Metamodel-Assisted Fast and Accurate Optimization of an OP-AMP for Biomedical Applications

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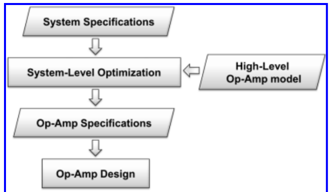
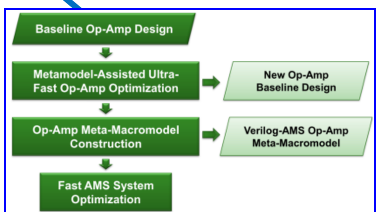
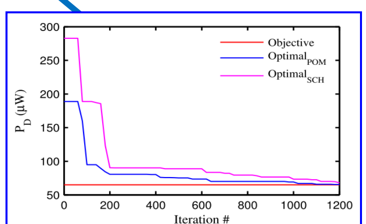
Agenda



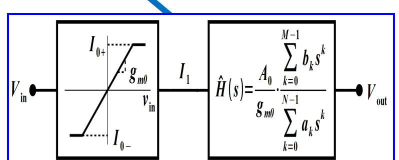
Motivation



Metamodel-assisted optimization flow



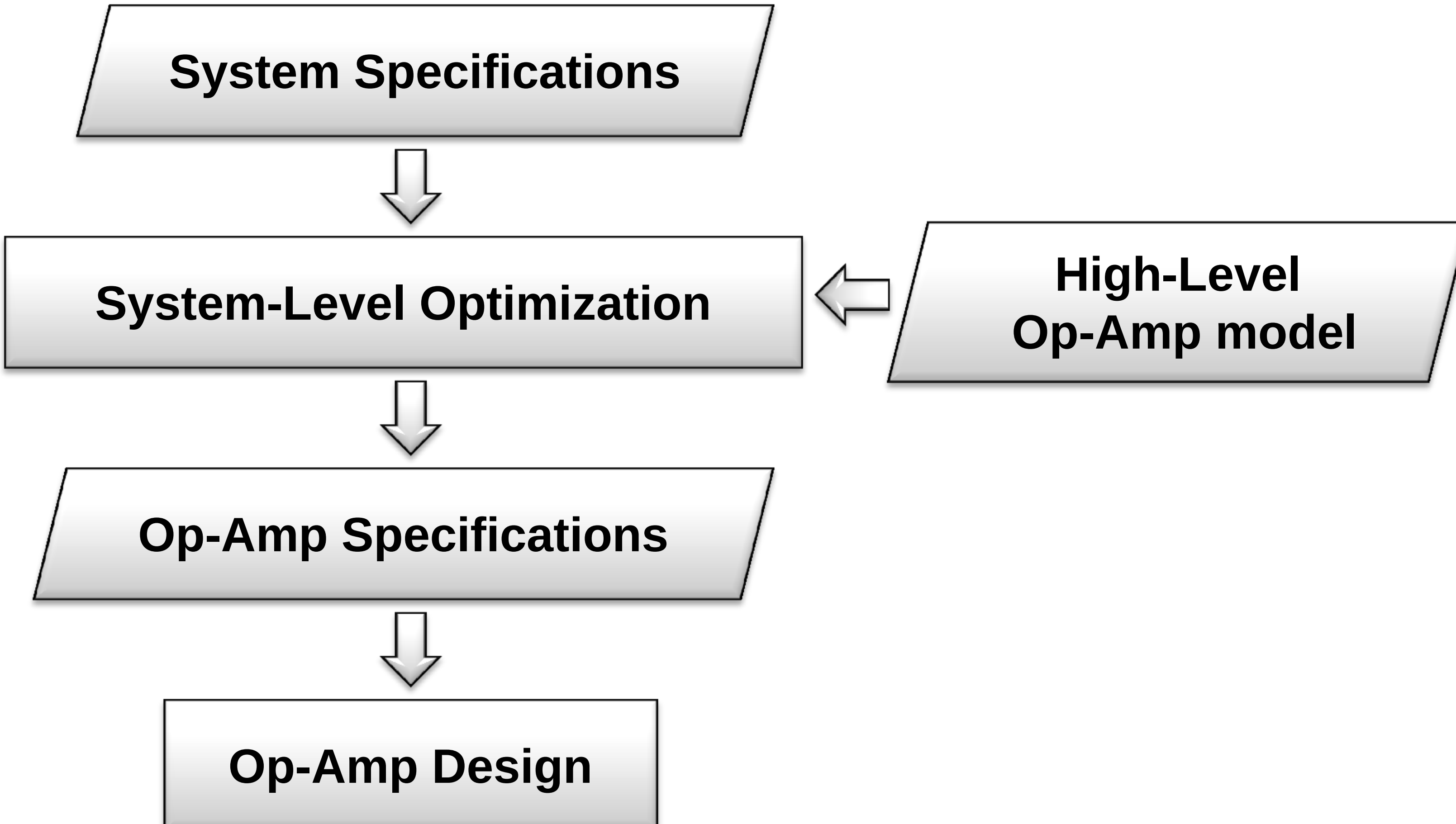
Op-Amp optimization



Verilog-AMS Op-Amp meta-macromodel

Conclusions

Traditional Top-down Approach



Traditional Top-down Approach

❖ **The high-level model is not a high-fidelity model**

System Specifications

