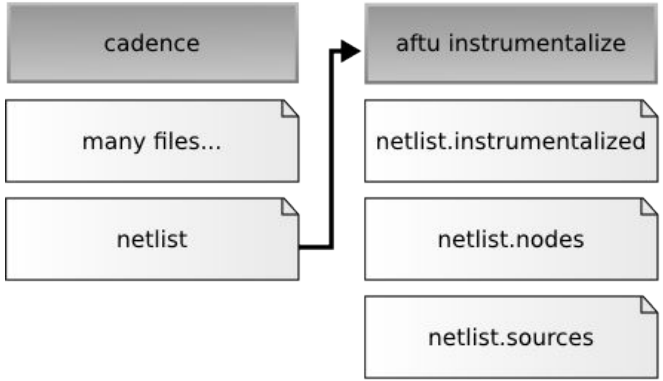
AFTU Toolchain



Before using AFTU:

- The user designs a circuit with Cadence as usual.
- The design is simulated through a testbench.
- Of all files generated by Cadence, we pick the **netlist**.

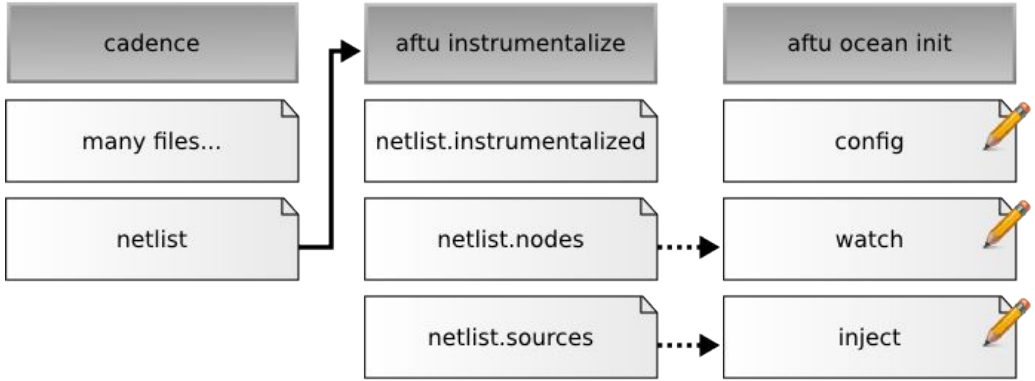
AFTU instrumentalize



The instrumentalizer implements a parser for the SPECTRE language

- Replaces the **netlist** with a *functionally identical* one allowing radiation emulation.
- **netlist.nodes** lists all observable circuit nodes.
- **netlist.sources** lists all transistors where an impact can be emulated.

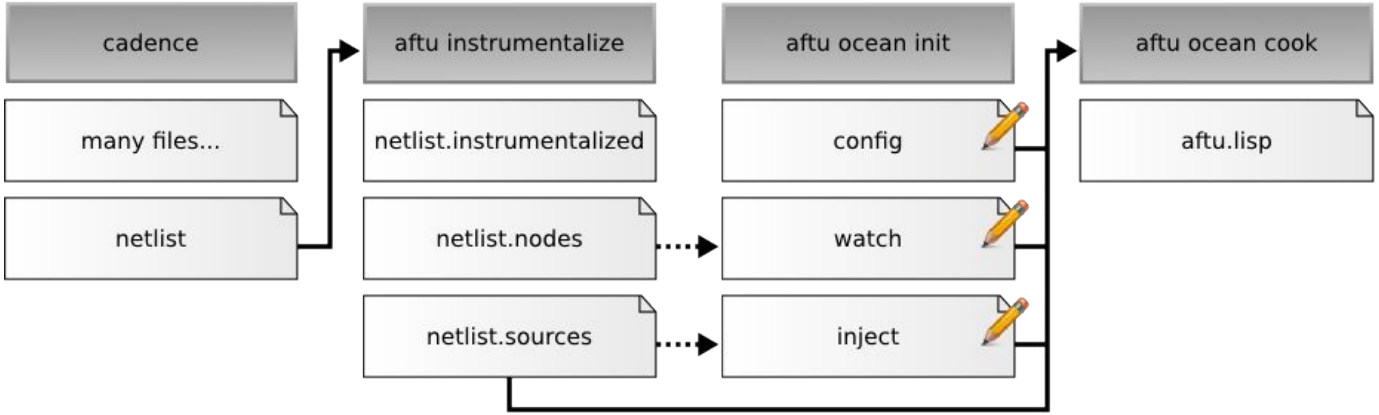
AFTU ocean init



AFTU projects are flexible and give the user many options for analysis.

