STEAM

“Spline-based Tables for Efficient and Accurate Device-Modelling”

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EECS Department, UC Berkeley

STEAM is about devices and models

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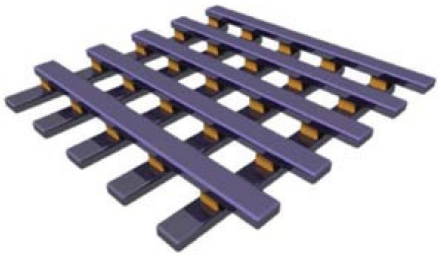
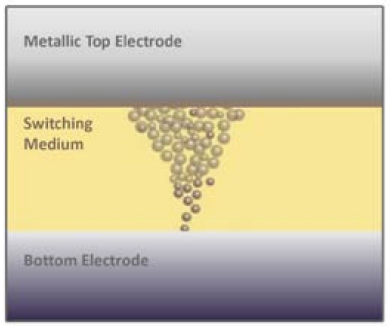
RRAM Crossbar





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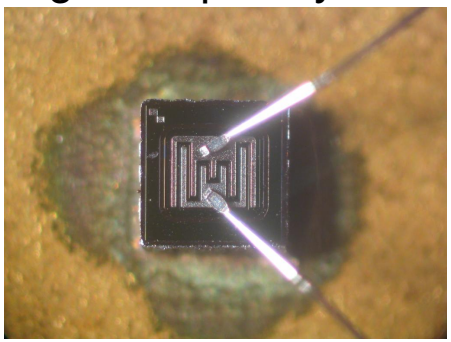
High Frequency NPN



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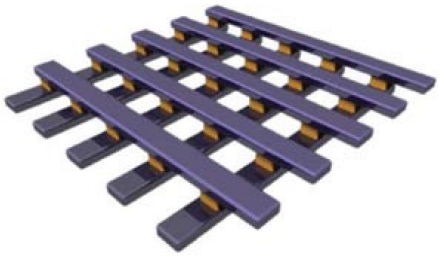

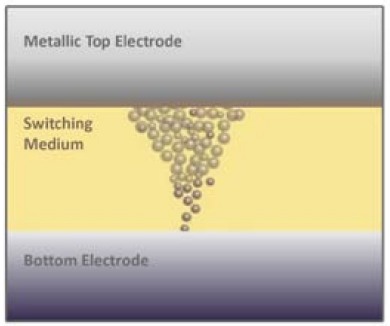

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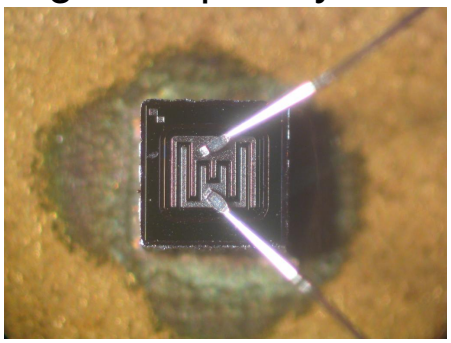

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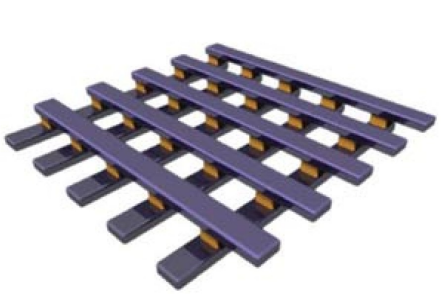
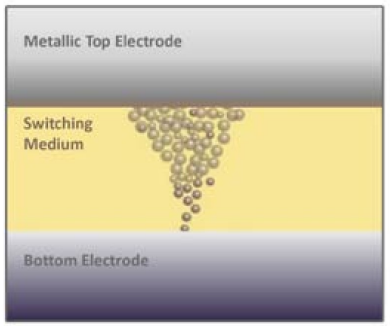
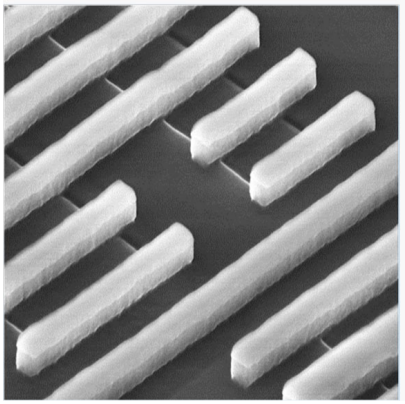




32nm planar FET



22nm tri-gate FET

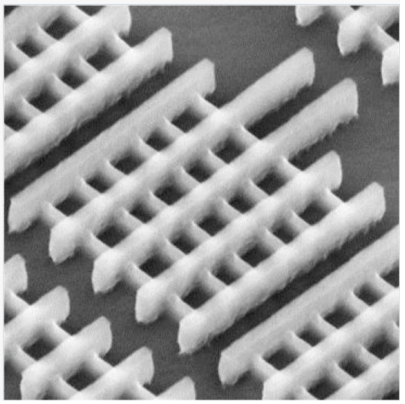


Image Source: Wikipedia

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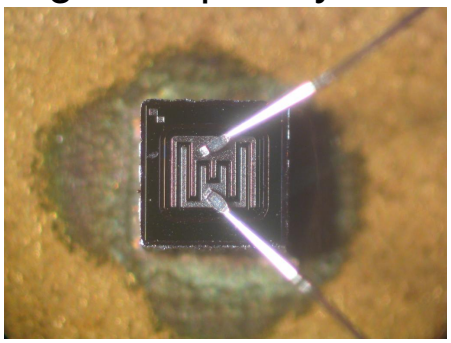

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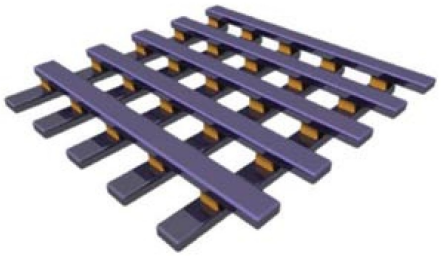

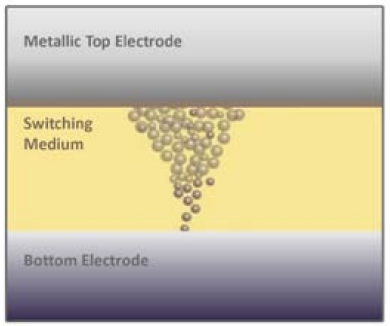

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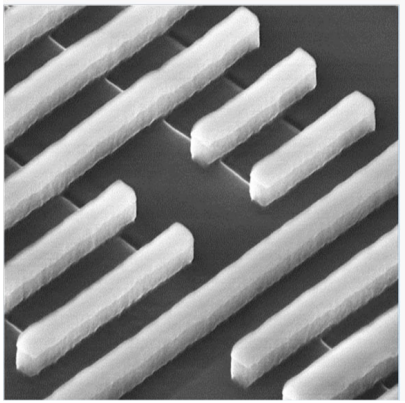

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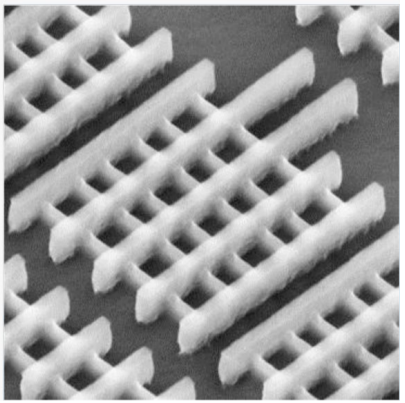

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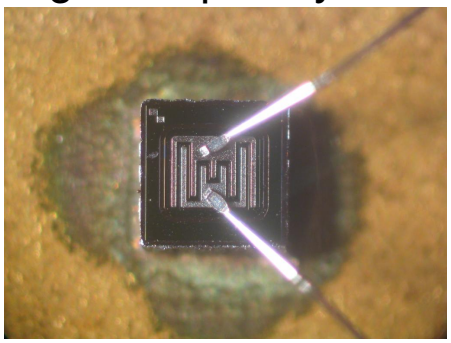

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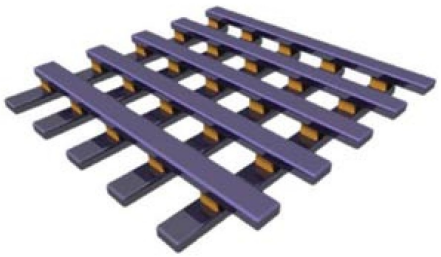

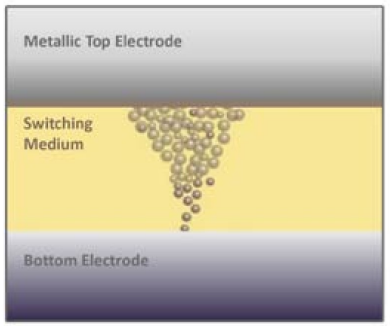


```
  1  function MOD = BSIM3v3_2_4_ModSpec(uniqID)...
1348
1349  %%%%%%%%%%%%%%%%%% NR INITIAL GUESS SUPPORT %%%%%%%%%%%%%%%%%%
1350  function vecLim = initGuess(u, MOD)... % initGuess
1793
1794  %%%%%%%%%%%%%%%%%% NR LIMITING SUPPORT %%%%%%%%%%%%%%%%%%%%%%
1795  function vecLim = limiting...
1796        (vecX,vecY,vecXold,vecYold, u, MOD)... % limiting
2300
2301  %%%%%%%%%%%%%%%%%% CORE DEVICE EVAL FUNCTIONS %%%%%%%%%%%%%%%%
2302  function [fe, qe, fi, qi] = fqei_all(vecX, vecY, vecLim, u, flag, MOD)...
5088
```

```
  1  function MOD = BSIM3v3_2_4d_ModSpec(uniqID)...
458
459  function [fqei_out, J_out] = fqeiJ(vecX, vecY, vecLim, vecU, flag, MOD)...
489
490    function [fe__, qe__, fi__, qi__,...
491              d_fe_d_X__, d_qe_d_X__, d_fi_d_X__, d_qi_d_X__,...
492              d_fe_d_Y__, d_qe_d_Y__, d_fi_d_Y__, d_qi_d_Y__] = ...
493           fqei_dfqeidXYU(vecX__, vecY__, MOD)...
4535
```

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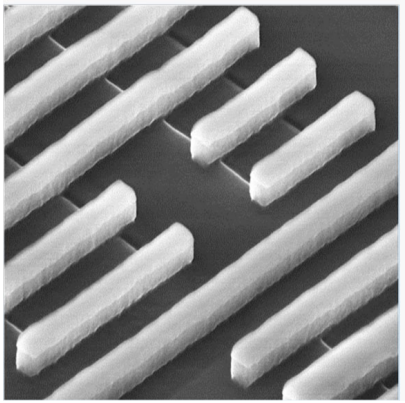

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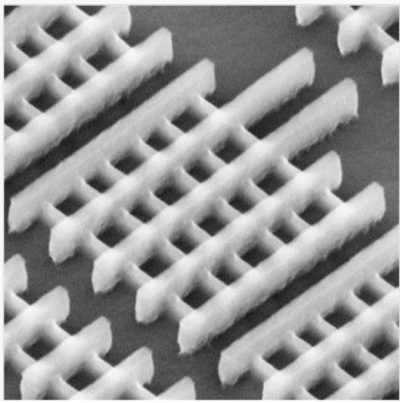

Image Source: Wikipedia

What constitutes a device model?

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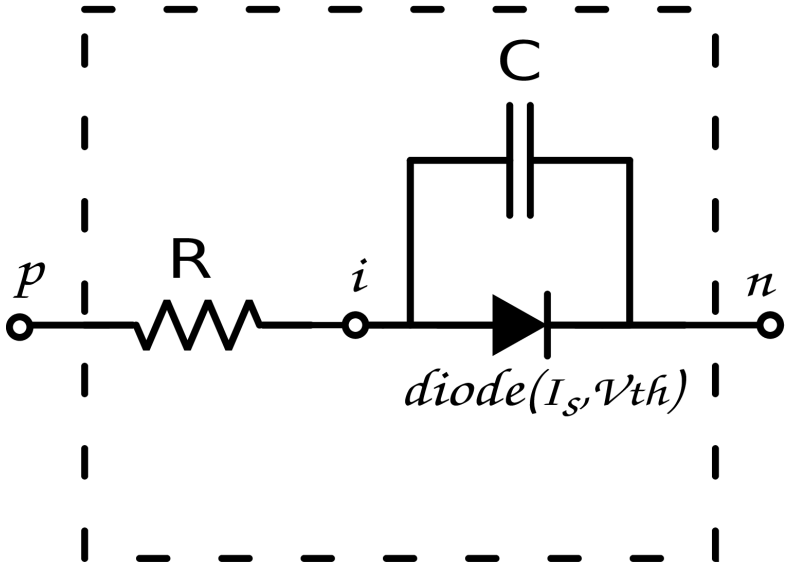

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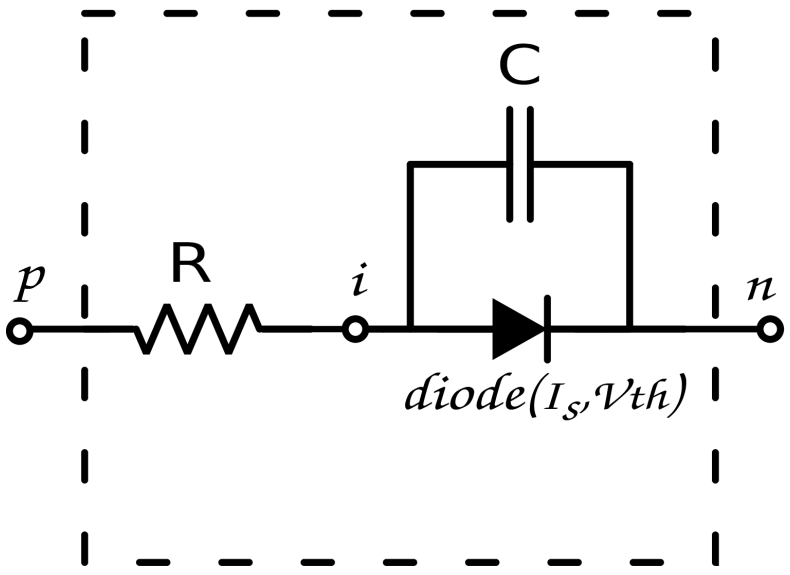

Simulator (equation engine...) gives v_{pn}, v_{in}

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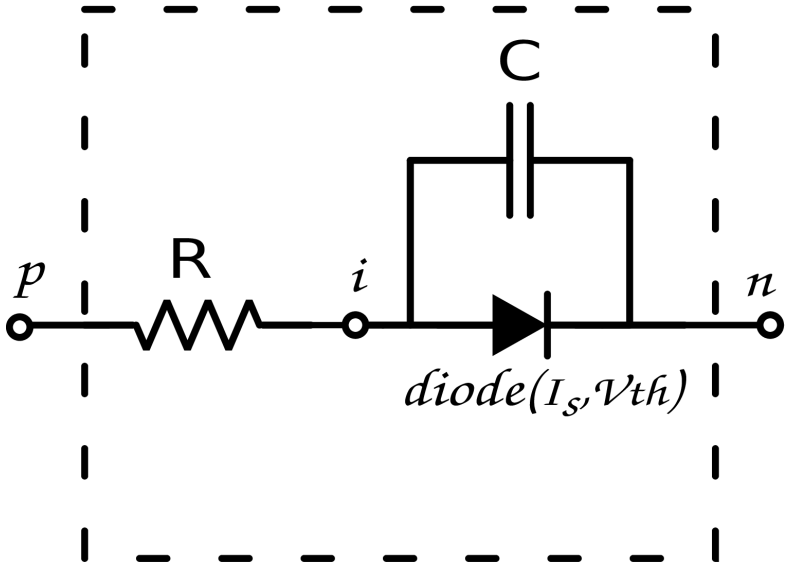
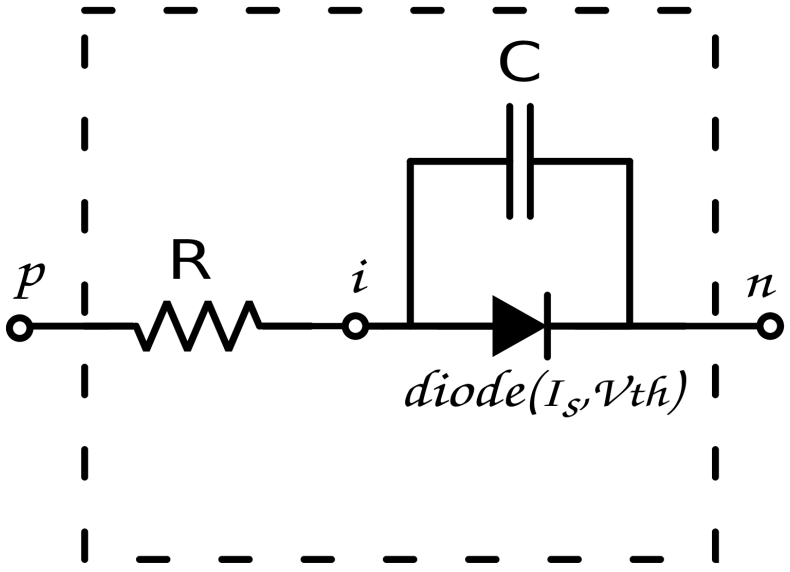


Simulator (equation engine...) gives v_{pn}, v_{in}

It wants i_{pn} to solve a system of equations!

What constitutes a device model?

i_{pn}: “explicit output”



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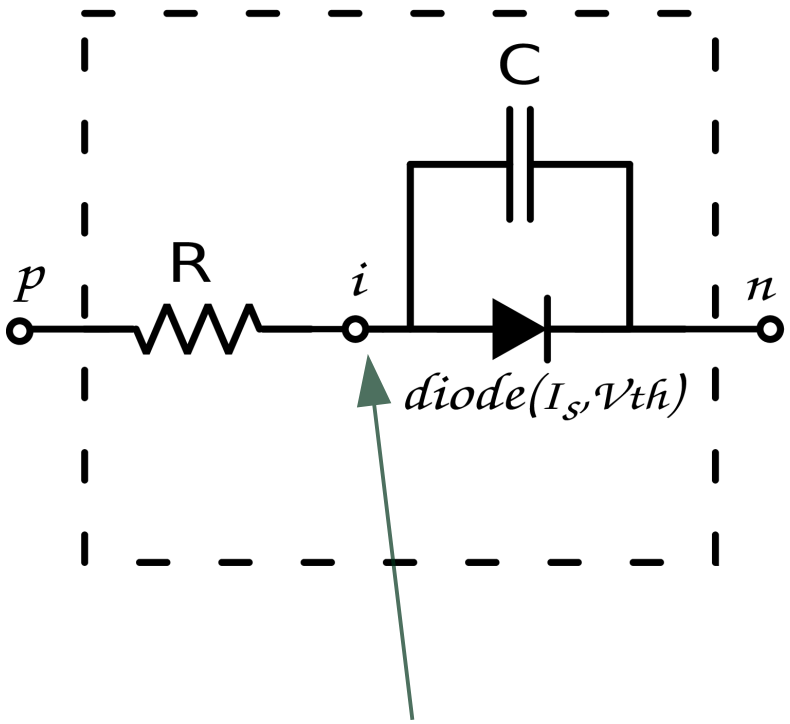

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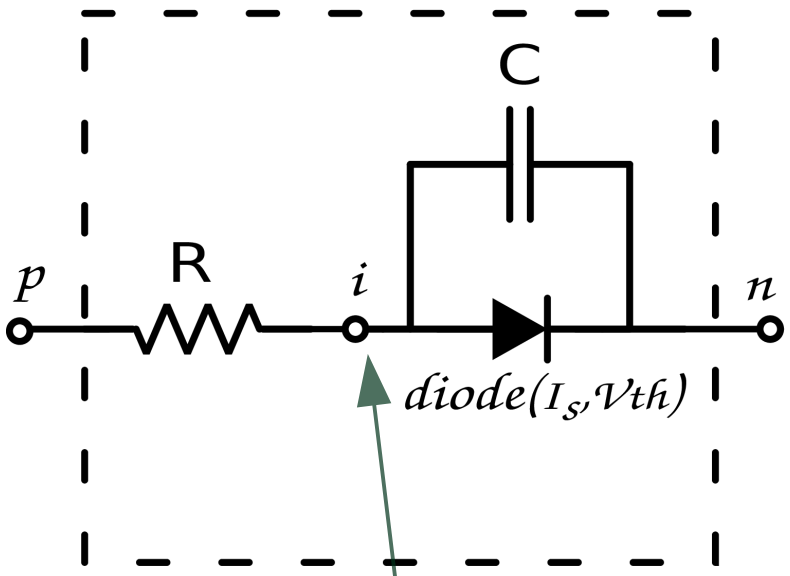

v_{in}: “internal unknown”