⇩

System-Level Optimization ⇦ **High-Level Op-Amp model**

⇩

Op-Amp Specifications

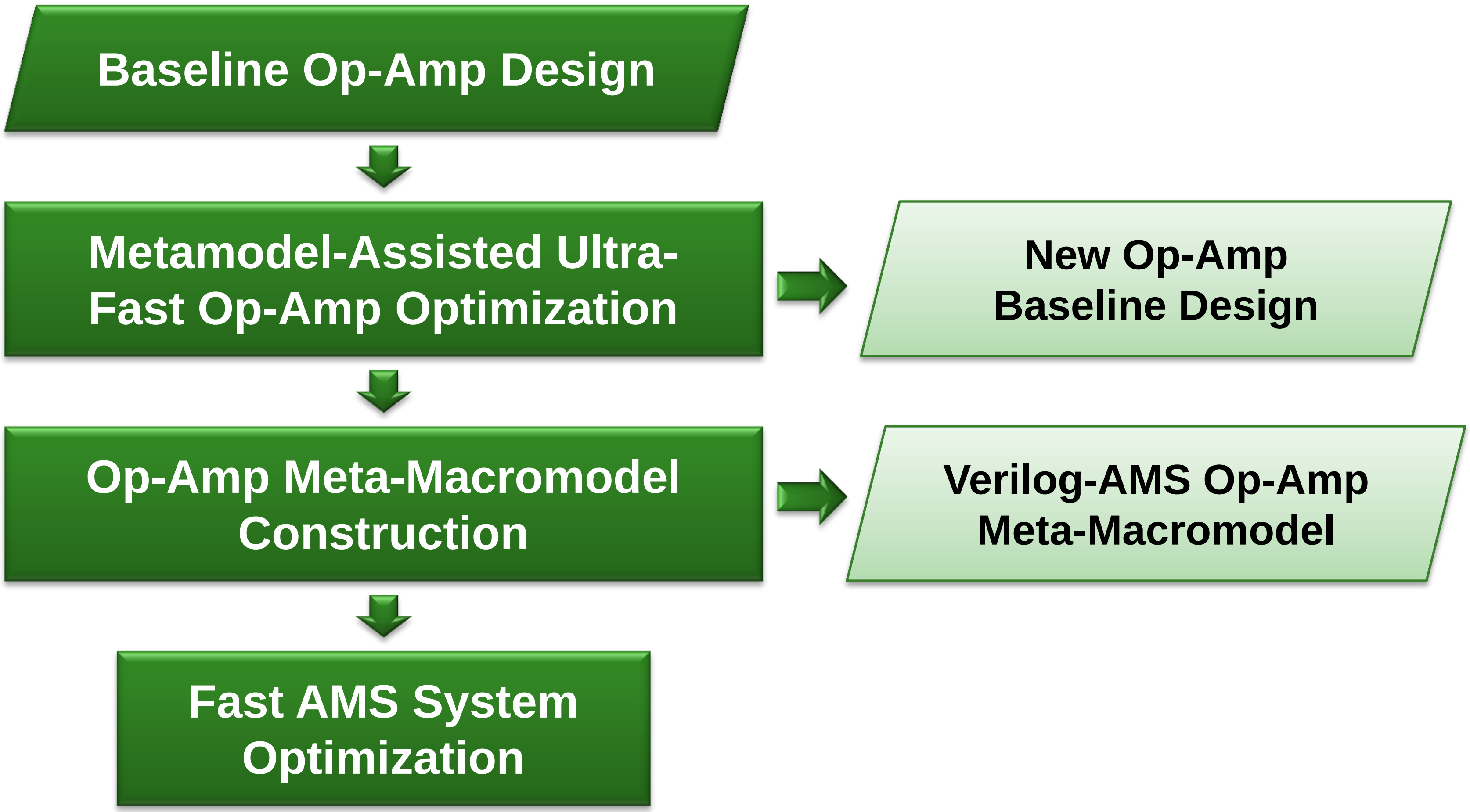
⇩

Op-Amp Design

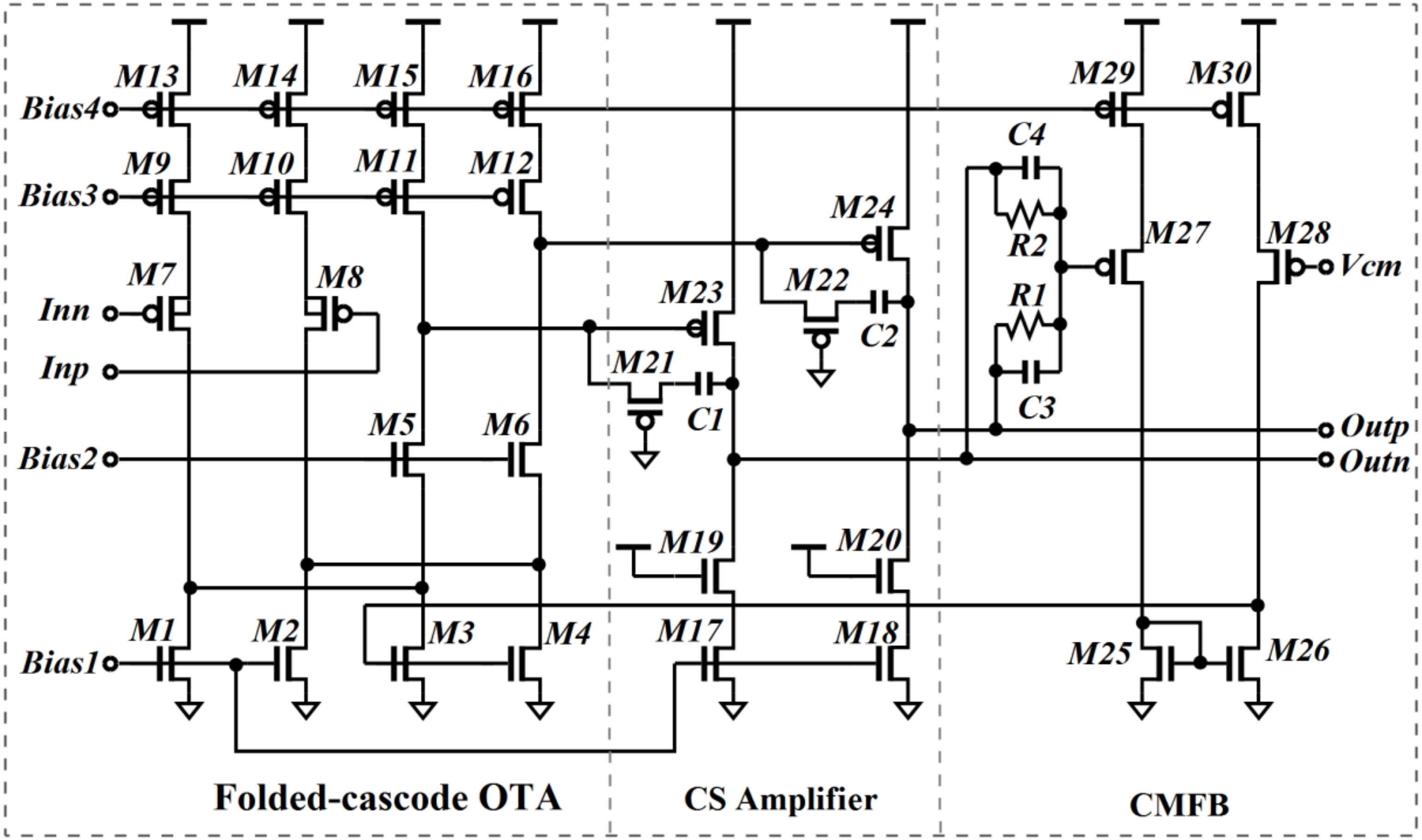
- **Low-order white-box models**
- **Some details are ignored**
- **Limited accuracy**
- **Lead to design iteration**