- **config** contains paths, times, heuristics, initial values…
- **watch** defines all elements in the circuit to be observed during the simulation
- **inject** defines where, when and how much charge we inject (radiation emulation).

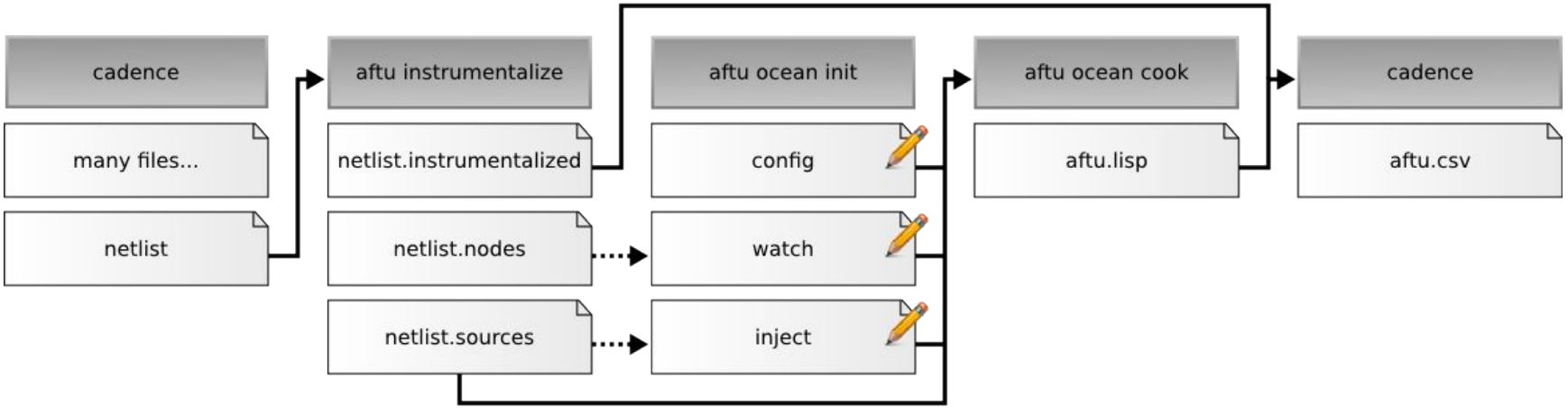
AFTU ocean cook



From all this data a simulation script is produced

- Includes all paths and required data.
- Describes the way to perform the user defined test campaign.
- Defines how to analyze the results of the campaign.

AFTU campaign



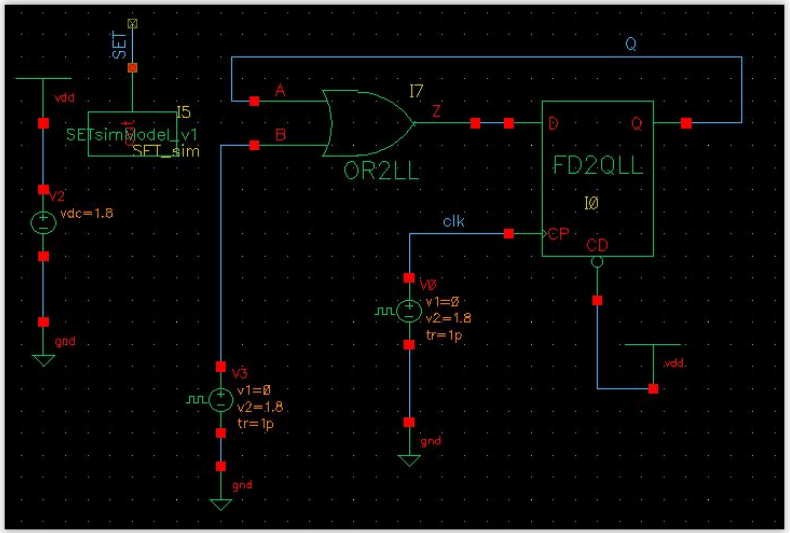
Cadence runs the provided script.

It produces a CSV file with the desired statistics.

This uncovers radiation vulnerabilities in the circuit.