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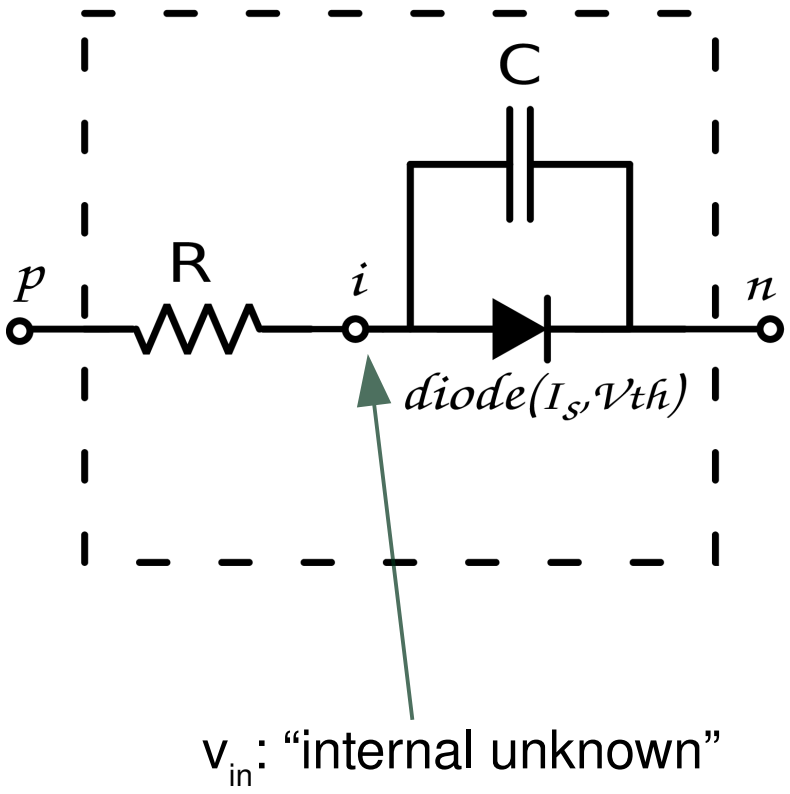

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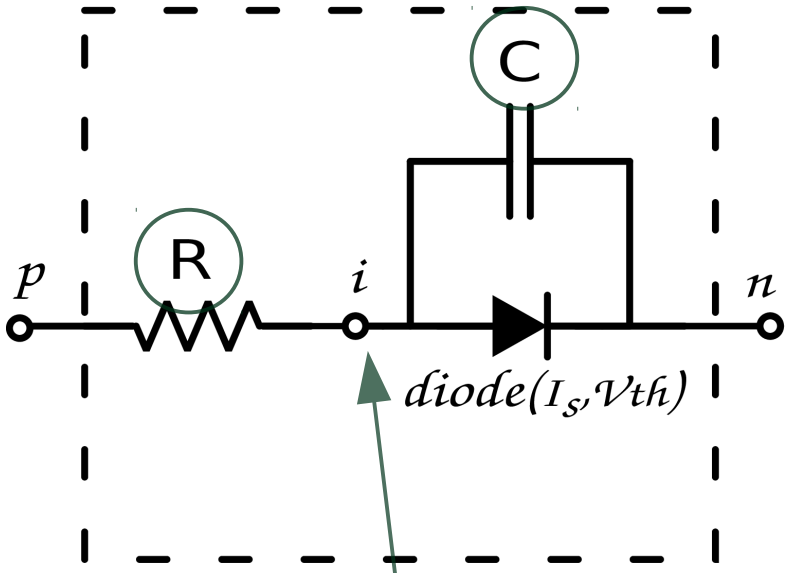

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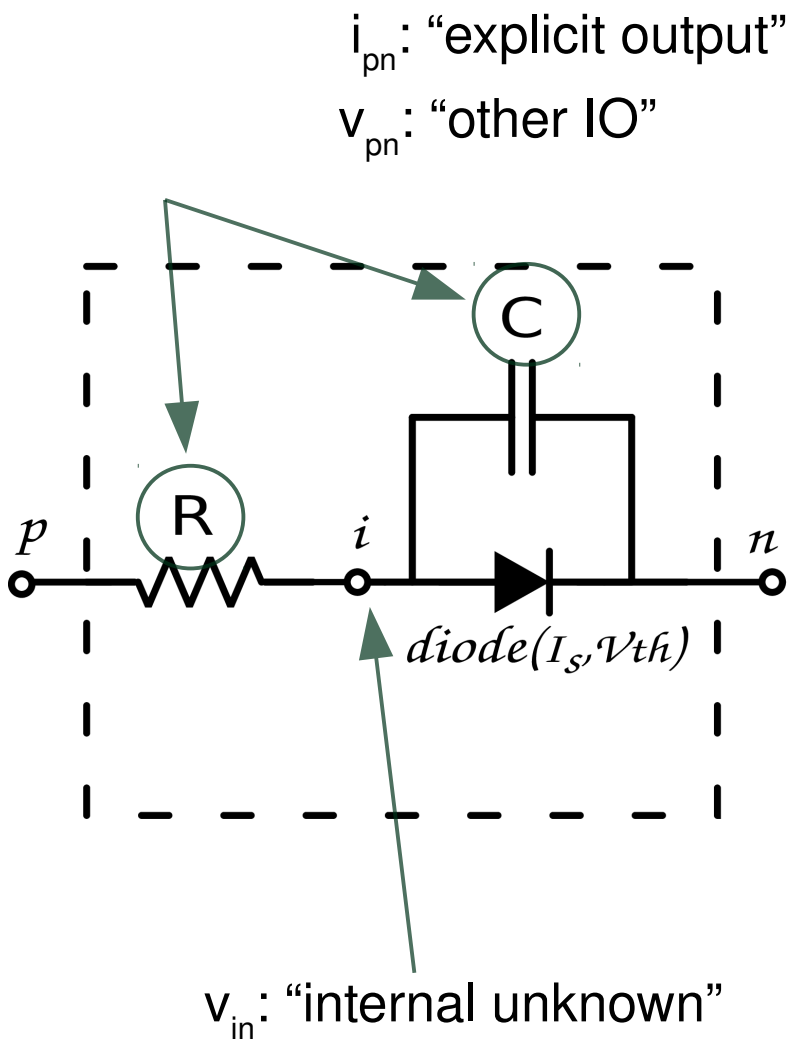

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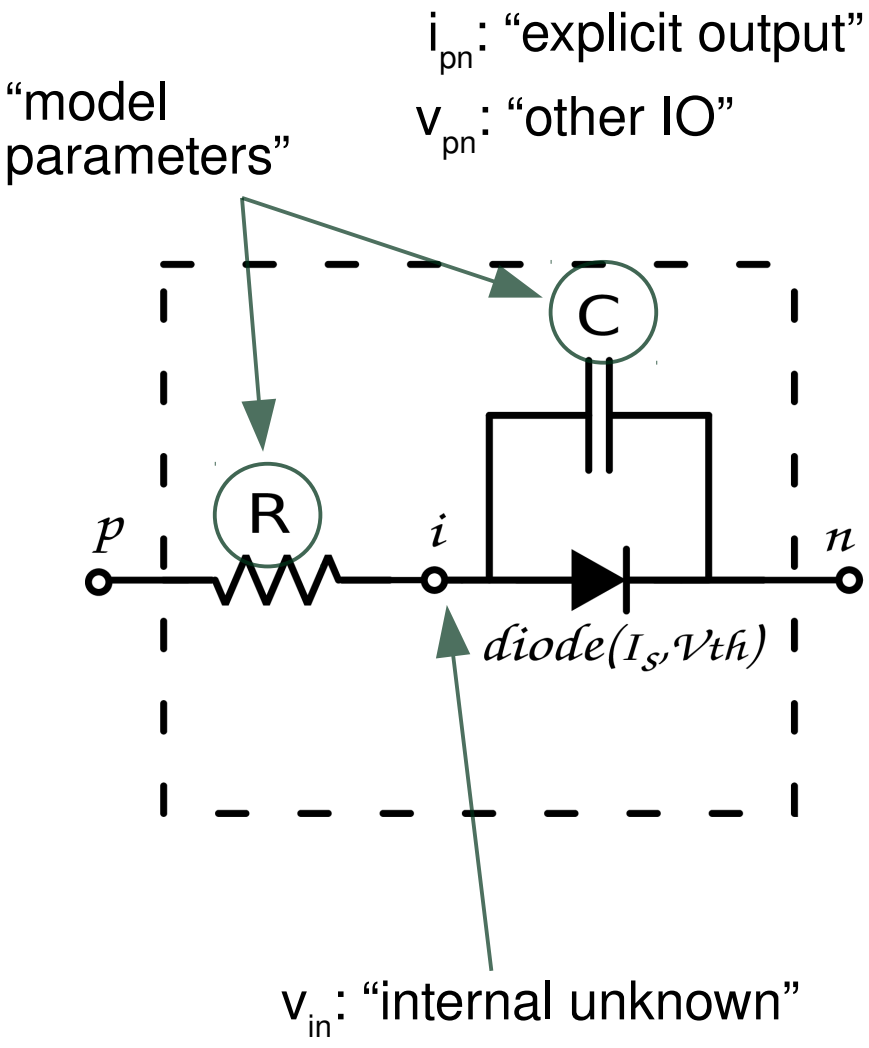

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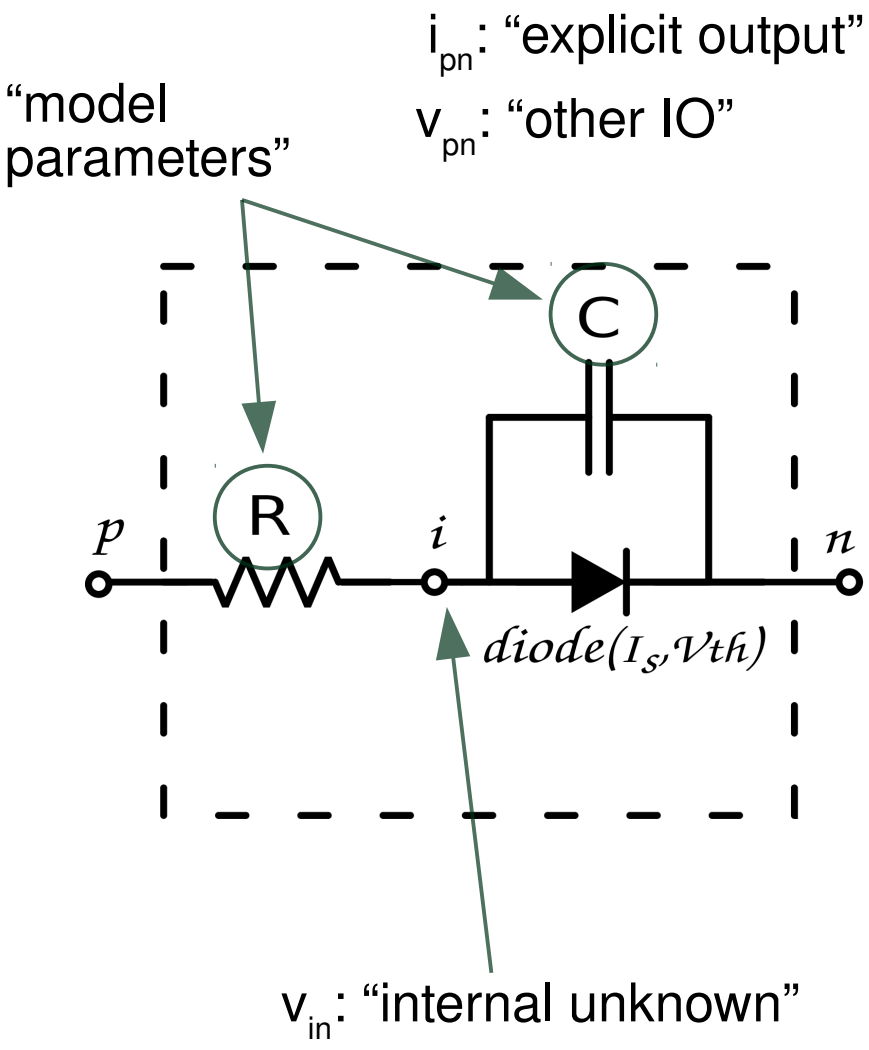

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Usually, it also wants some derivatives

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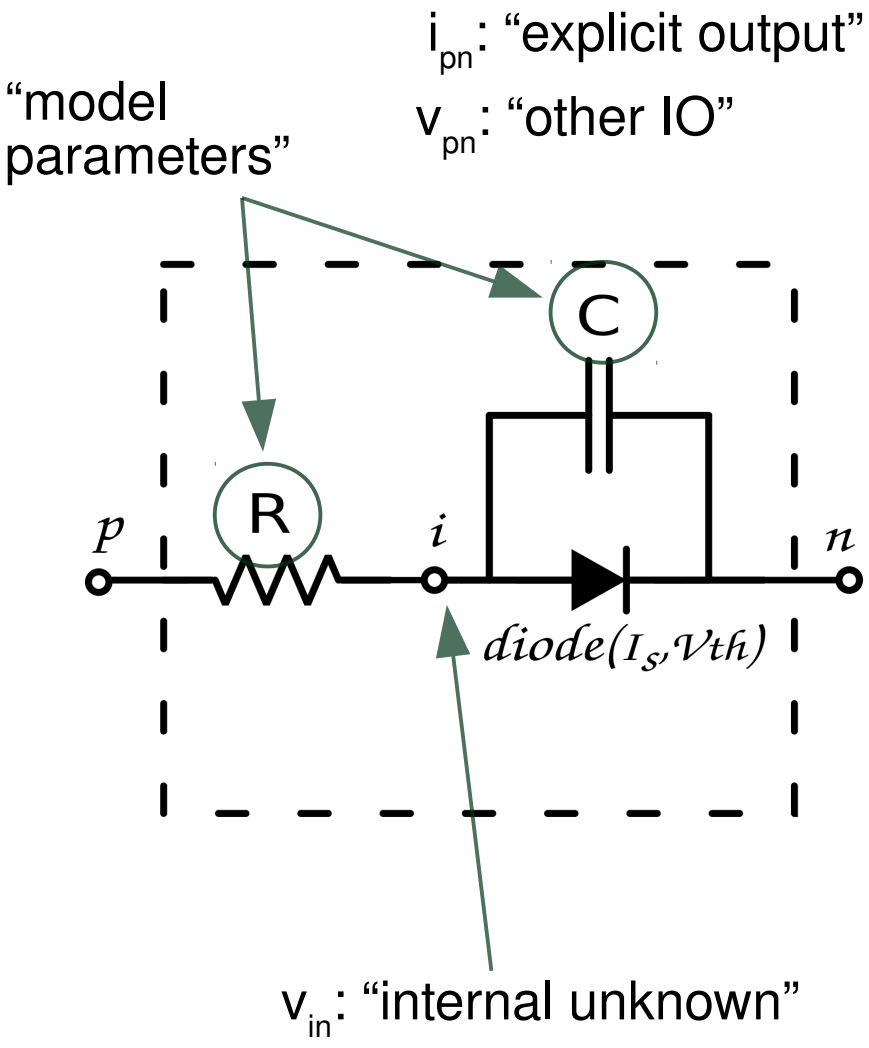

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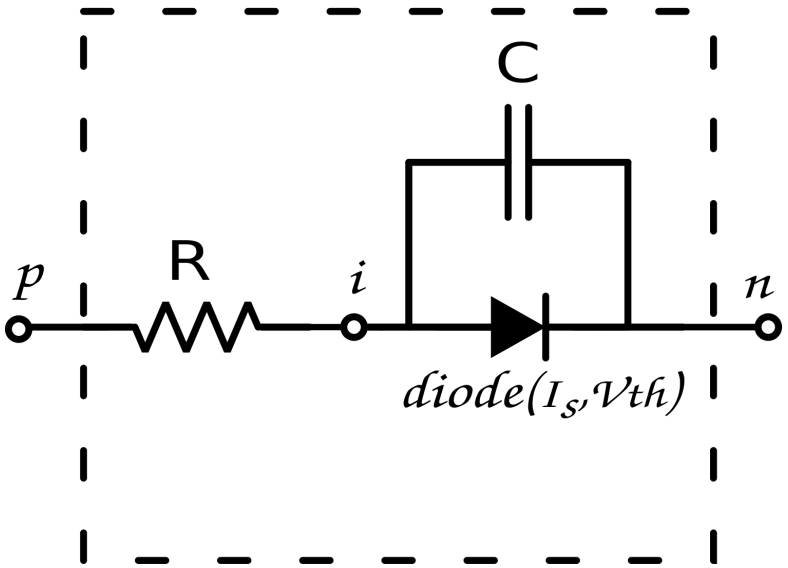
We want some sort of Look-Up table to give us i_{pn} and derivatives

Dynamics are governed by Differential Algebraic Equations



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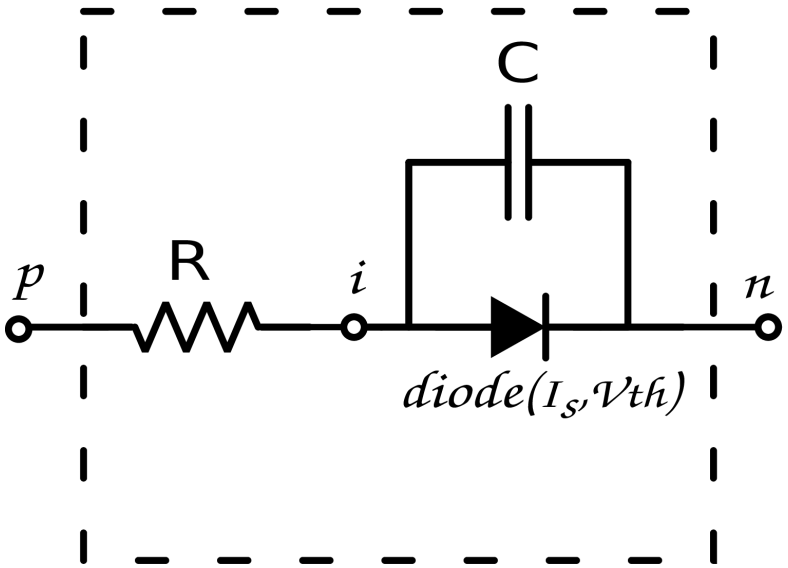

$$\frac{d}{dt}0+\frac{v_{pn}-v_{in}}{R}=i_{pn}$$

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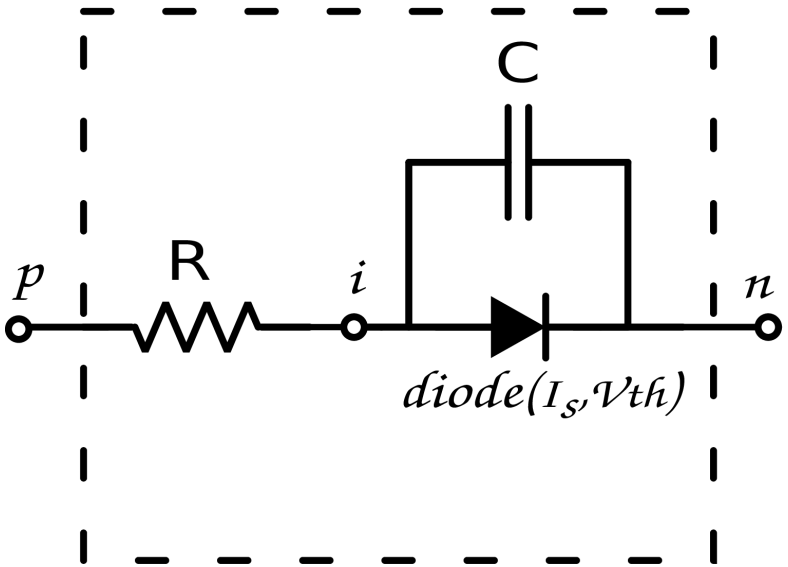

$$\frac{d}{dt}0+\frac{v_{pn}-v_{in}}{R}=i_{pn}$$

$$\frac{d}{dt}Cv_{in}+diode(v_{in})+\frac{v_{in}-v_{pn}}{R}=0$$

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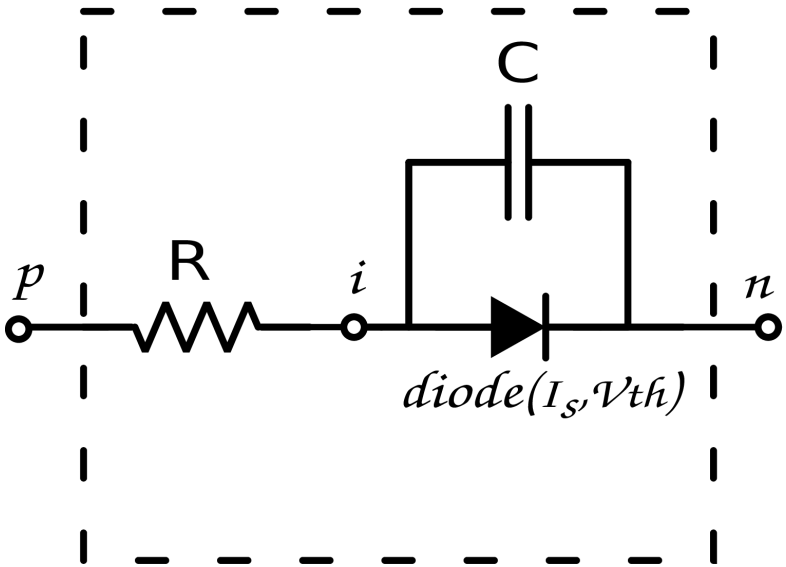

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This can be generalized to practically any circuit or model that we are interested in.