Three-Step Bottom-Up Flow

❖ **Metamodel-assisted optimization flow are proposed**



Op-Amp Schematic



- 30 transistors, 90 nm CMOS, 1-V VDD

Polynomial Op-Amp Metamodel

- The op-amp characteristics are estimated using POlynomial Metamodel (POM)

Gain

Bandwidth

Phase Margin

Slew Rate

Power

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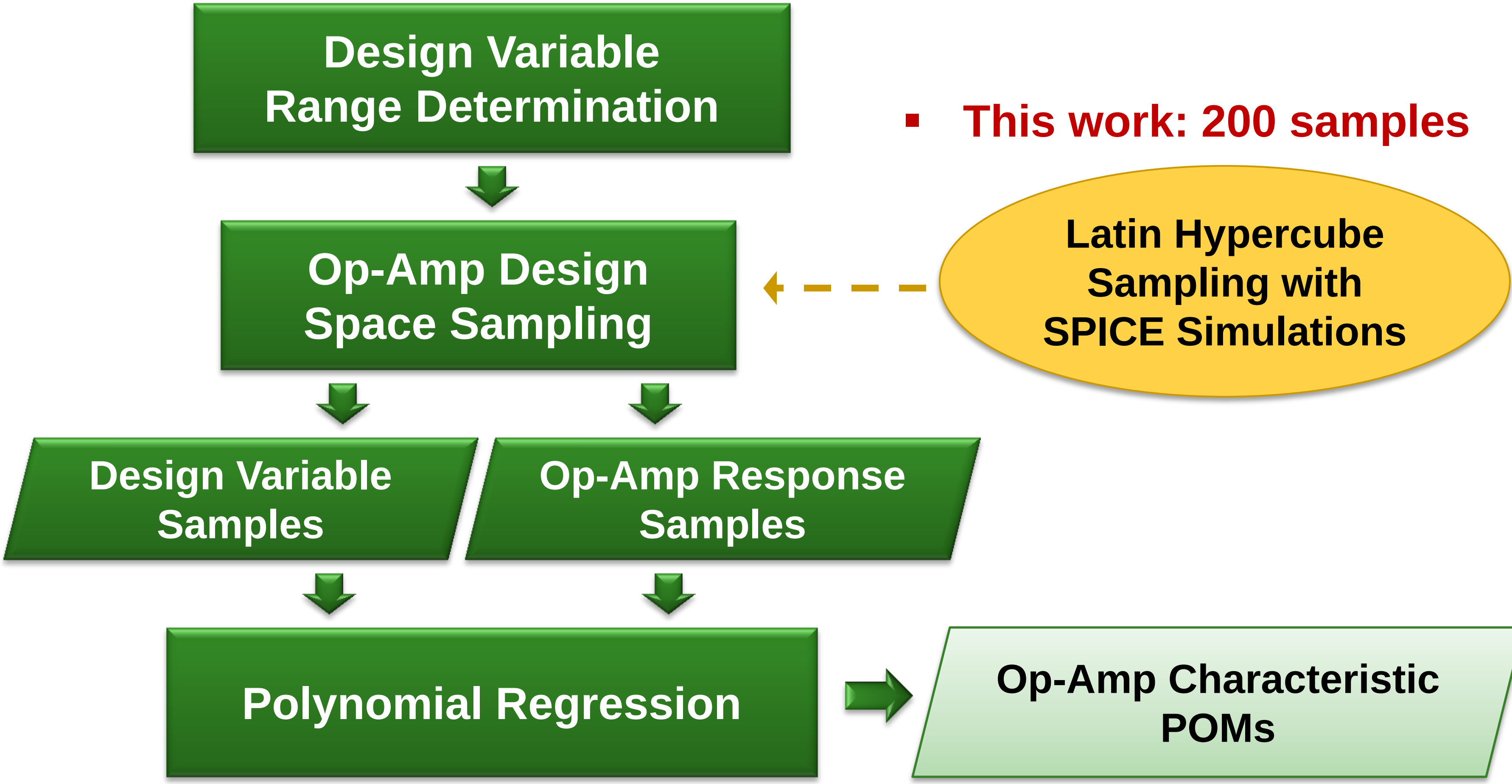
$$f(x) = \sum_{i=0}^{N_B - 1} \beta_i x_1^{p_1} x_2^{p_2} x_3^{p_3} \ldots x_N^{p_N}$$