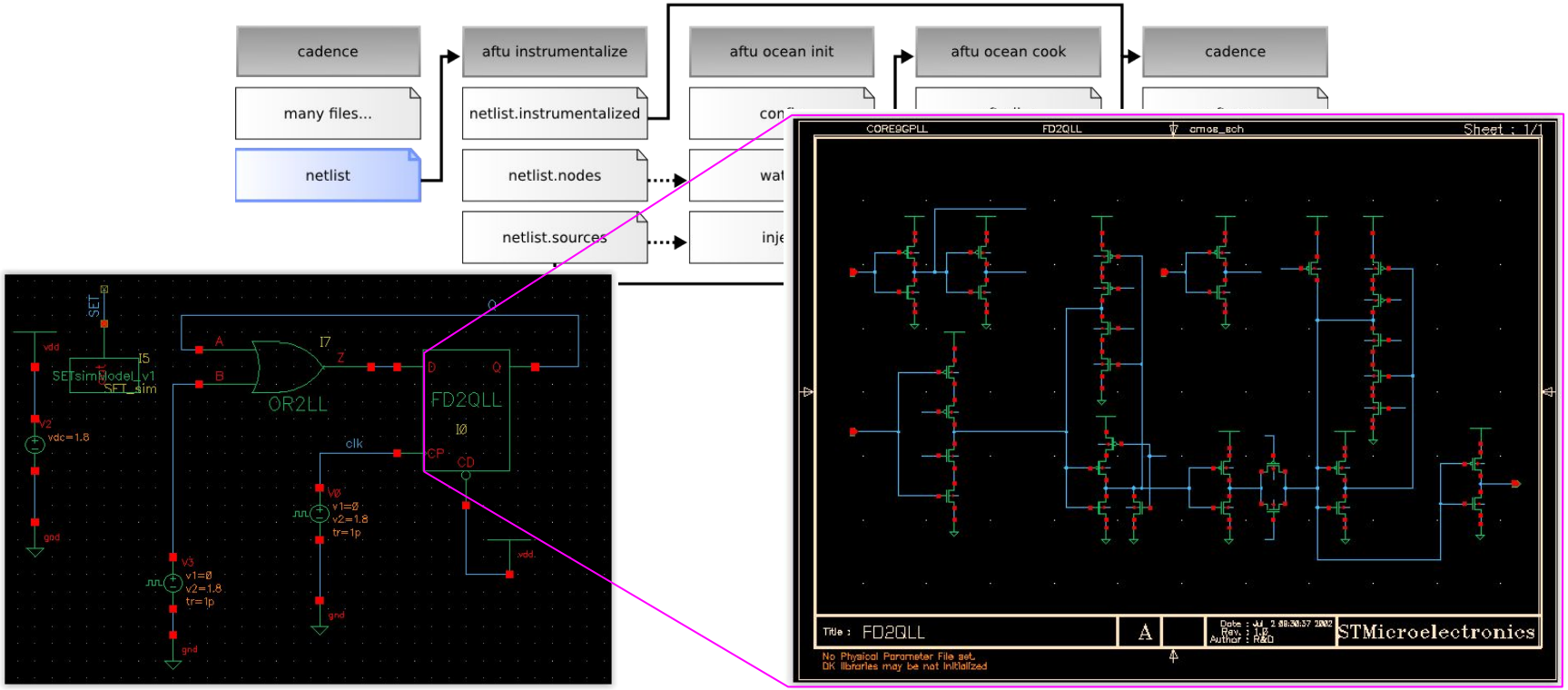
A Practical Example

Let's say we have this circuit:

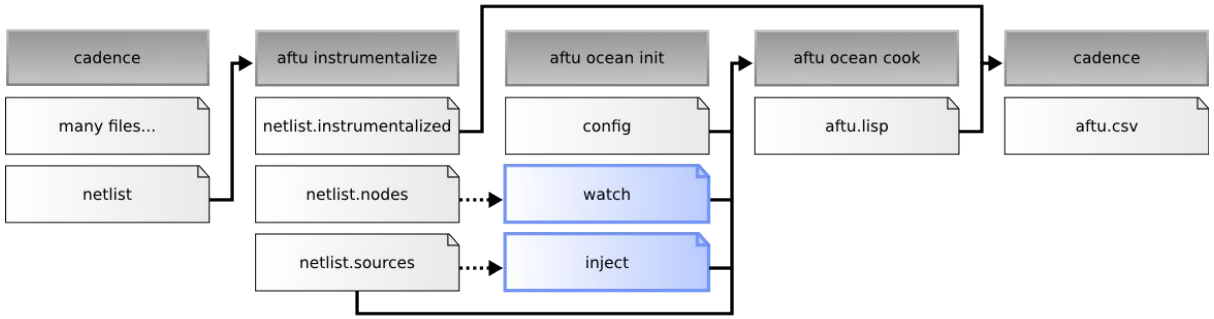


What is the critical charge to produce a SEU?