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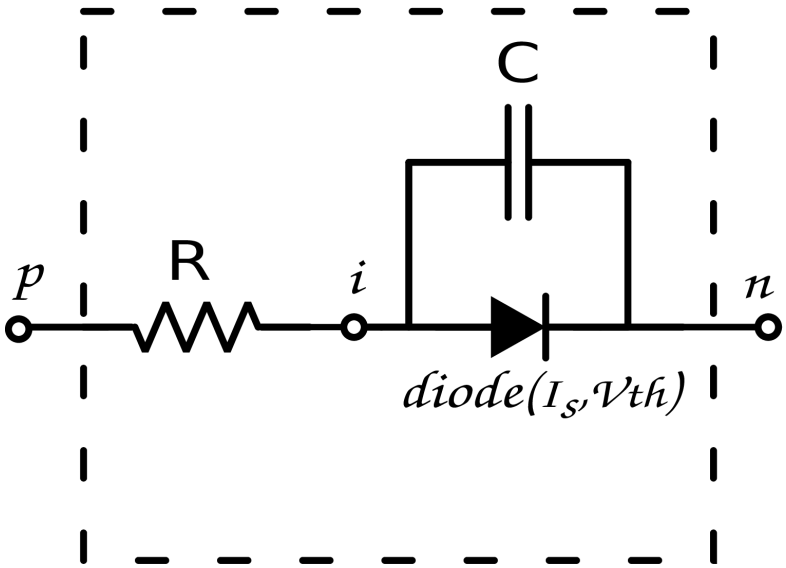

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$$\frac{d}{dt}q_e(\ldots)+f_e(\ldots)=z(t)$$

$$\frac{d}{dt}q_i(\ldots)+f_i(\ldots)=0$$

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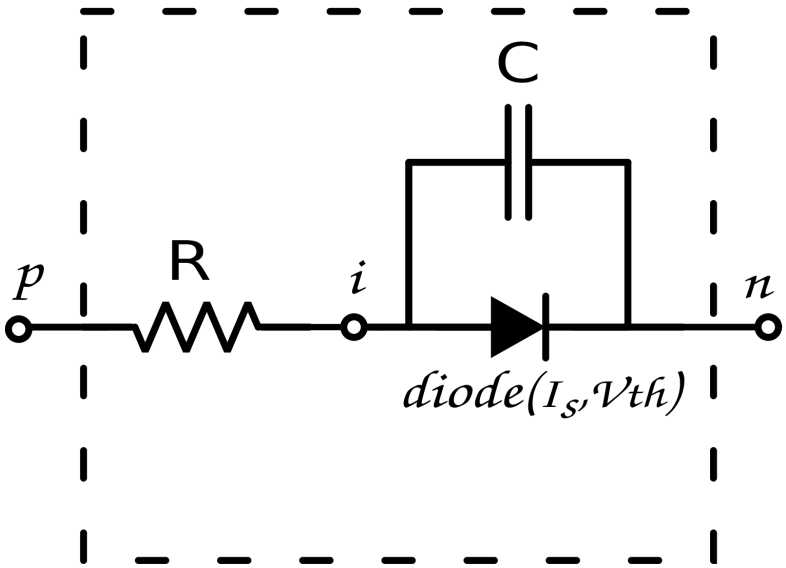

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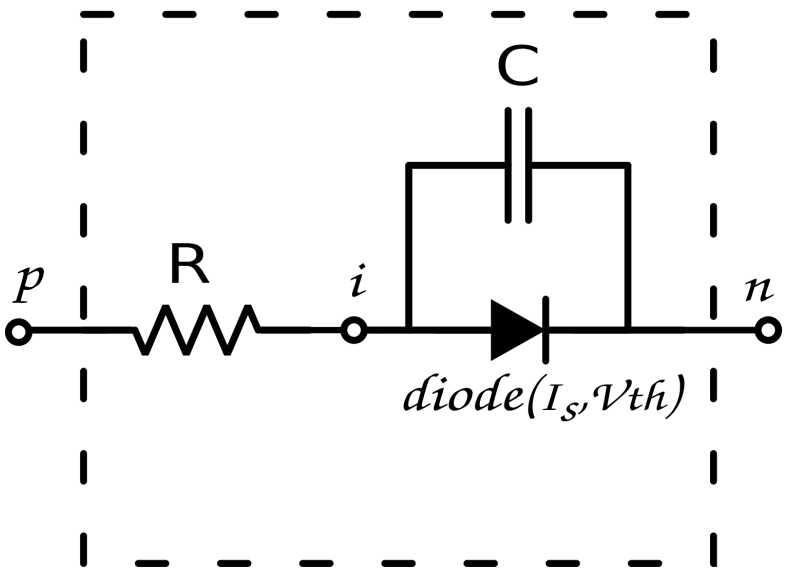

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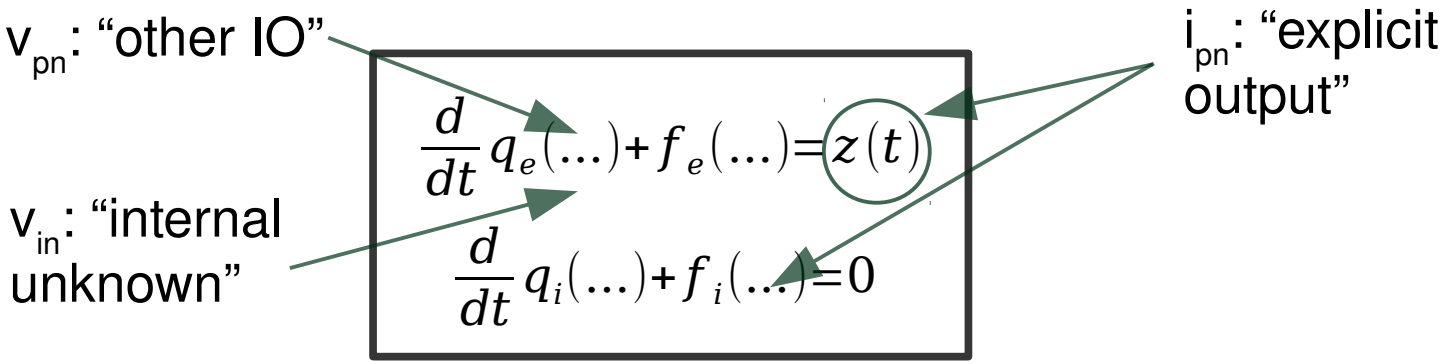
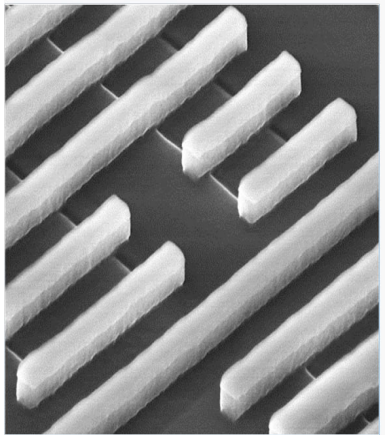


A device is a set of functions

32 nm Planar Transistors



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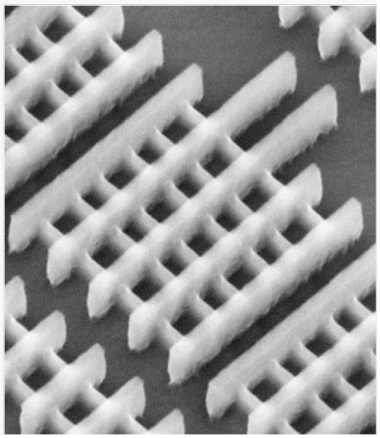

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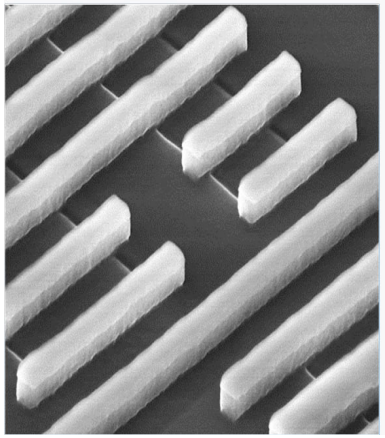

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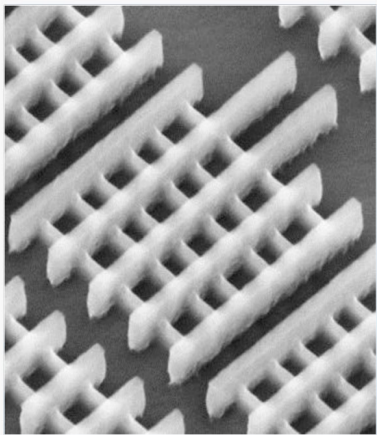

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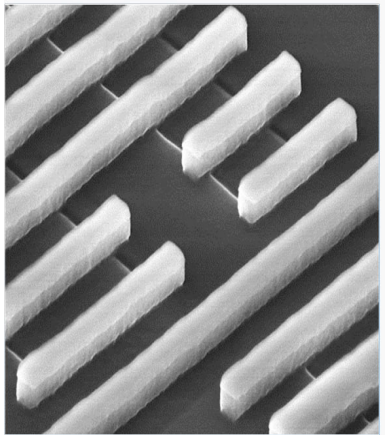

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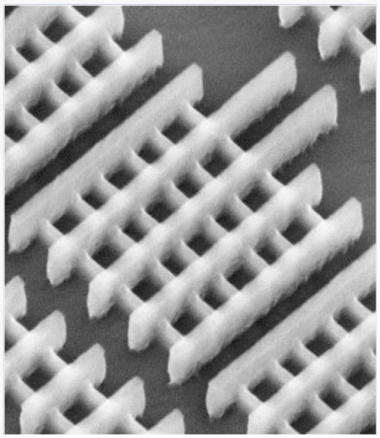

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Model parameters,

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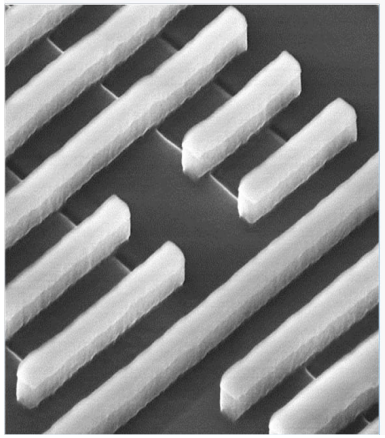

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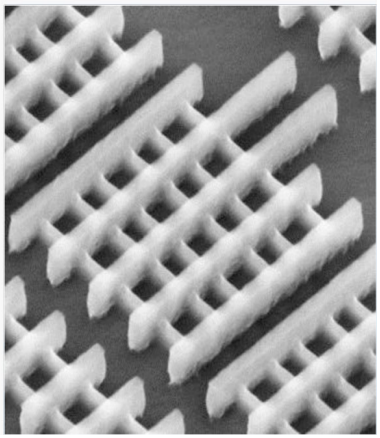

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Model parameters,
Internal unknown(s),

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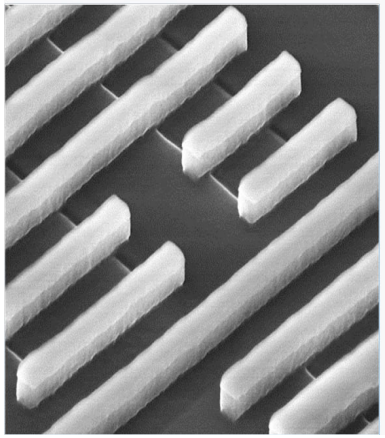

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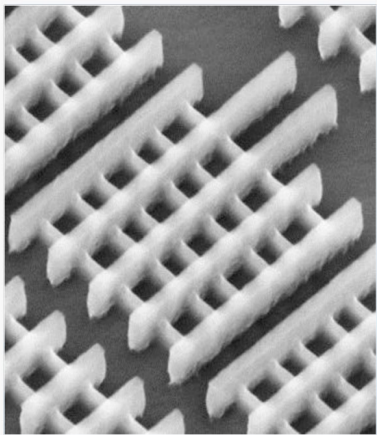

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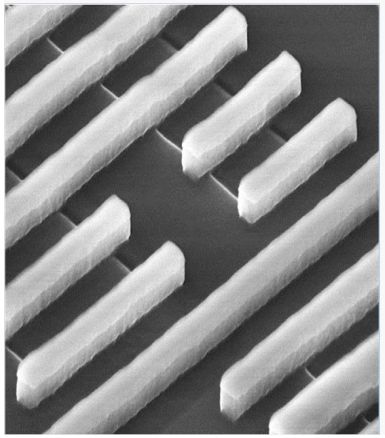

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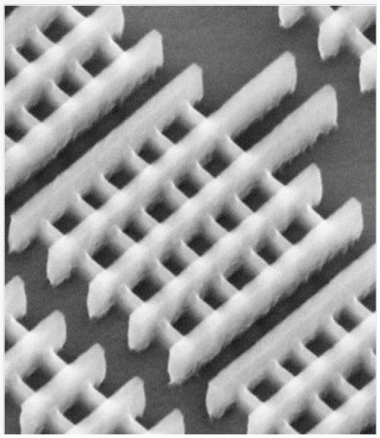

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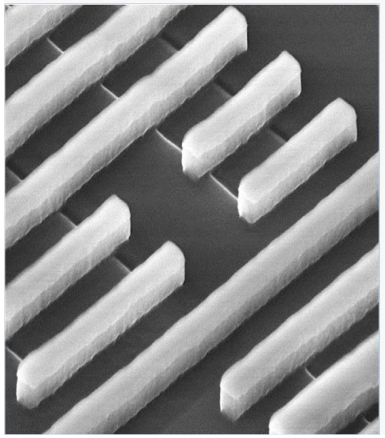

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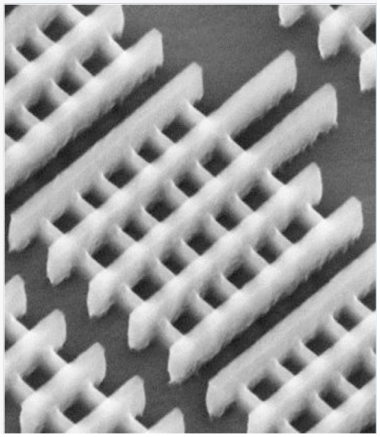

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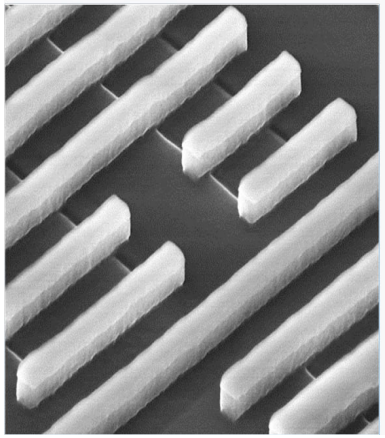

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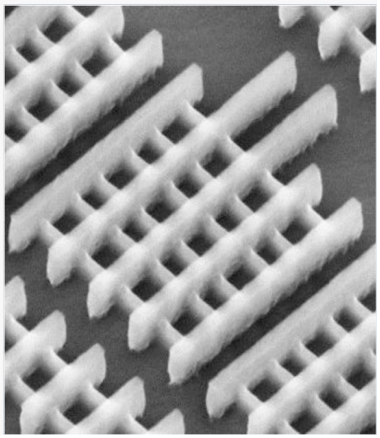

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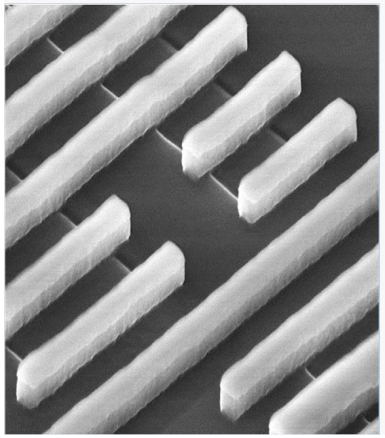

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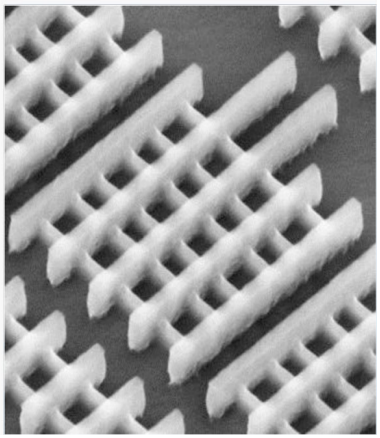

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Explicit outputs,

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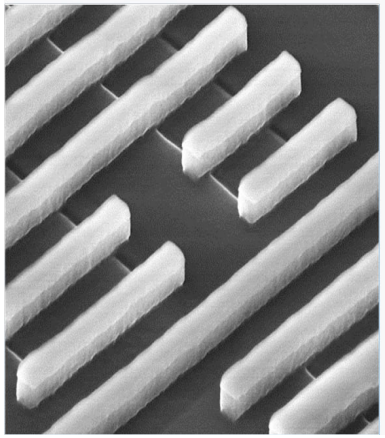

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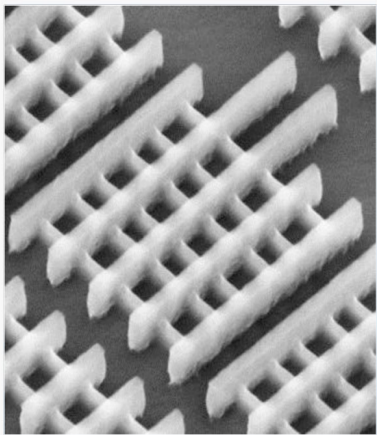

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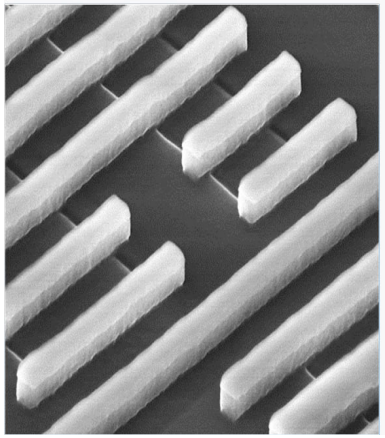

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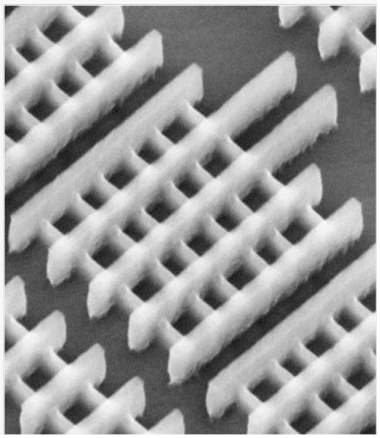

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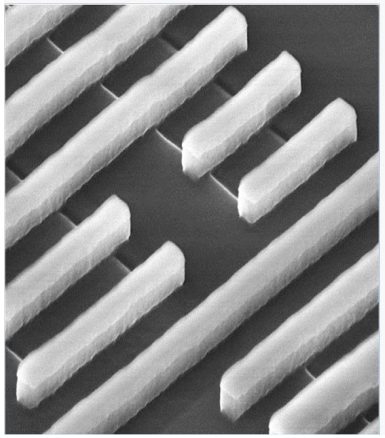

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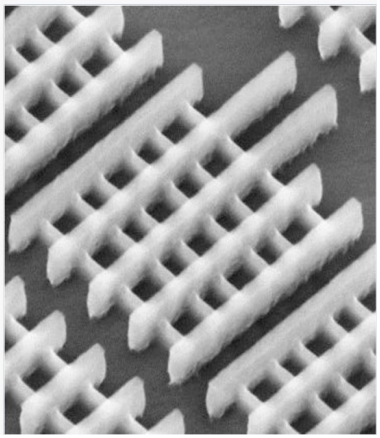

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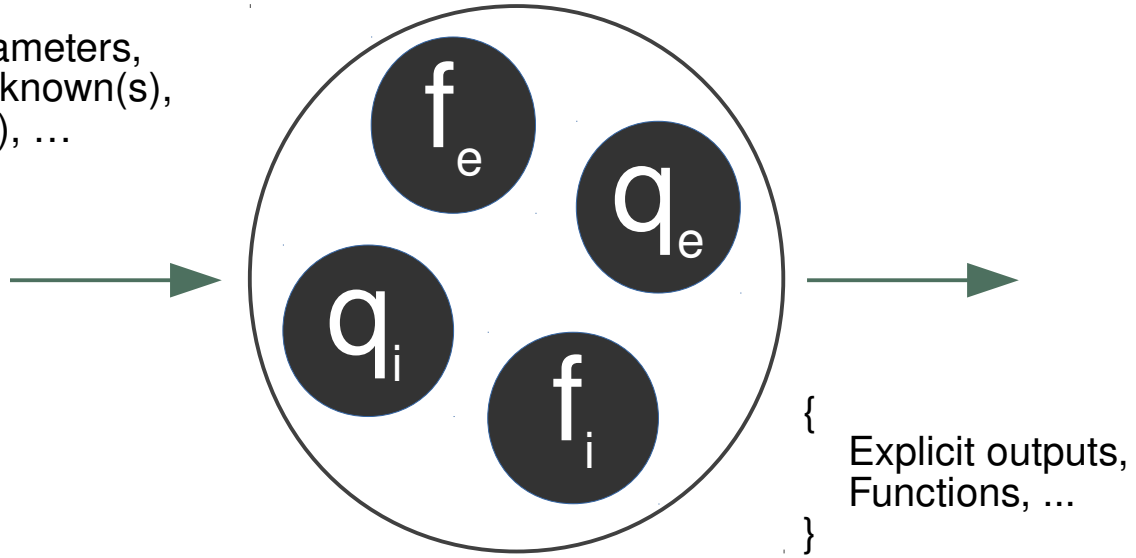