Transistor widths, lengths, bias current, …

Op-Amp POM Generation

❖ **The goal is to find the coefficients for the polynomials**

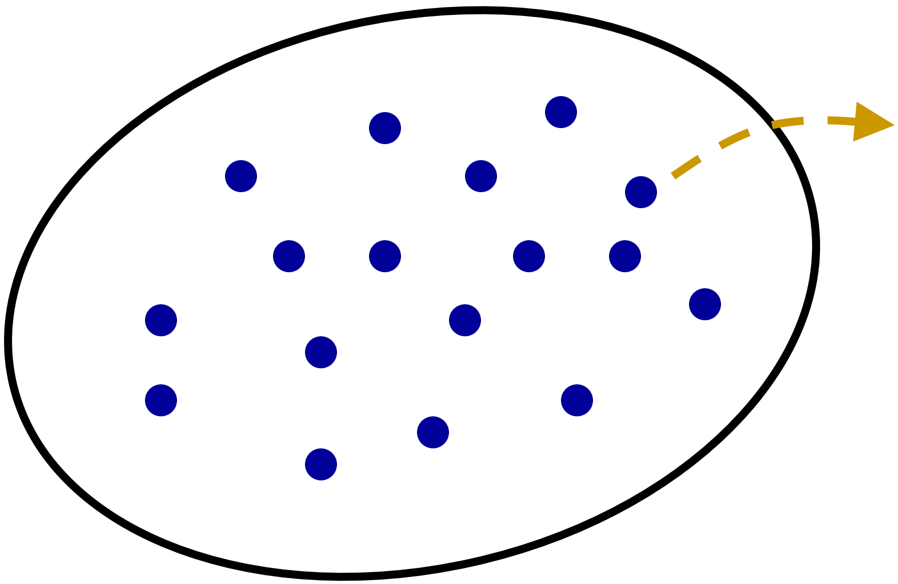
- **This work: 200 samples**



Op-Amp Optimization

- The power is to be minimized with other performance metrics as constraints

Op-Amp Design Space



Power $\xrightarrow{\text{minimize}}$ Objective

Gain

Bandwidth

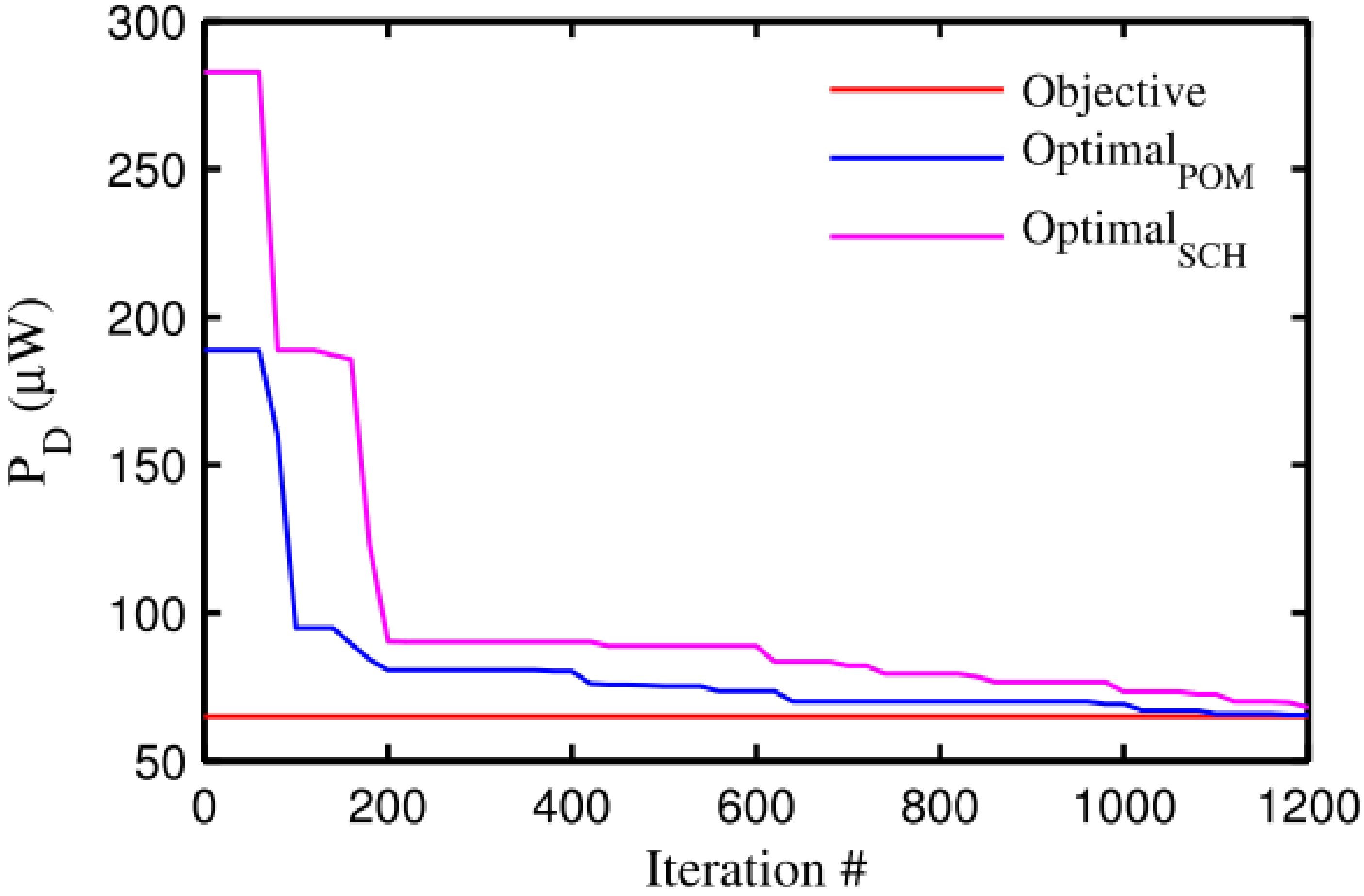
Phase Margin

Slew Rate

Constraints

Cuckoo Search Optimization