Netlist


cadence
aftu instrumentalize
aftu ocean init
aftu ocean cook
cadence
many files...
netlist.instrumentalized
netlist
netlist.nodes
netlist.sources
OR2LL
FD2QLL
SETsimModel_v1
SET_sim
vdc=1.8
clk
CORE9GPLL
FD2QLL
cmos_sch
Sheet : 1/1
Title : FD2QLL
STMicroelectronics
No Physical Parameter File set.
OK libraries may be not initialized

Watch & Inject



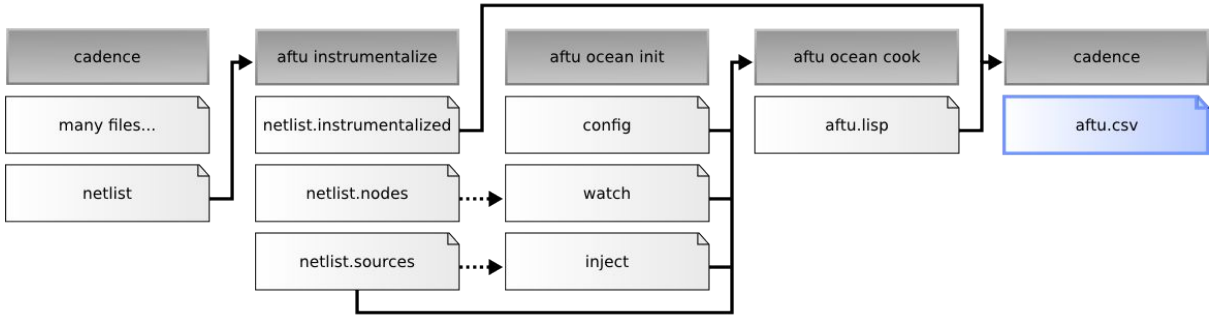

```
watch Q = /Q :
    threshold = 0.975 ;
```

```
inject I0_MP19:
    Q = .025p, .05p, 0.1p, .2p, .5p, .75p, 1p, 1.5p;
    t = 1.0n, 1.1n, 1.2n, 1.3n, 1.4n, 1.5n, 1.6n, 1.7n, 1.8n, 1.9n;

inject I0_MN19:
    Q = .025p, .05p, 0.1p, .2p, .5p, .75p, 1p, 1.5p;
    t = 1.0n, 1.1n, 1.2n, 1.3n, 1.4n, 1.5n, 1.6n, 1.7n, 1.8n, 1.9n;

inject I0_MP18:
    Q = .025p, .05p, 0.1p, .2p, .5p, .75p, 1p, 1.5p;
    t = 1.0n, 1.1n, 1.2n, 1.3n, 1.4n, 1.5n, 1.6n, 1.7n, 1.8n, 1.9n;
```