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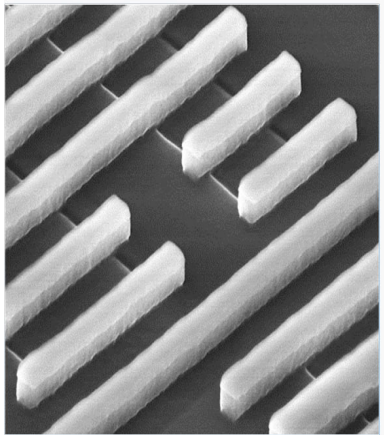

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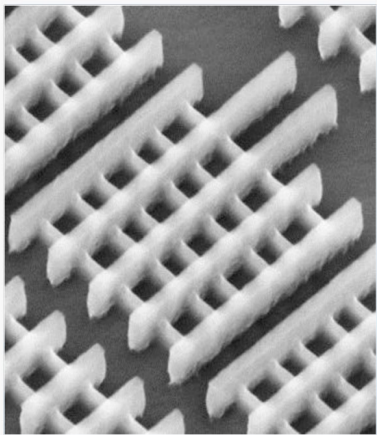

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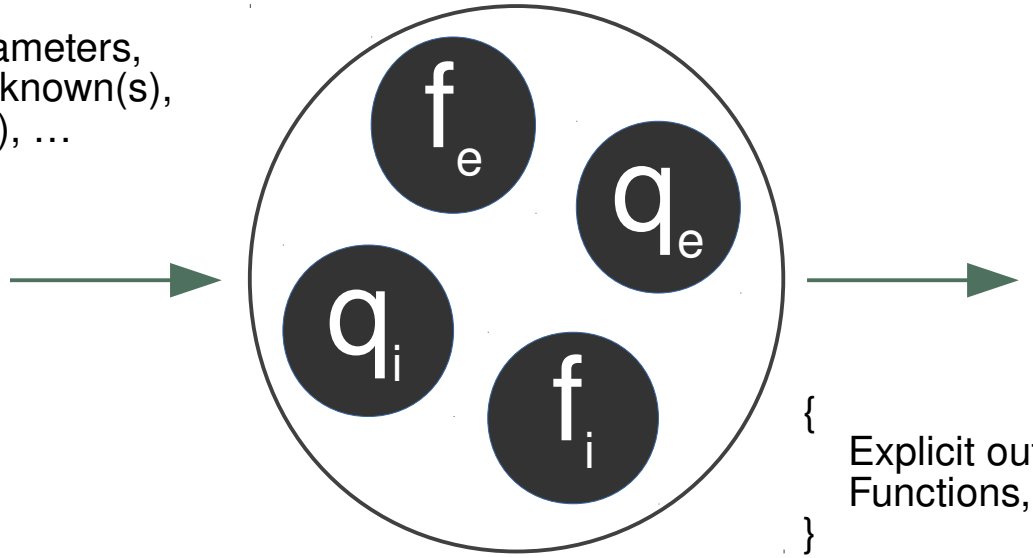

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$$\frac{d}{dt} q_e(\ldots) + f_e(\ldots) = z(t)$$

$$\frac{d}{dt} q_i(\ldots) + f_i(\ldots) = 0$$

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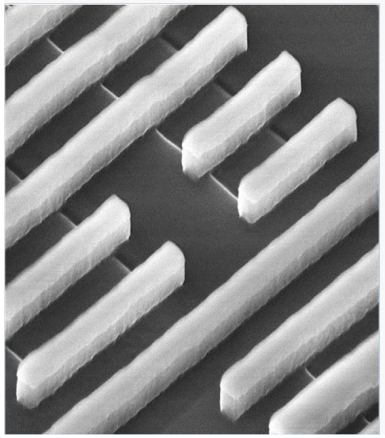

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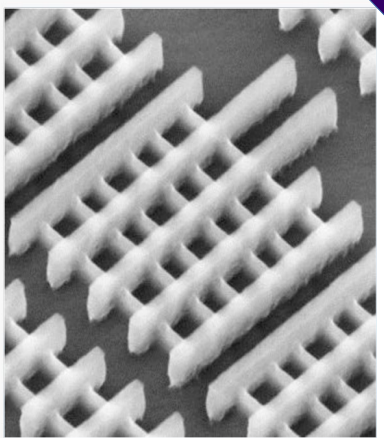
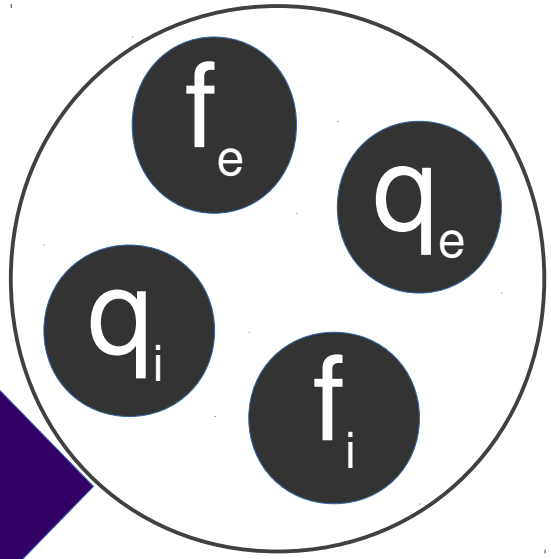


MODSPEC



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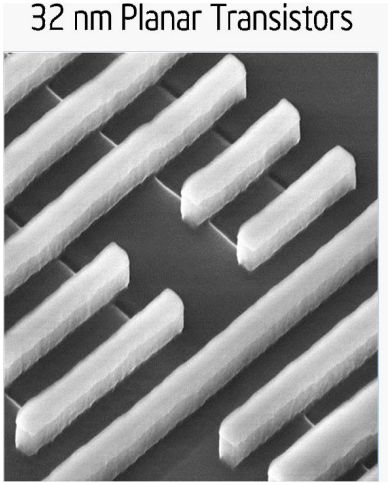
From ModSpec to table-based model



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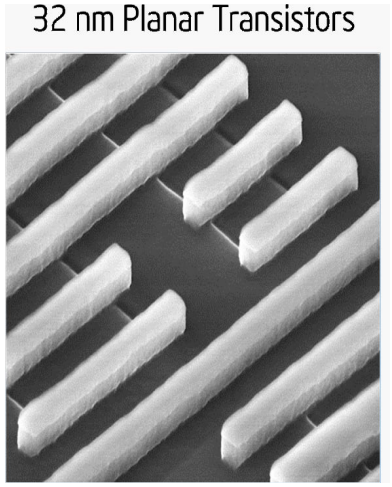

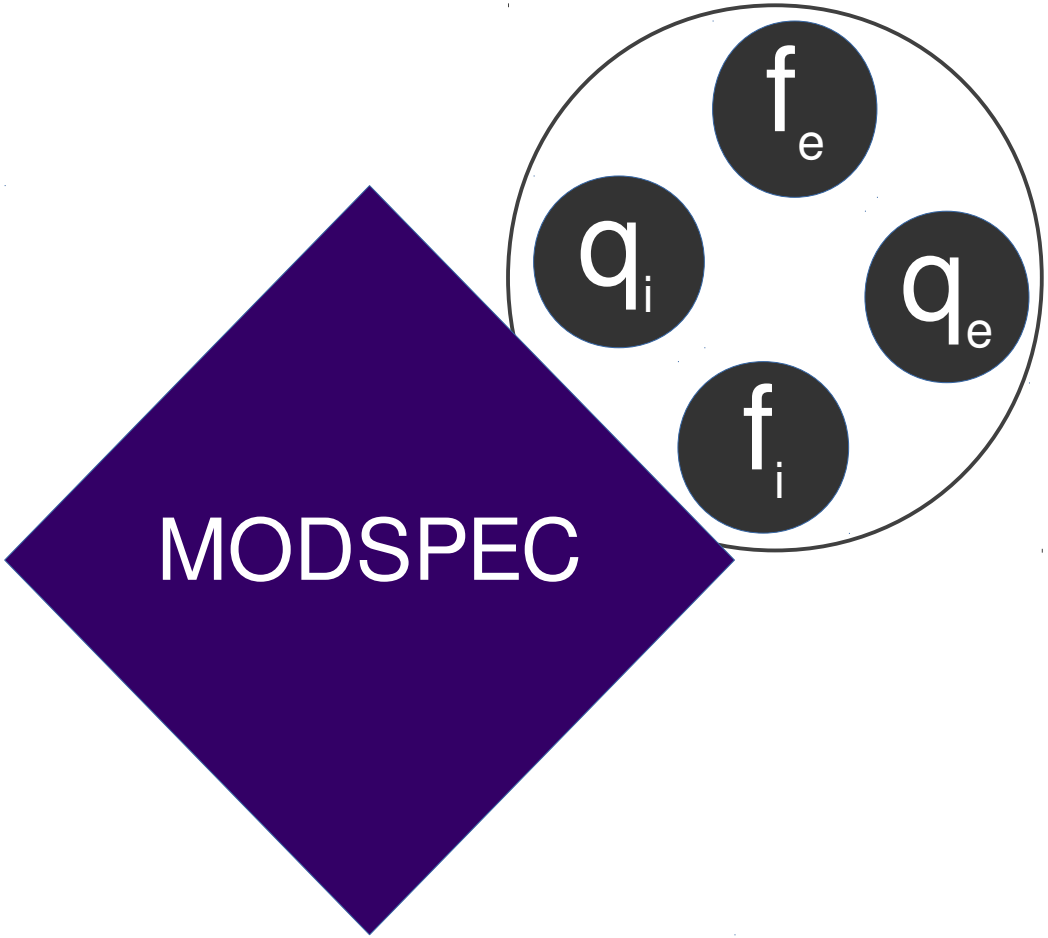

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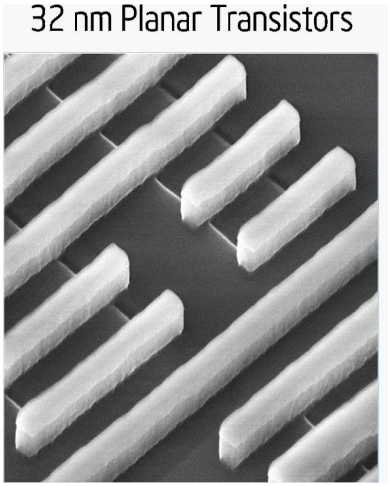
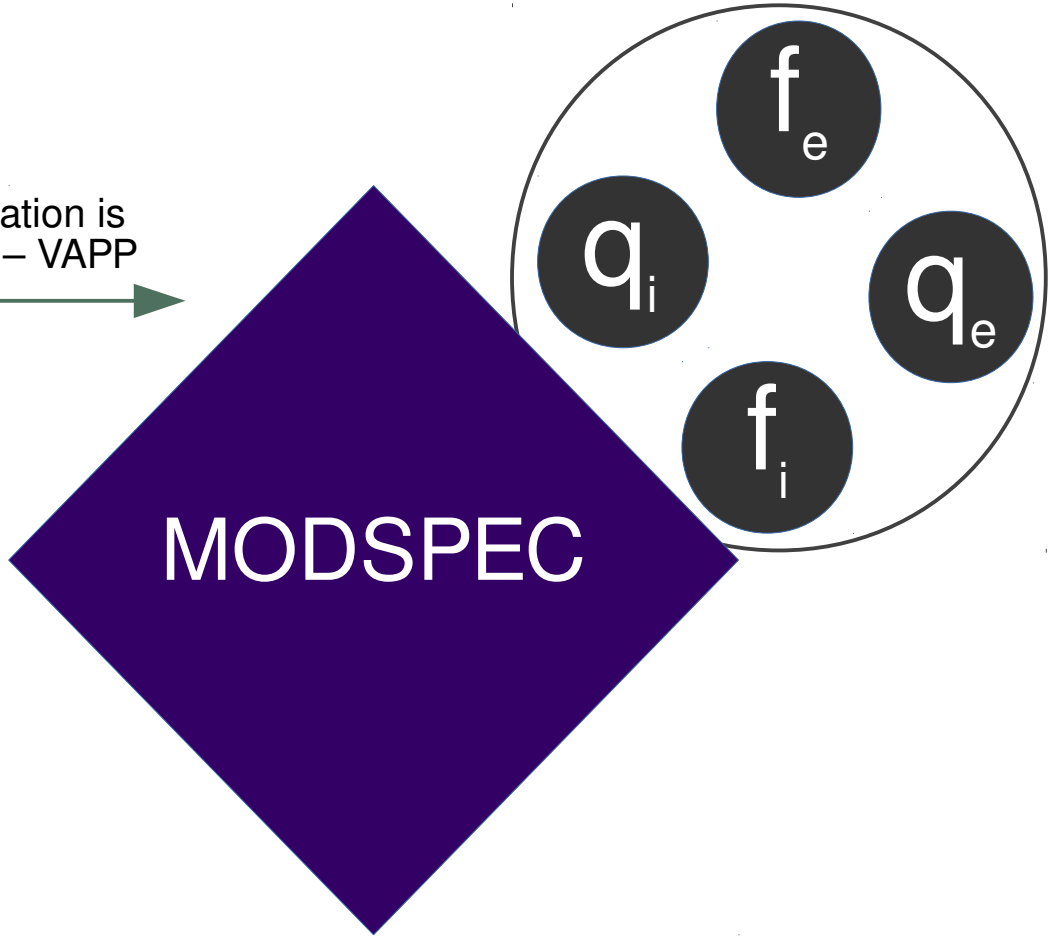


Machine Translation is openly available – VAPP



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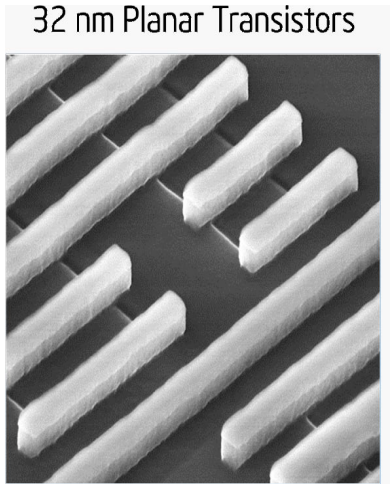

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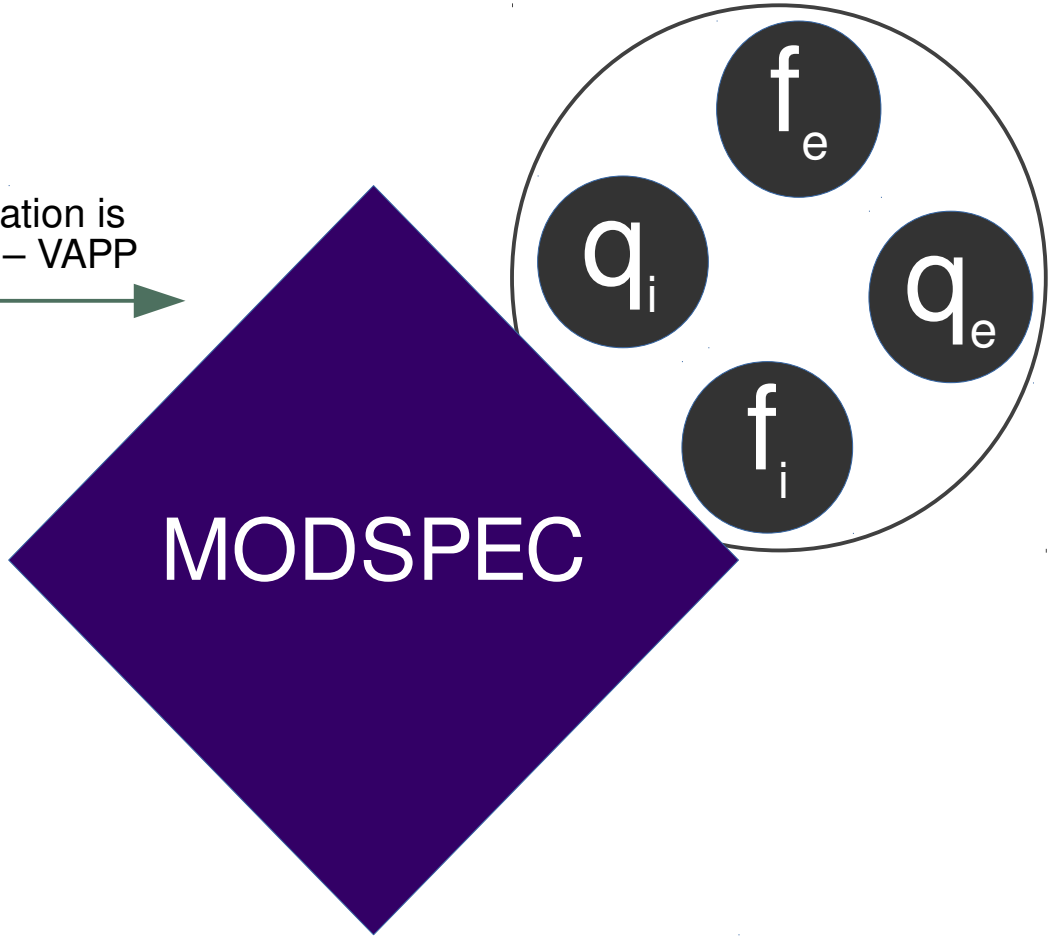

f_e

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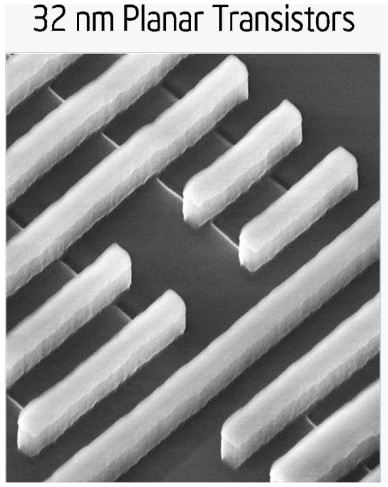

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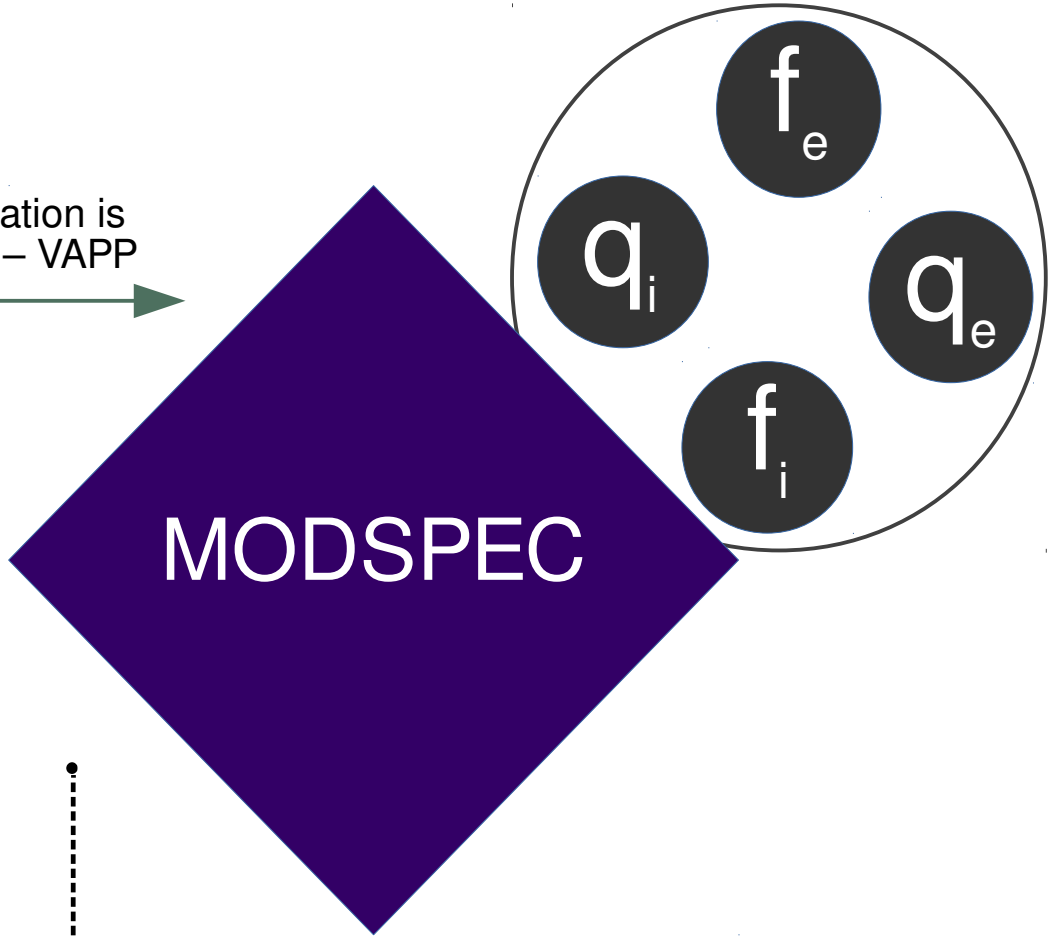