- The Cuckoo Search algorithm provides high converge rate



Optimization Results

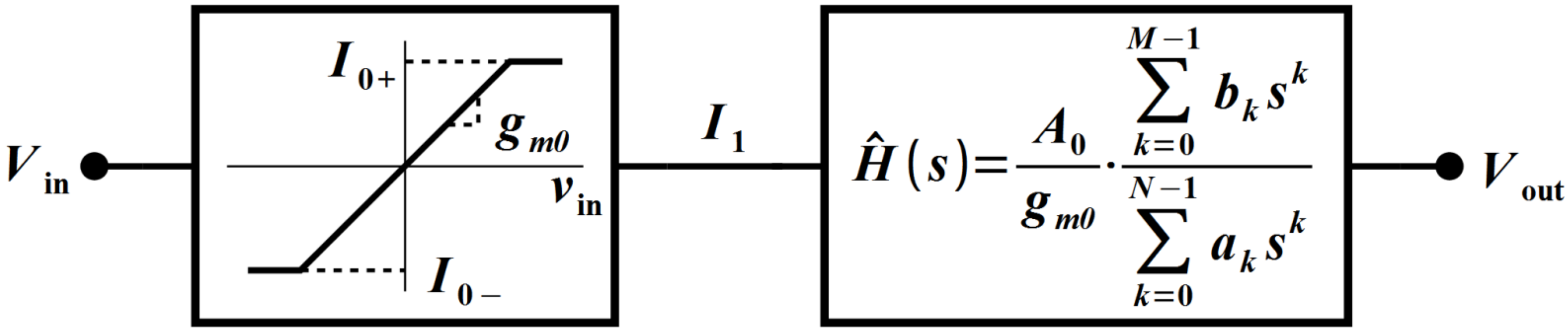
❖ **POM-assisted optimization is much faster**

Performance	Constraint	$\text{Optimal}_{\text{POM}}$	$\text{Optimal}_{\text{SCH}}$
A_0 (dB)	> 43	56.4	52.8
BW (kHz)	> 50	58.9	85.5
PM (degree)	> 70	84.4	87.7
SR (mV/ns)	> 5	7.1	8
	Objective		
P_D (μW)	~ 65	65.5	68.1

Performance	$\text{Optimal}_{\text{SCH}}$	$\text{Optimal}_{\text{POM}}$
Power Reduction	$\times 3.71$	$\times 3.86$