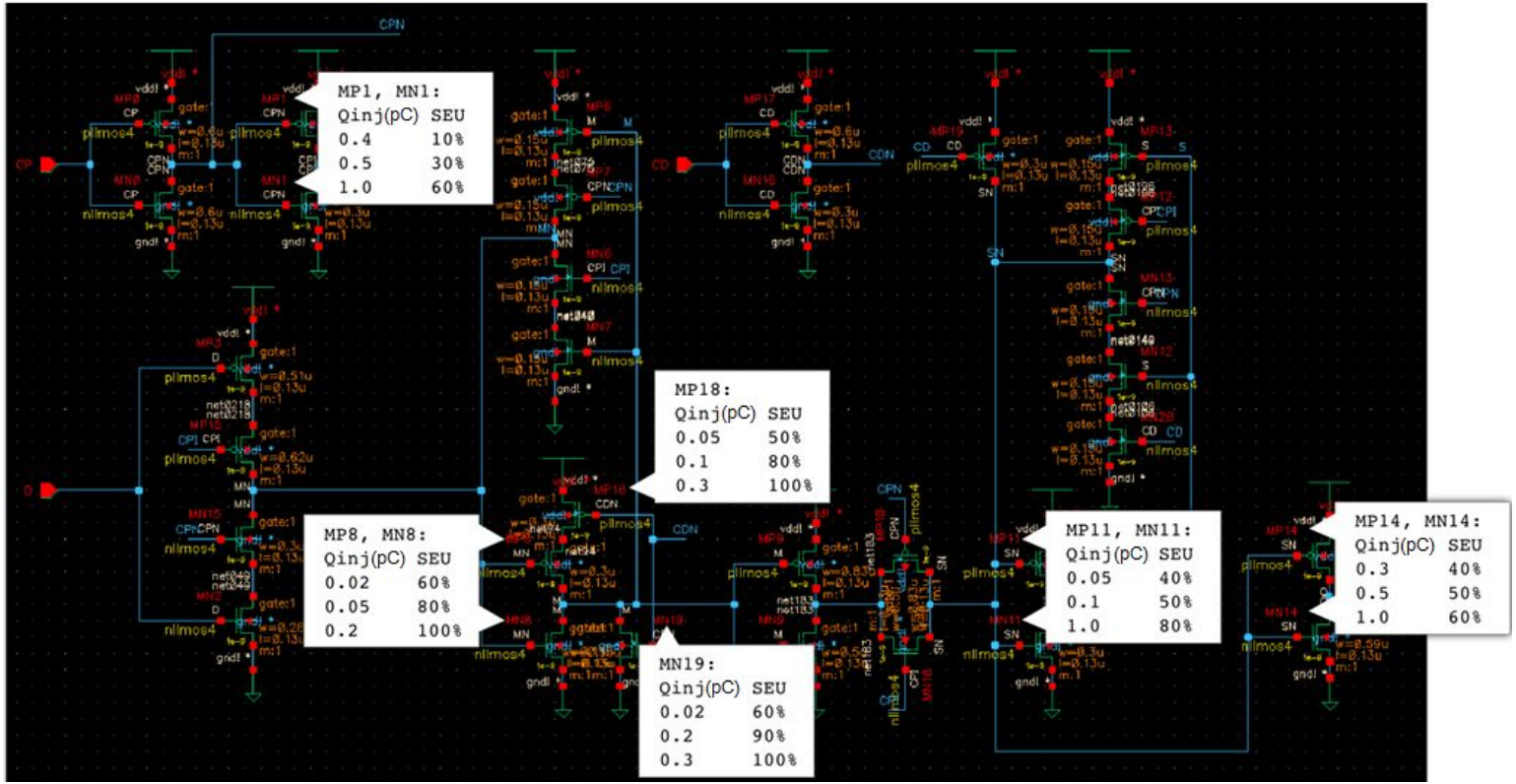
Results



Output	ImpactNode	Qinj	Timp	Trec	Vmax
V_Q	I0_MP18	2.5e-14	1e-09	0.000000	0.001941
V_Q	I0_MP18	2.5e-14	1.1e-09	0.000000	0.00219
V_Q	I0_MP18	2.5e-14	1.9e-09	0.000000	0.003664
V_Q	I0_MP18	5e-14	1e-09	2.000000	1.807421
V_Q	I0_MP18	5e-14	1.1e-09	1.910000	1.807422
V_Q	I0_MP18	5e-14	1.2e-09	1.800000	1.807426
V_Q	I0_MP18	5e-14	1.3e-09	1.700000	1.807384
V_Q	I0_MP18	5e-14	1.8e-09	0.000000	0.519730
V_Q	I0_MP18	5e-14	1.9e-09	1.100000	1.803023

Output	ImpactNode	Qinj	Timp	Trec	Vmax
V_Q	I0_MN11	2.5e-14	1e-09	0.000000	0.006827
V_Q	I0_MN11	2.5e-14	1.9e-09	0.000000	0.016568
V_Q	I0_MN11	5e-14	1e-09	0.000000	0.017084
V_Q	I0_MN11	5e-14	1.3e-09	0.000000	0.005371
V_Q	I0_MN11	5e-14	1.4e-09	1.610000	1.806680
V_Q	I0_MN11	5e-14	1.5e-09	1.500000	1.806814
V_Q	I0_MN11	5e-14	1.6e-09	1.400000	1.805740
V_Q	I0_MN11	5e-14	1.7e-09	1.300000	1.802925
V_Q	I0_MN11	5e-14	1.8e-09	0.240000	1.404223

Results


MP1, MN1:
Qinj(pC) SEU
0.4 10%
0.5 30%
1.0 60%
MP18:
Qinj(pC) SEU
0.05 50%
0.1 80%
0.3 100%
MP8, MN8:
Qinj(pC) SEU
0.02 60%
0.05 80%
0.2 100%
MN19:
Qinj(pC) SEU
0.02 60%
0.2 90%
0.3 100%
MP11, MN11:
Qinj(pC) SEU
0.05 40%
0.1 50%
1.0 80%
MP14, MN14:
Qinj(pC) SEU
0.3 40%
0.5 50%
1.0 60%

Where do we go from here?

More technologies

More heuristics

Total dose analysis

Integrate in FTU2 cloud-based GUI

Research Mixed AFTU/FTU2 simulations

Speed up Cadence simulation