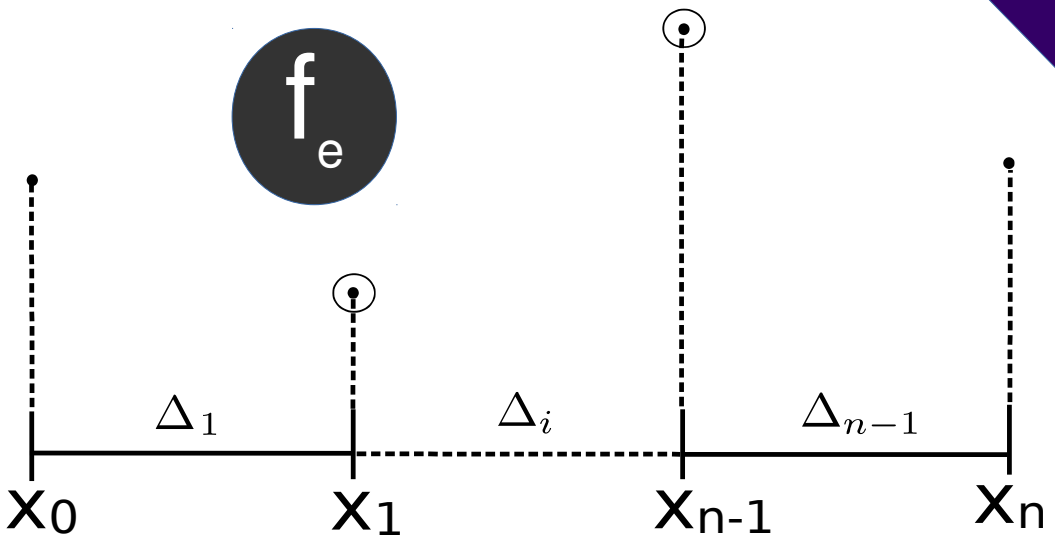

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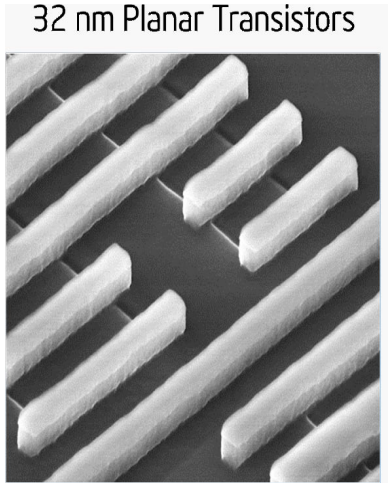

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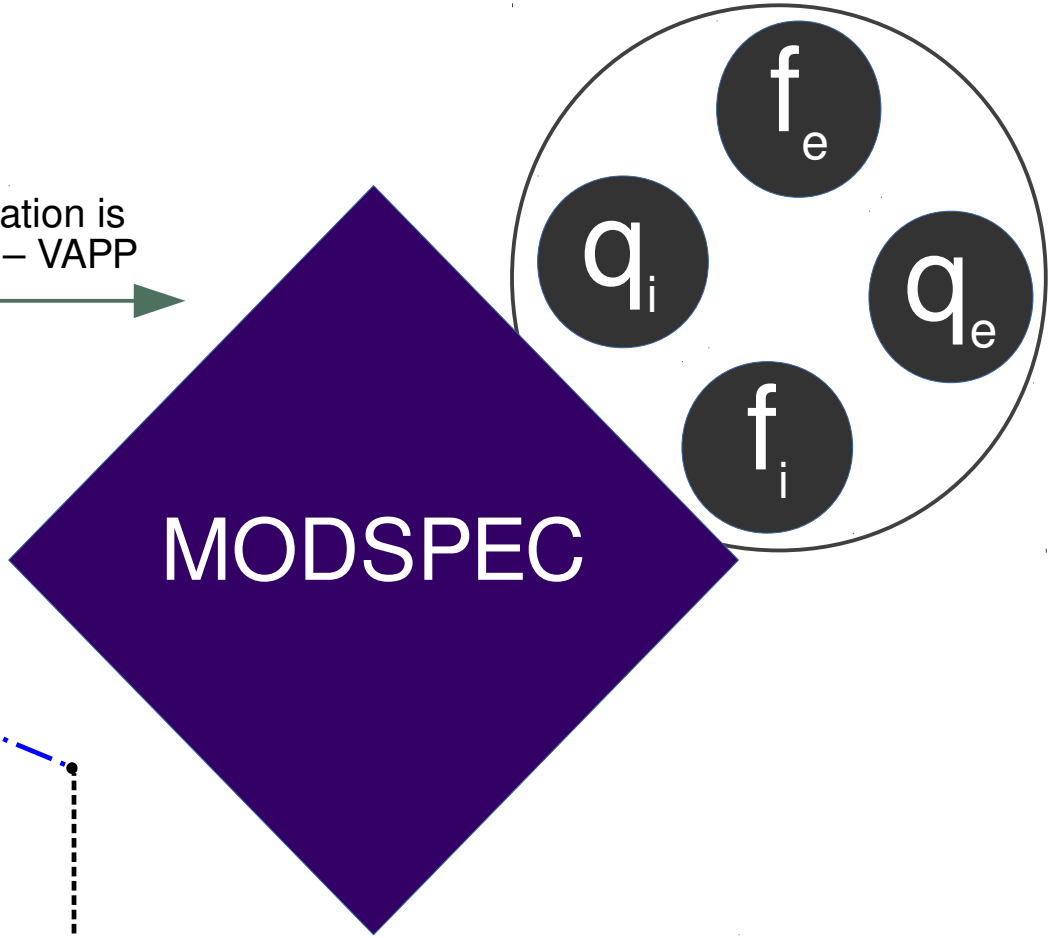

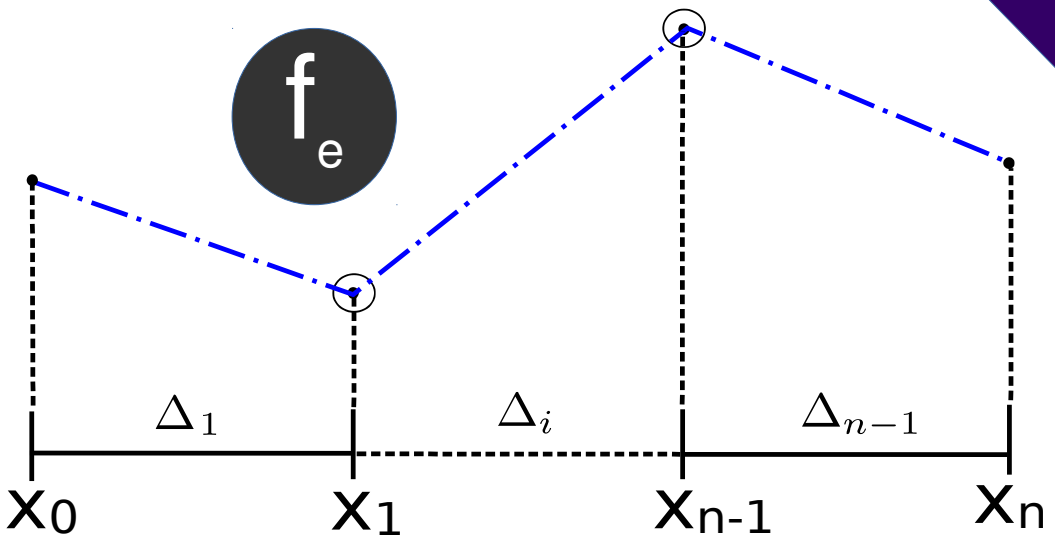

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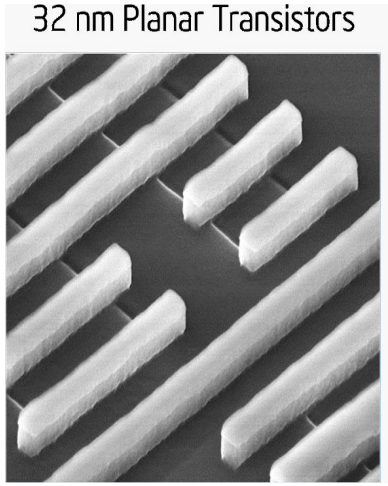

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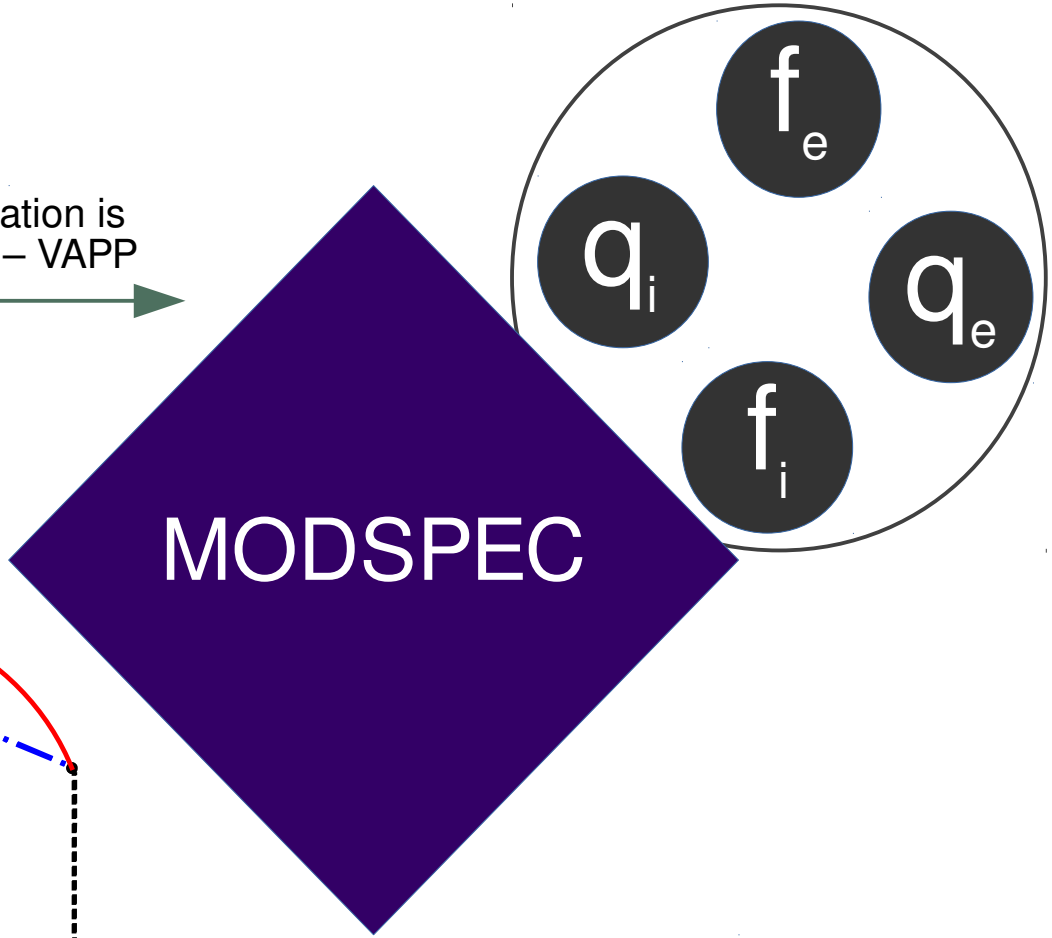

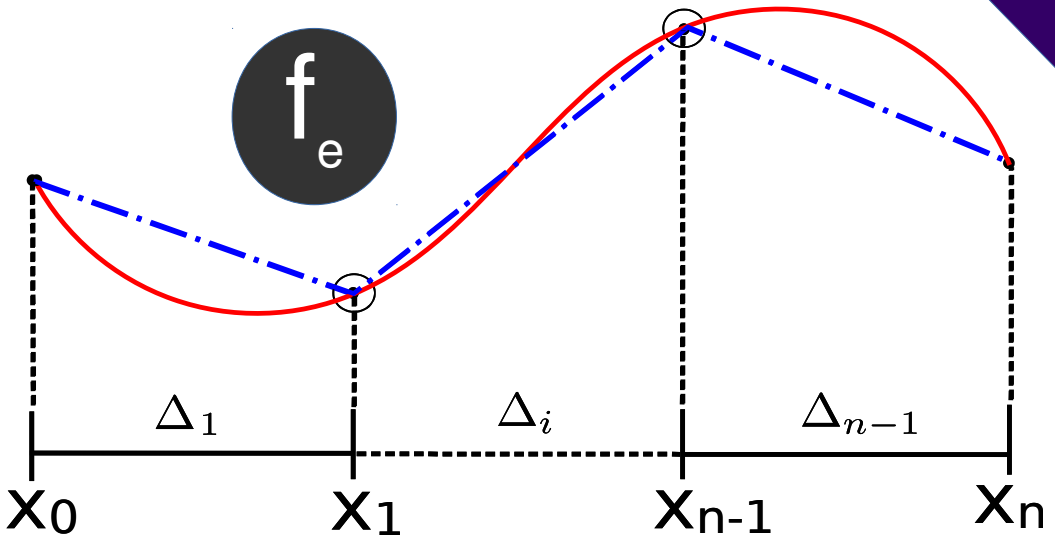

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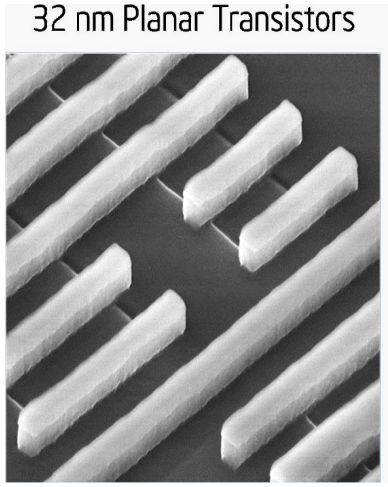

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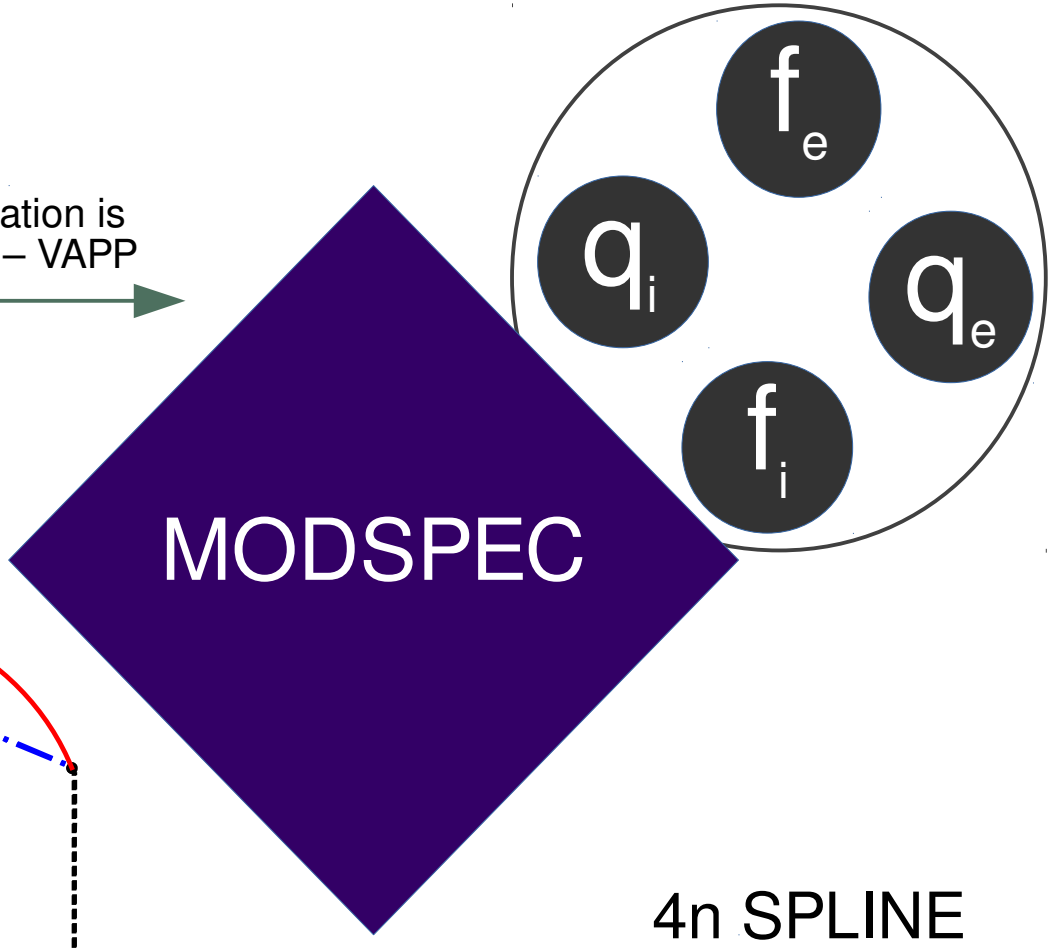

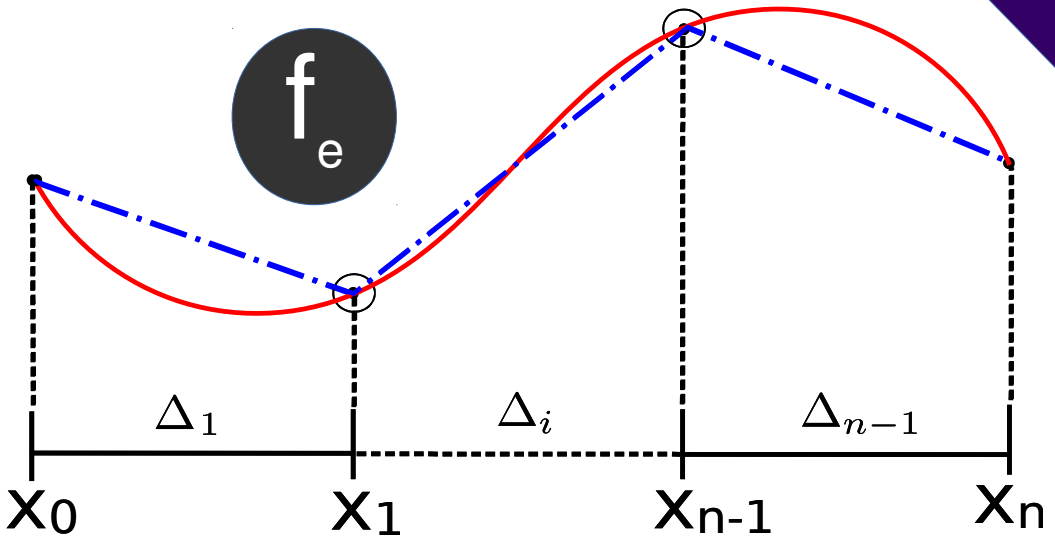

4n SPLINE COEFFICIENTS

Extrapolation!

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Linear extrapolation is an option

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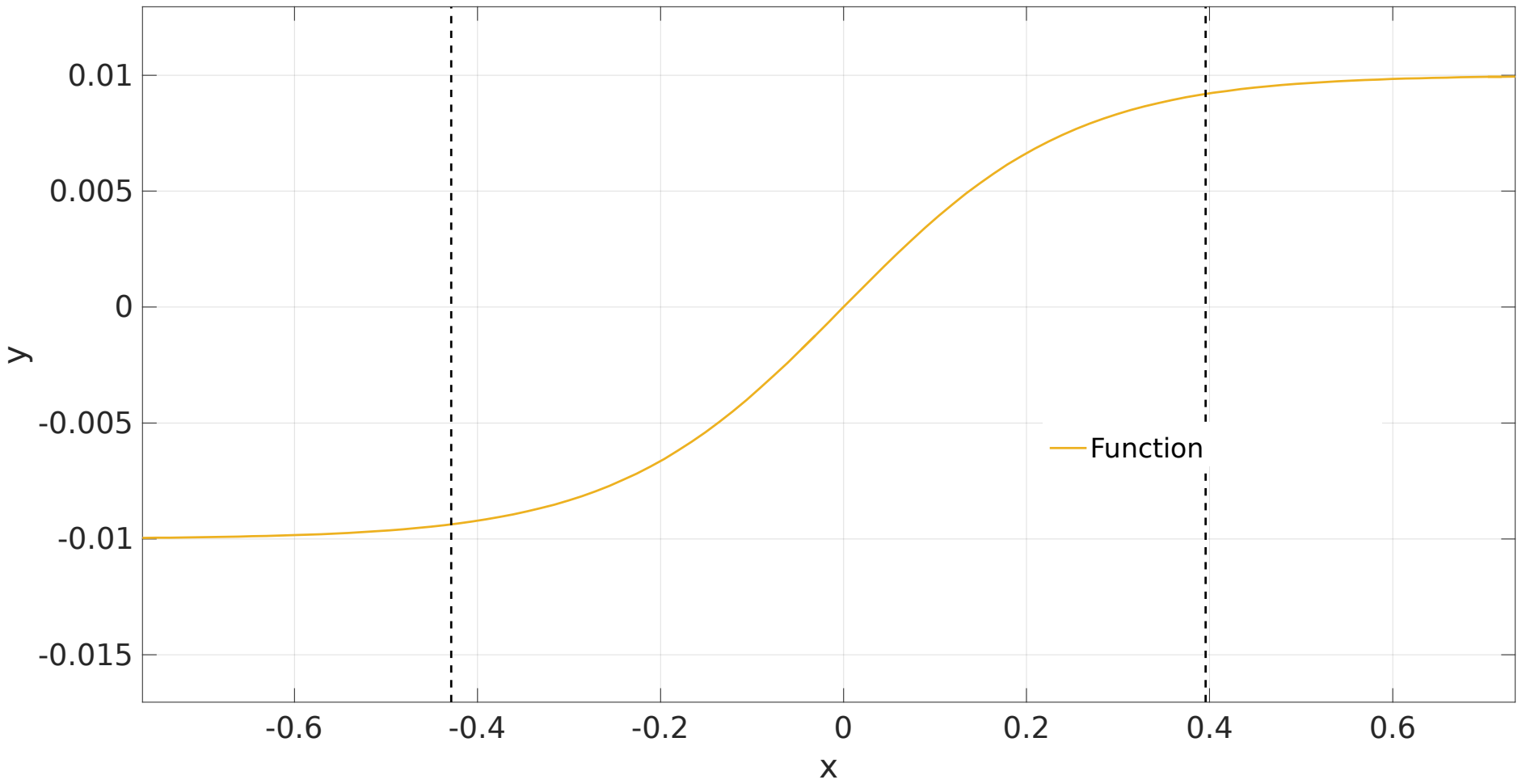

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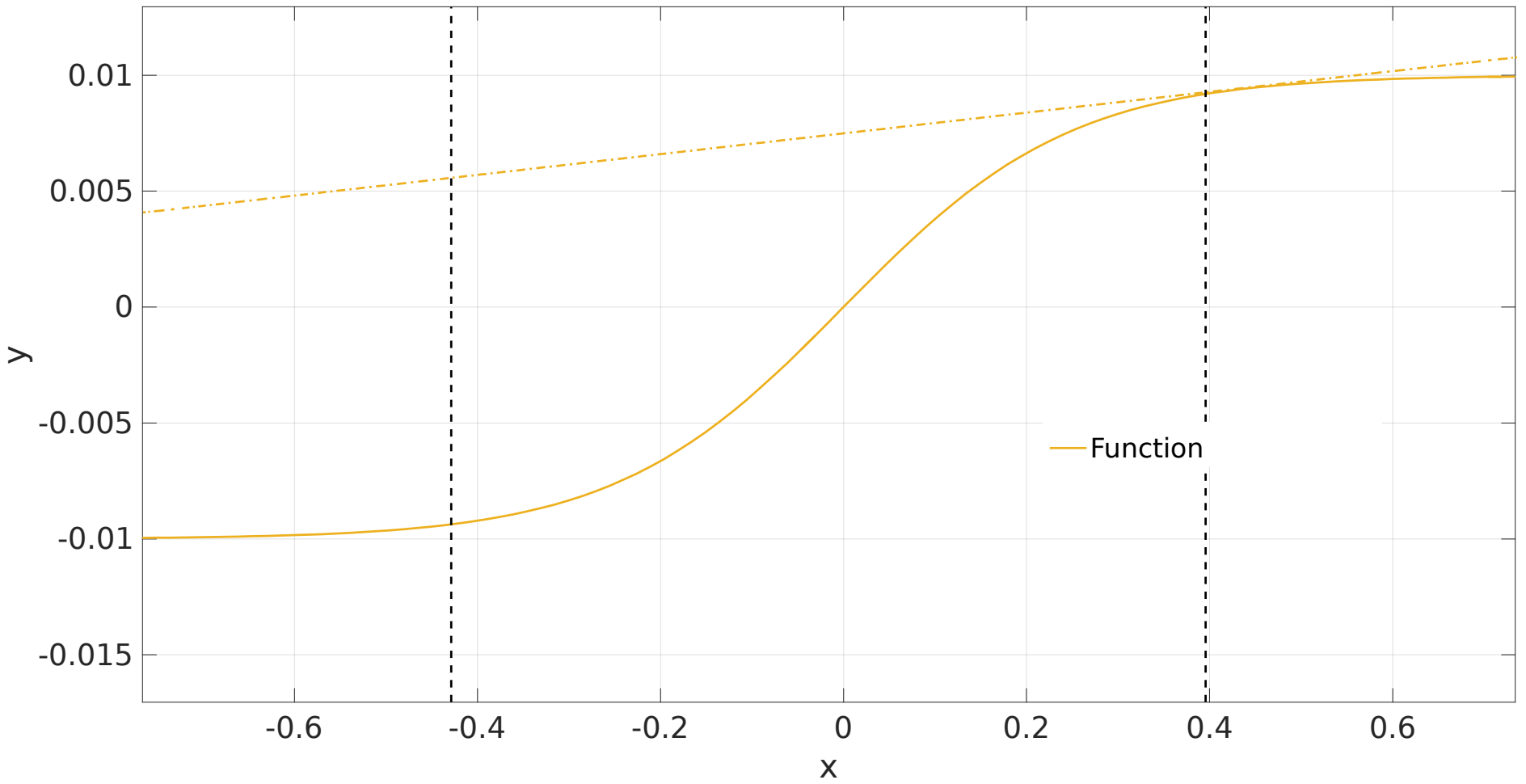

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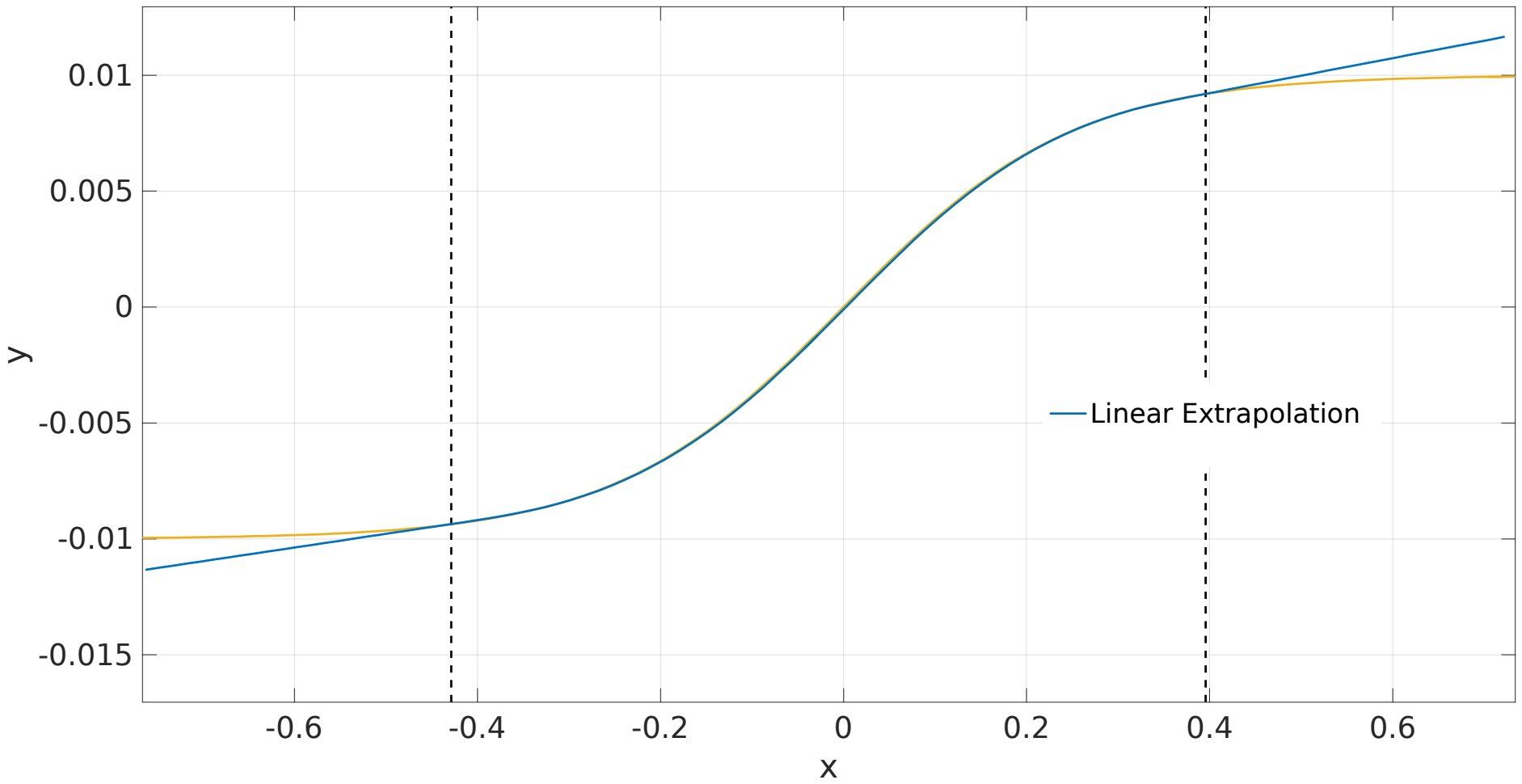

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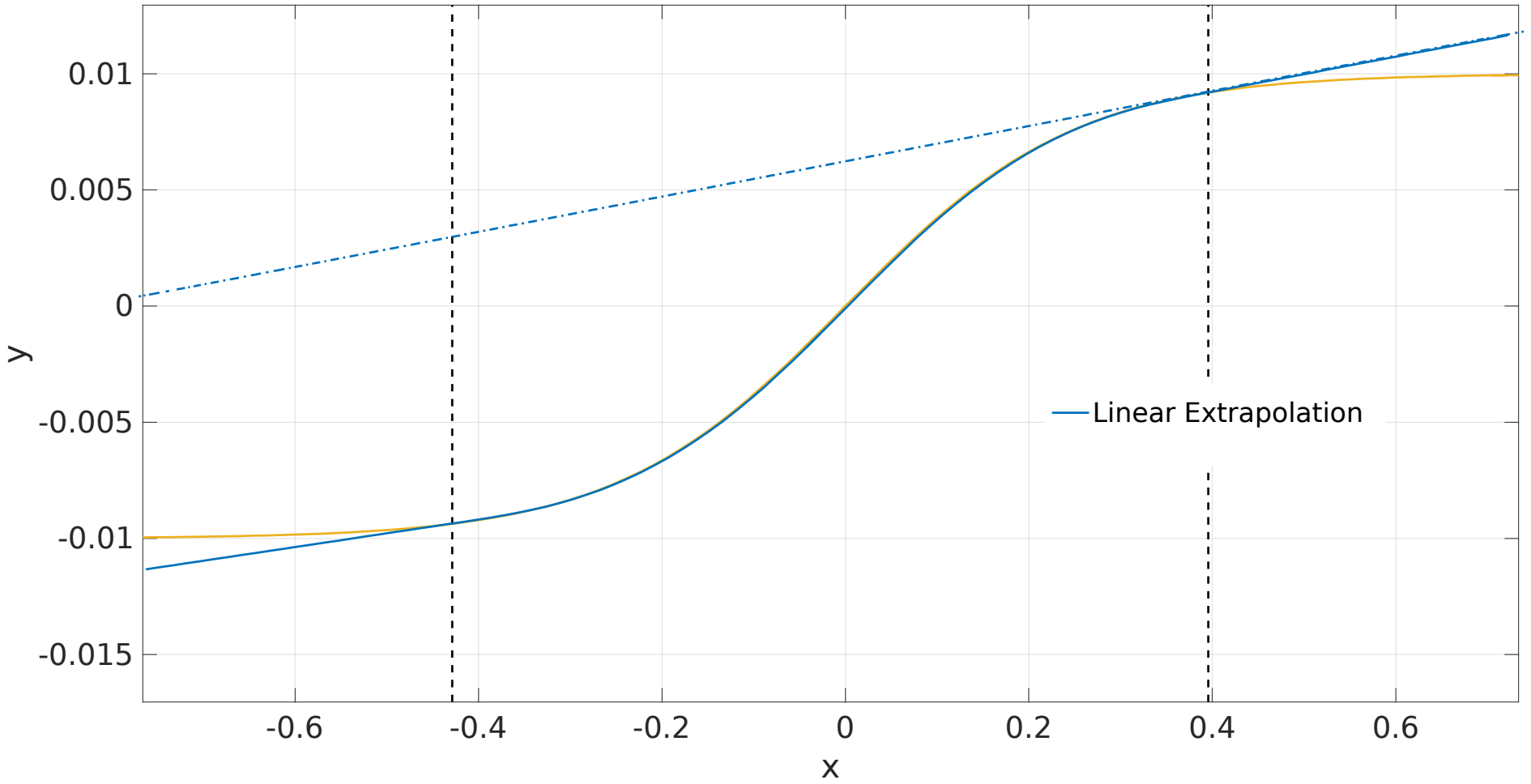

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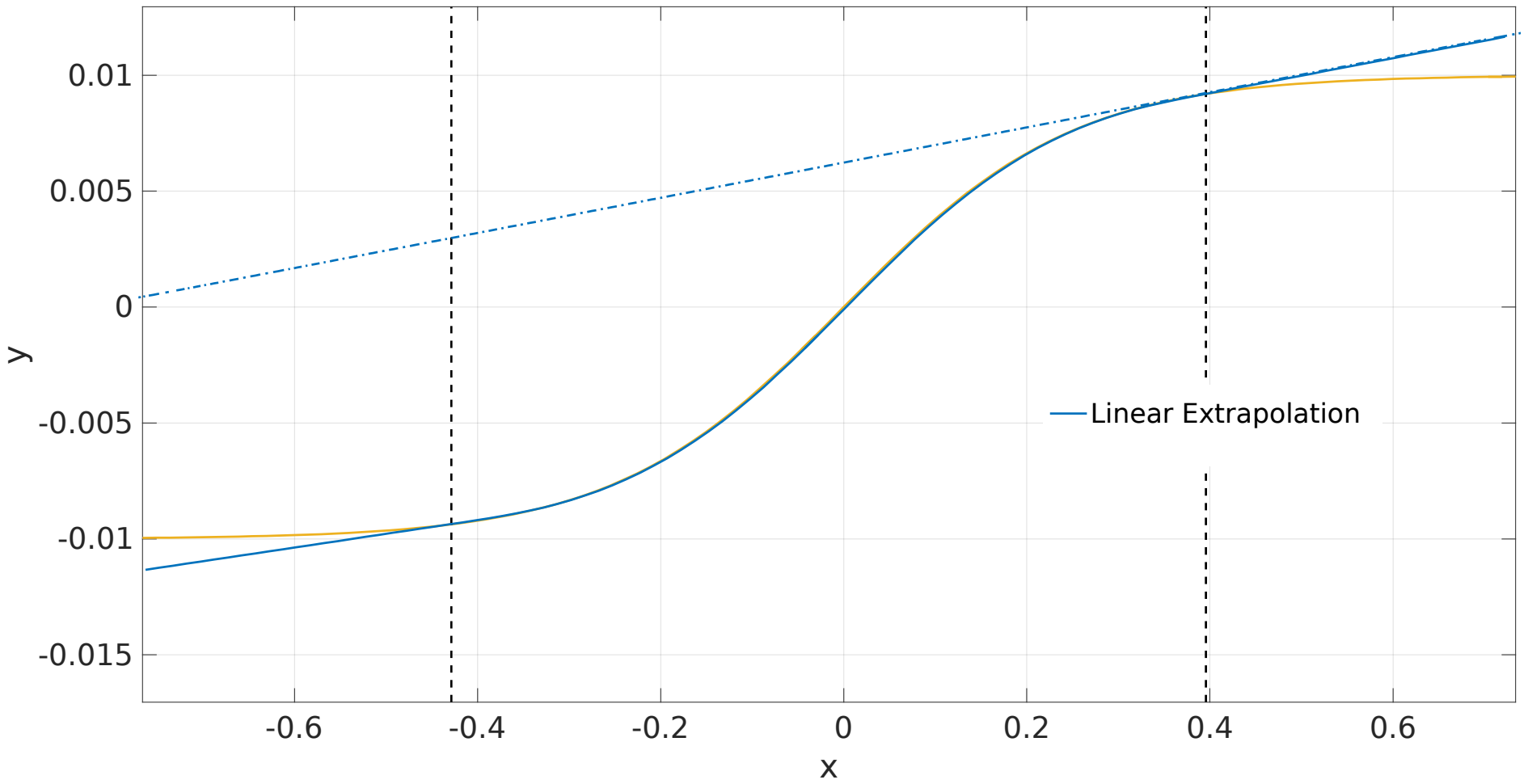
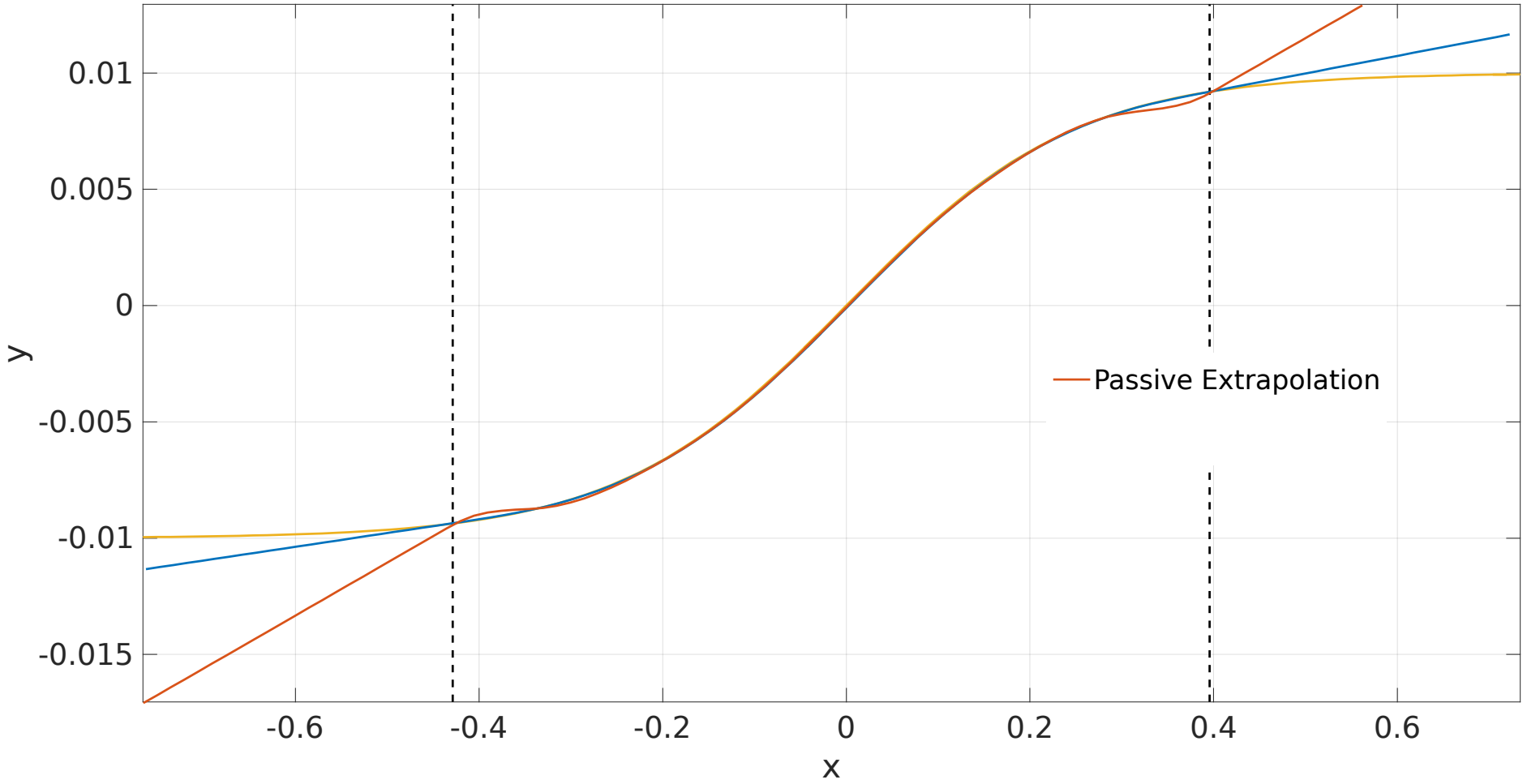


Linear extrapolation can be too restrictive!

Extrapolation!



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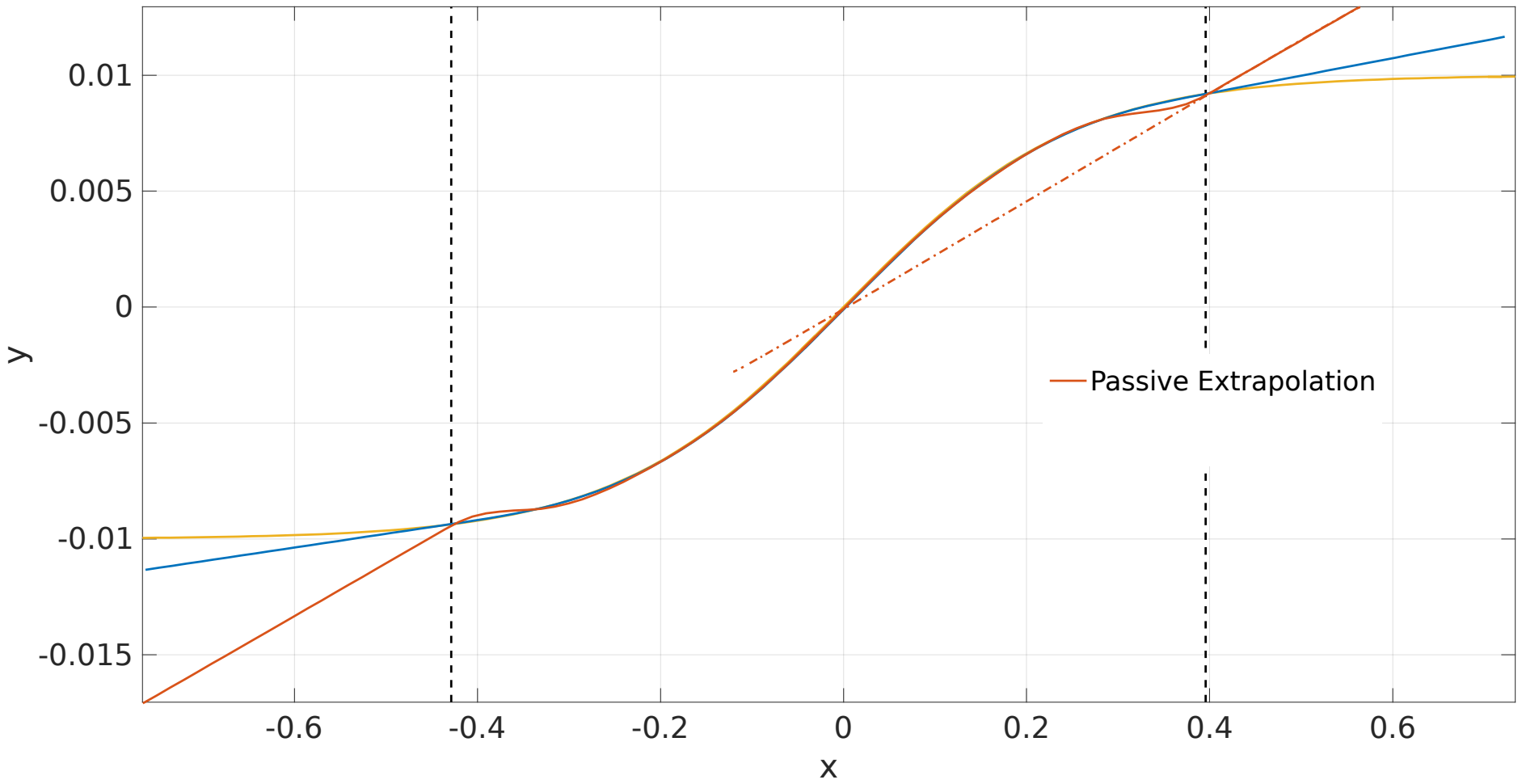

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Speedup
Accuracy
Memory

Simulation Results

Test Circuits and Waveforms

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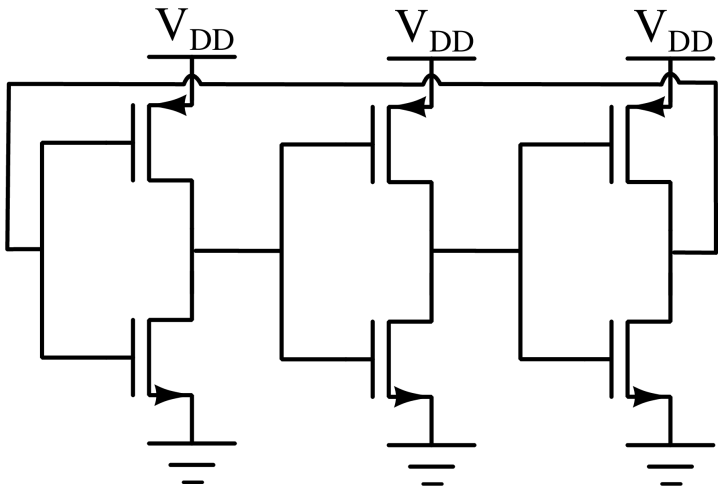
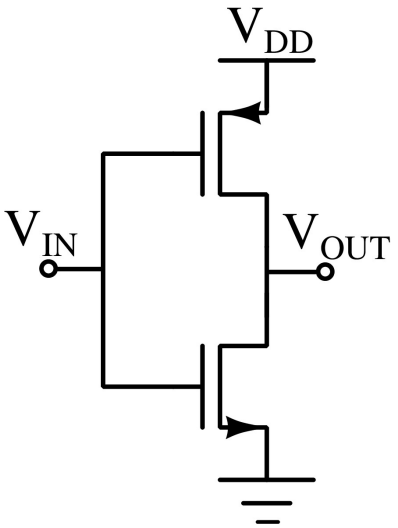
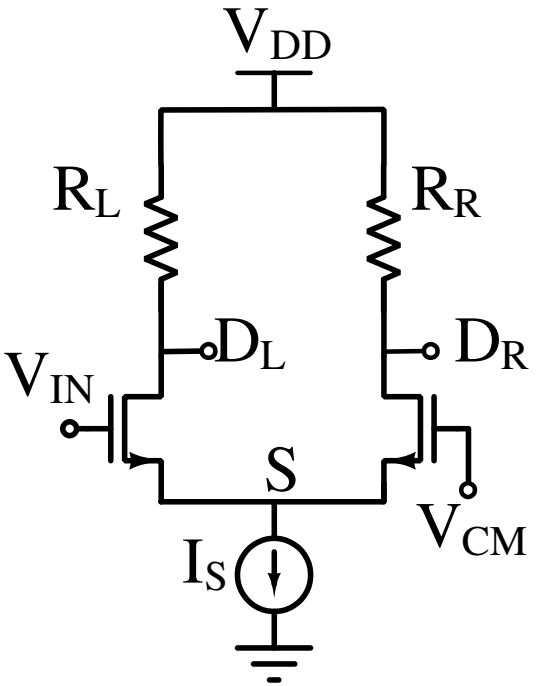
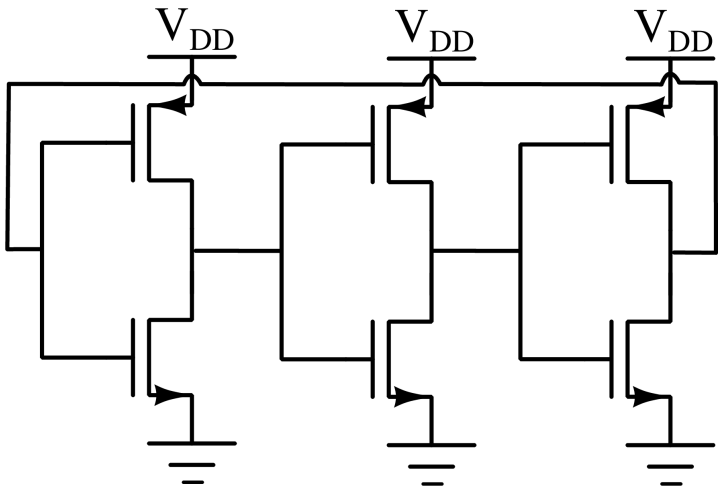
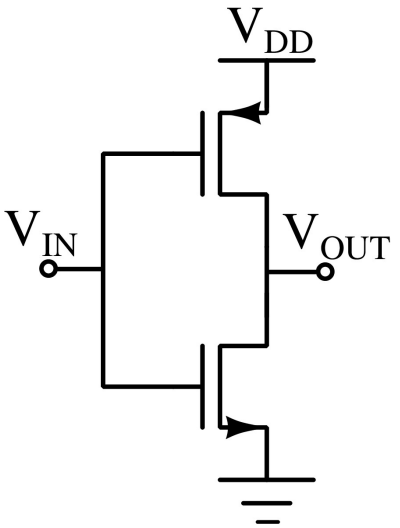


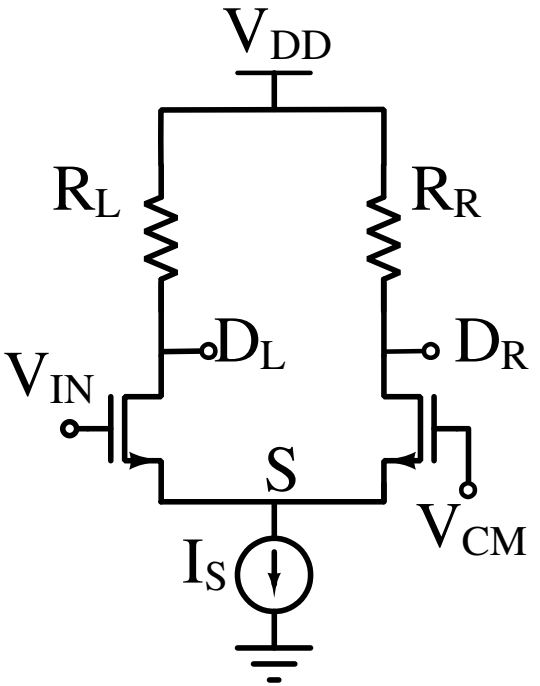


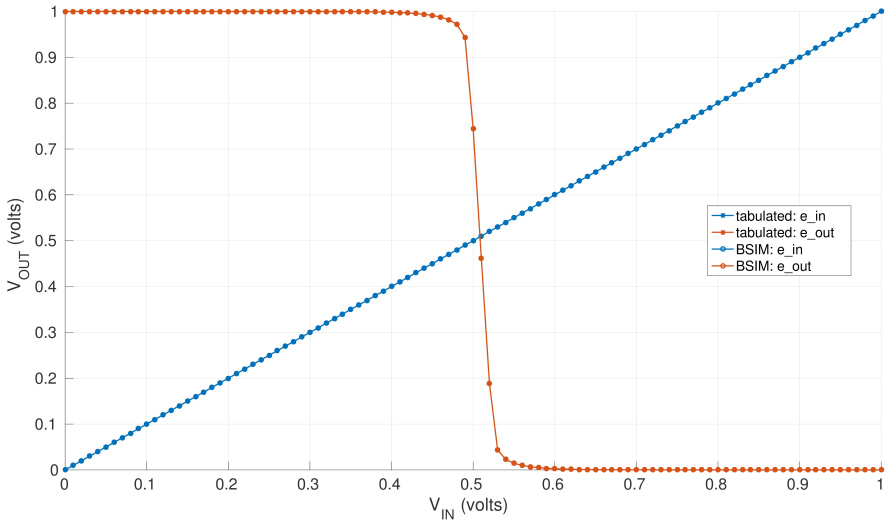


Test Circuits and Waveforms









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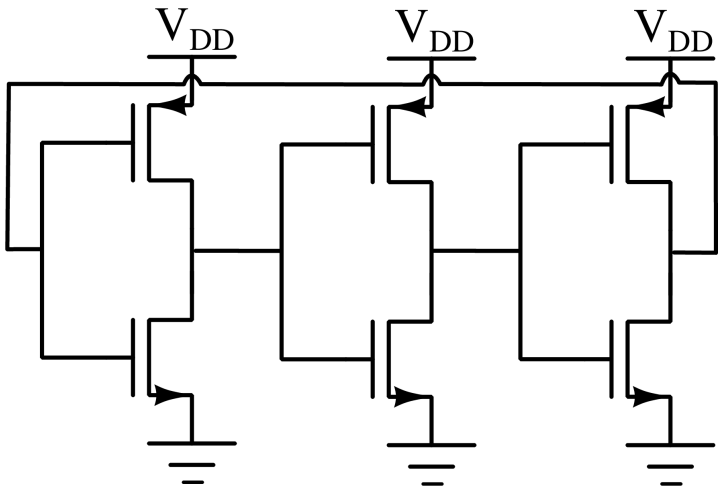

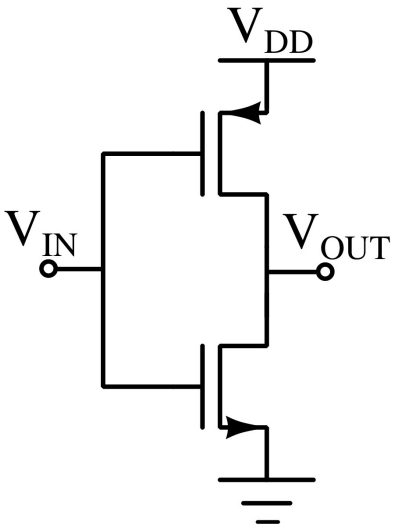

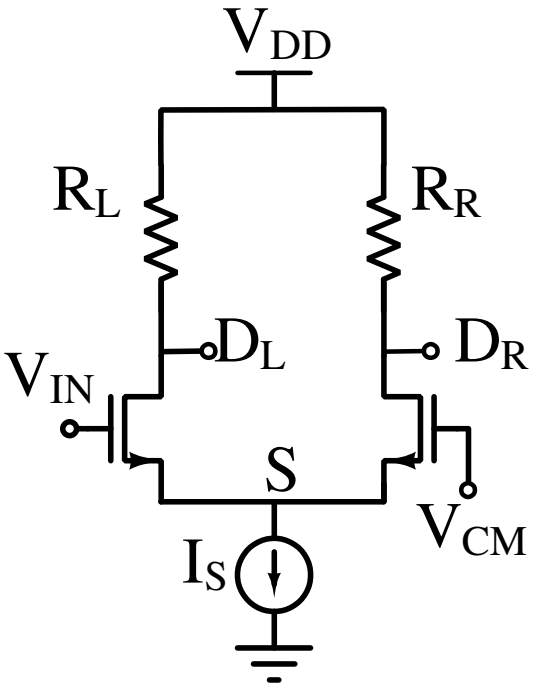

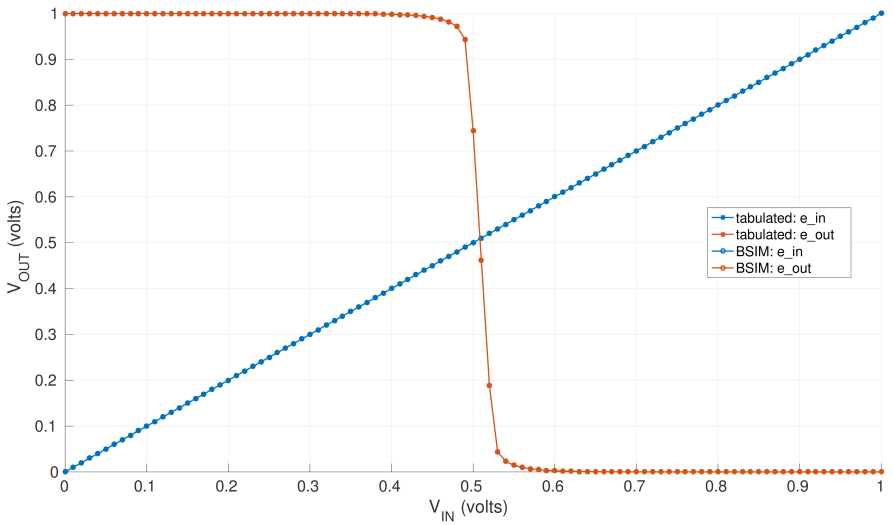

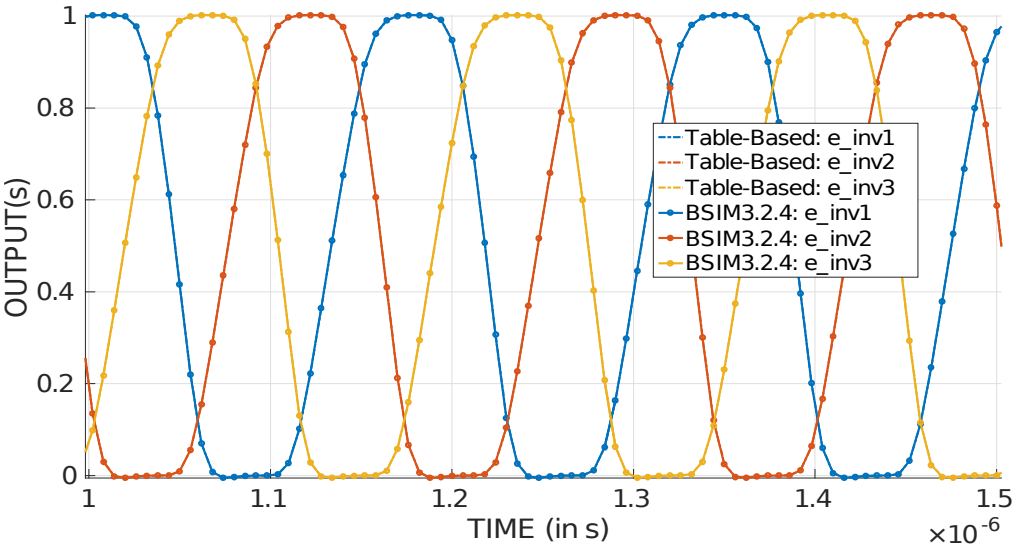

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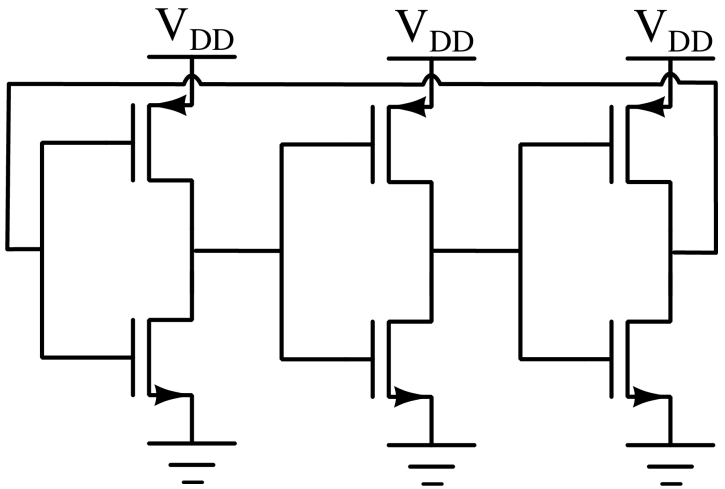

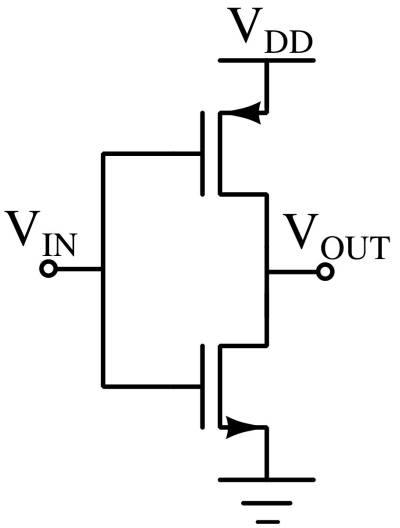

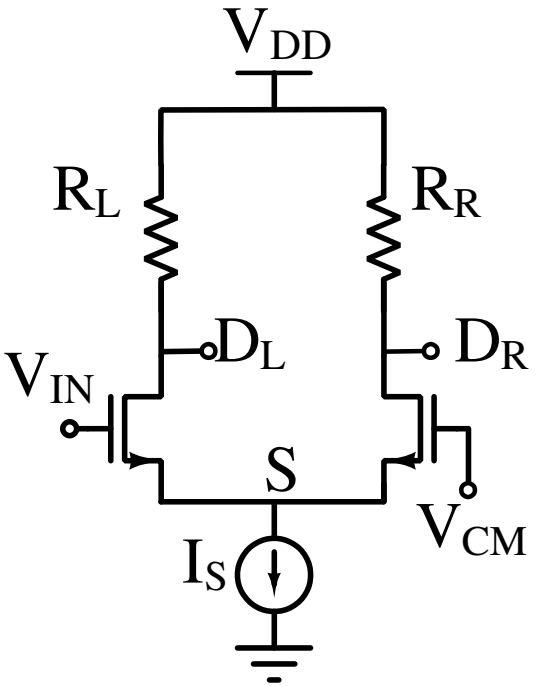

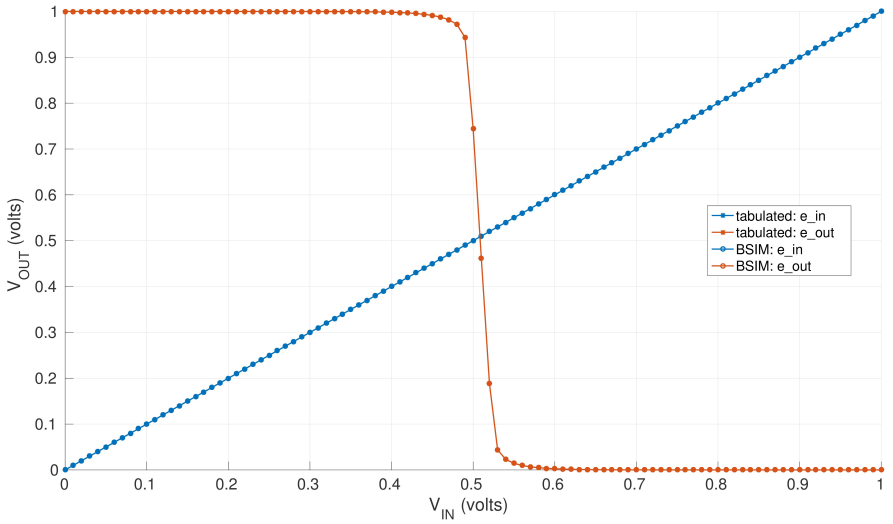

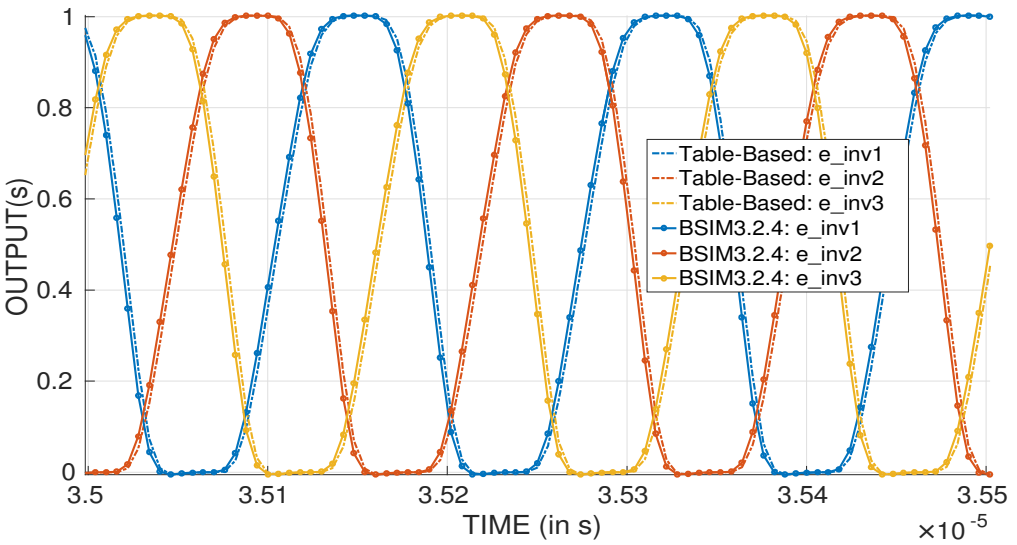

Speedup Evaluation

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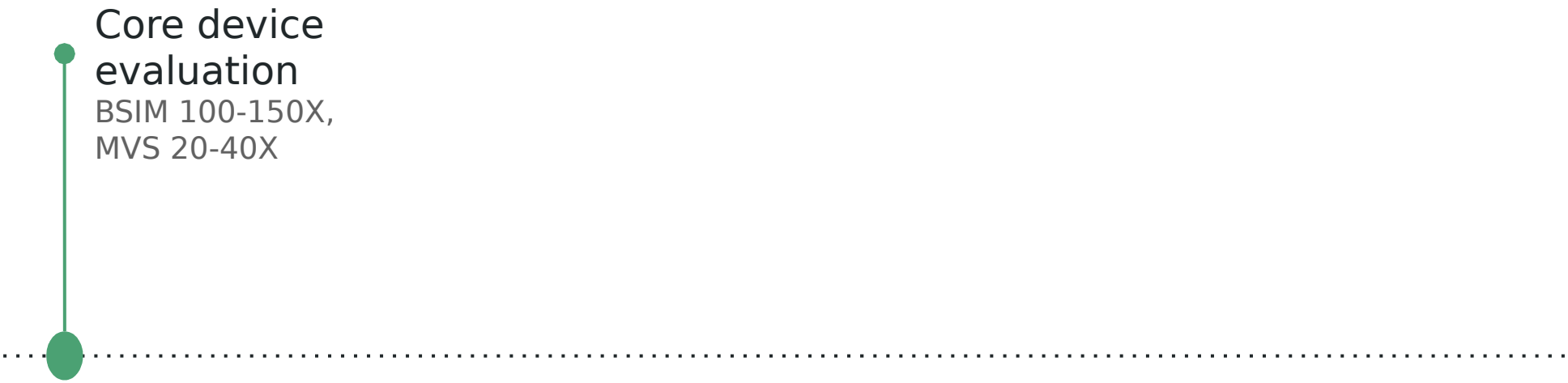
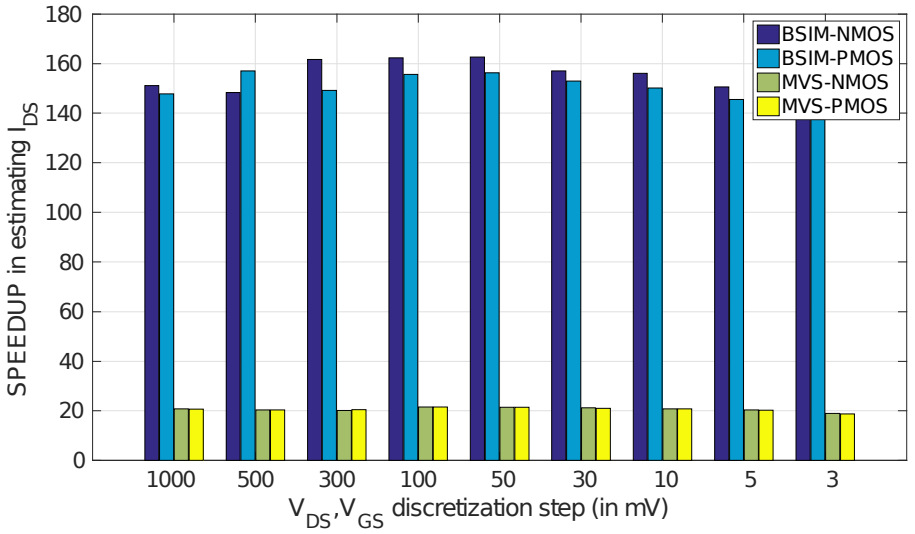


Speedup Evaluation

Core device evaluation

BSIM 100-150X, MVS 20-40X



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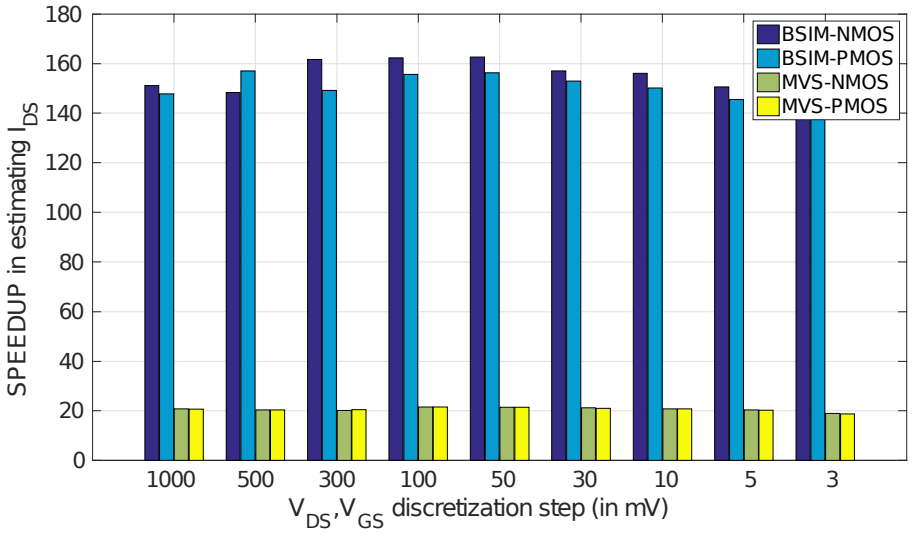

Analysis (BSIM)

DC (QSS) 14-20X,
AC 7-10X,
TRANSIENT 6-8X

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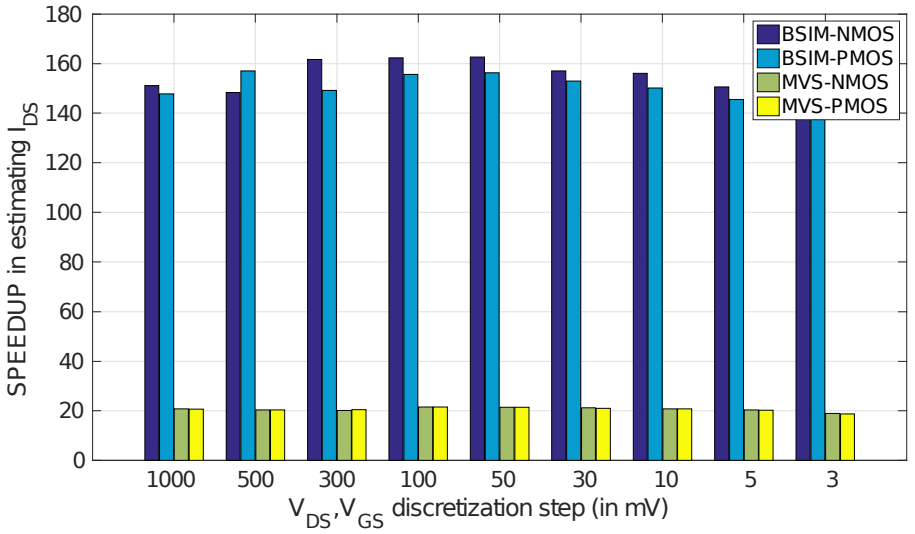

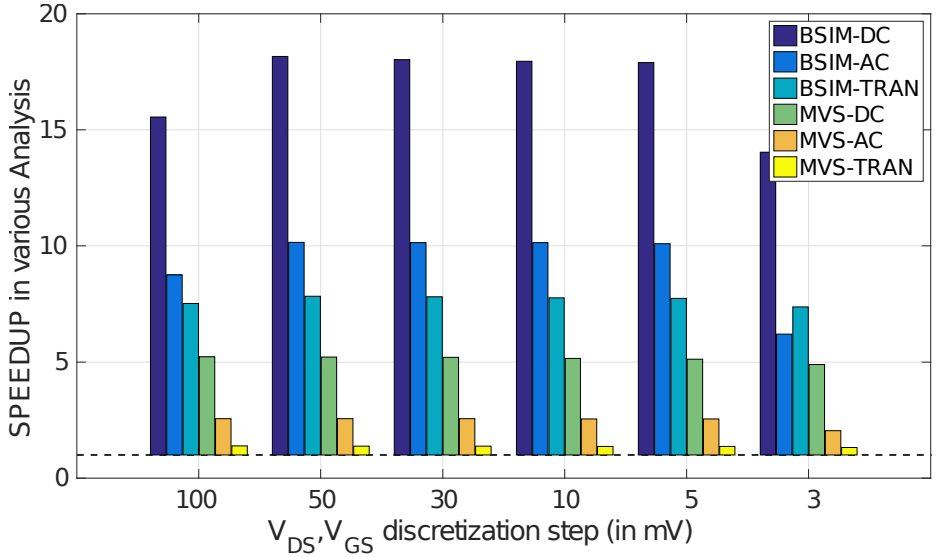

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Error Evaluation

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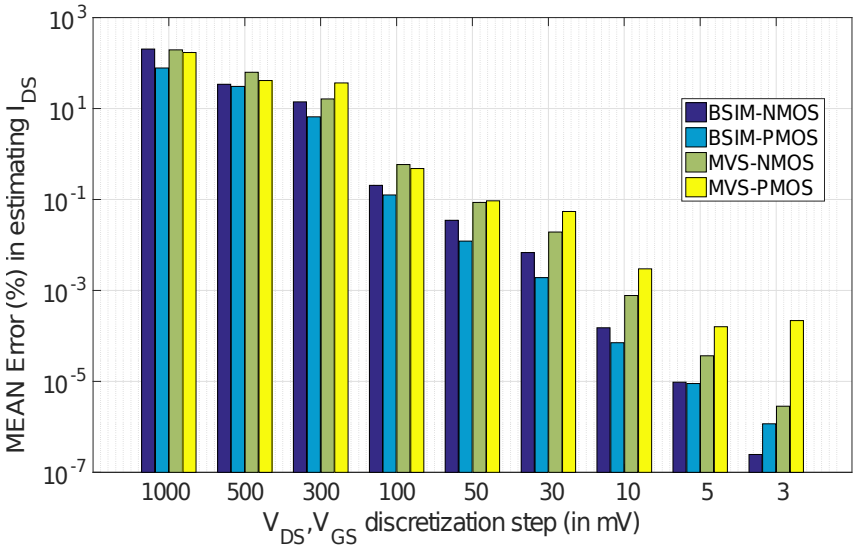
Core device evaluation

BSIM < 0.00001%

MVS < 0.001%



Error Evaluation

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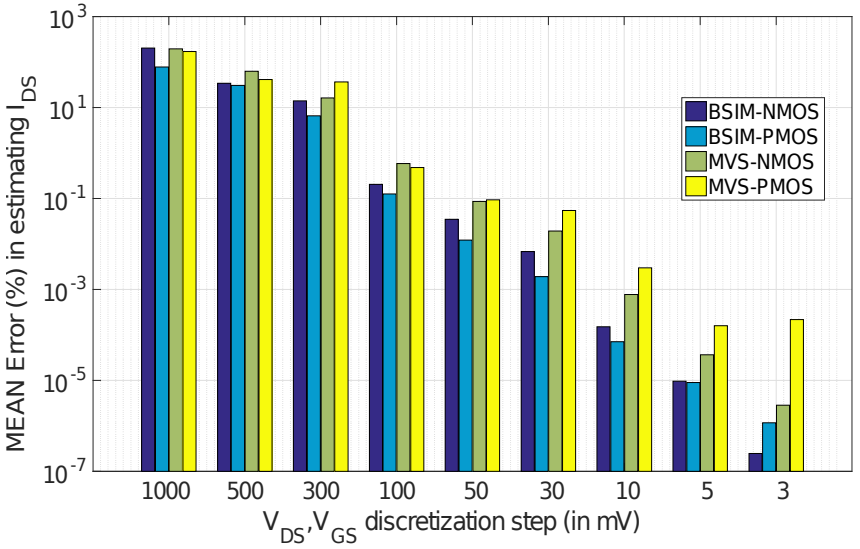


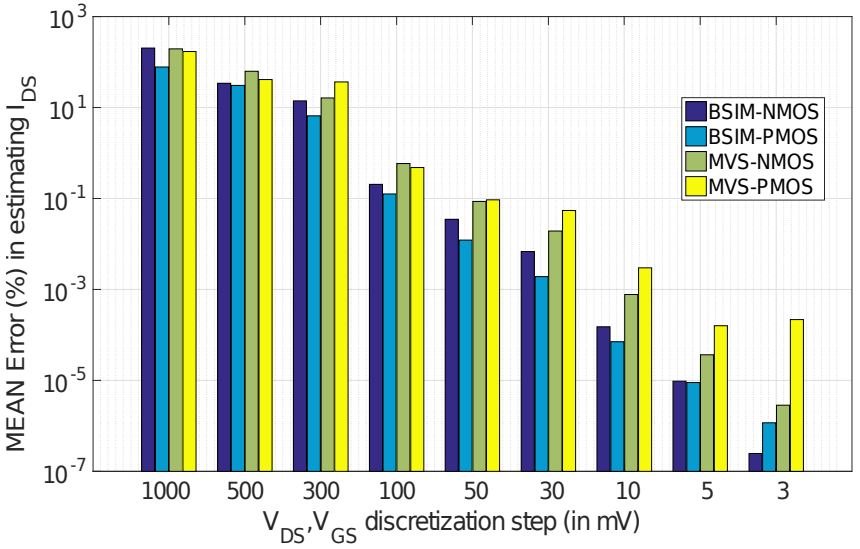
Analysis

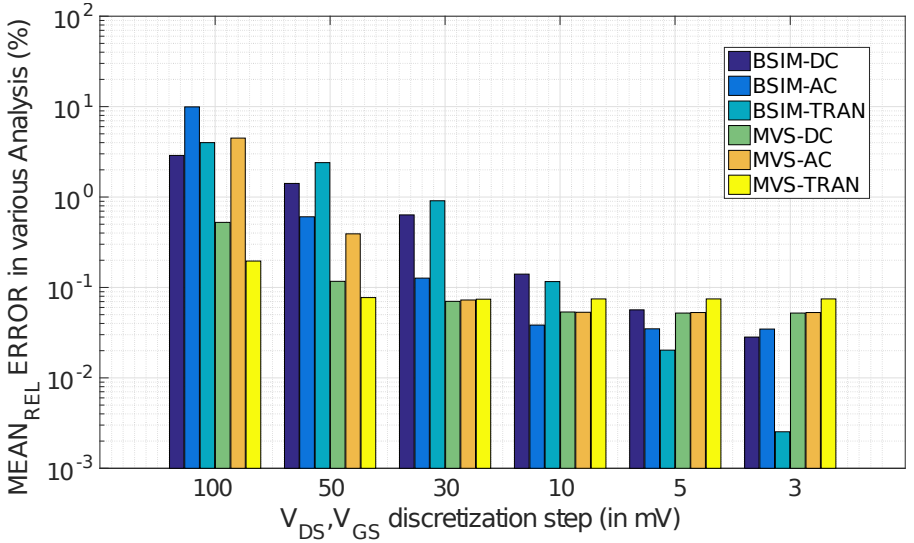
DC < 0.1%,
AC < 0.1%,
TRANSIENT < 0.01%

Error Evaluation

Core device evaluation

BSIM < 0.00001%
MVS < 0.001%





Analysis

DC < 0.1%,
AC < 0.1%,
TRANSIENT < 0.01%

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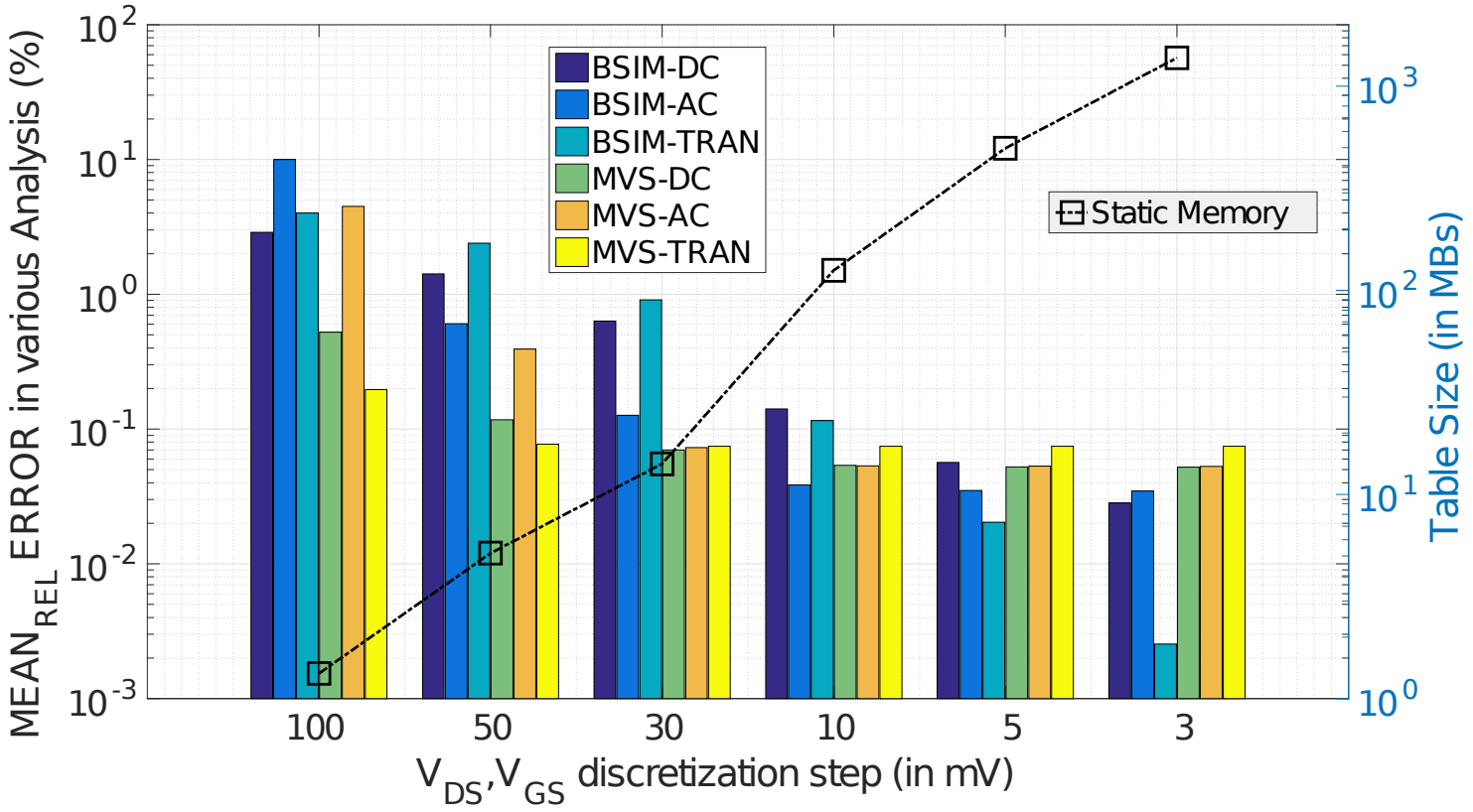

Spline evaluation

Table sizes and computation times

Future Work and problems

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- Exploiting structure in the polynomial coefficients obtained from table-based modelling
- Simulating circuits with measurement data!

QUESTIONS