Number of iterations	1200	1200
Computation Time	12.5 h	2.6 s
Normalized Speed	1	$\times 17120$

Meta-macromodeling

❖ **Parametrized op-amp macromodel with the parameters estimated using POMs is constructed in Verilog-AMS (Verilog-AMS-POM)**

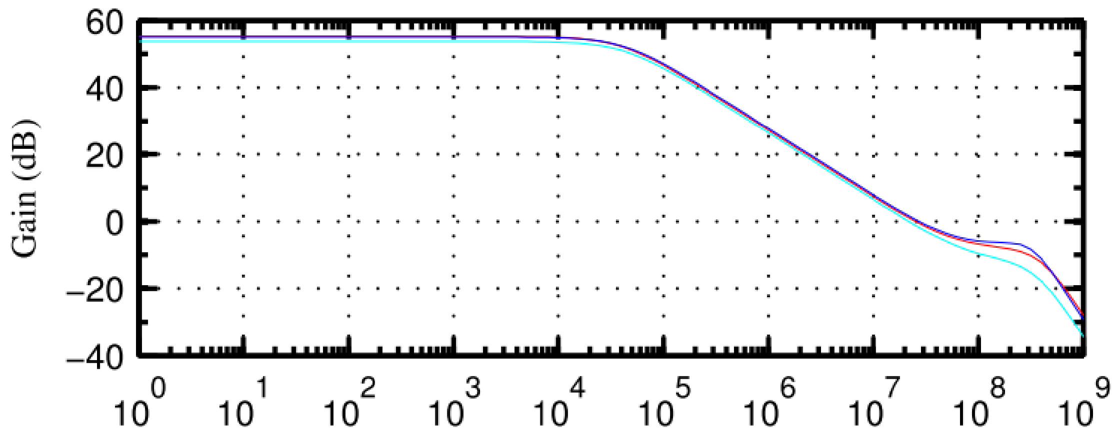


- The parameters are computed in Verilog-AMS **initial** block
- The transfer function is implemented using **laplace_nd()** function
- The op-amp Verilog-AMS-POM can be used in system-level simulations

SPICE vs Verilog-AMS-POM

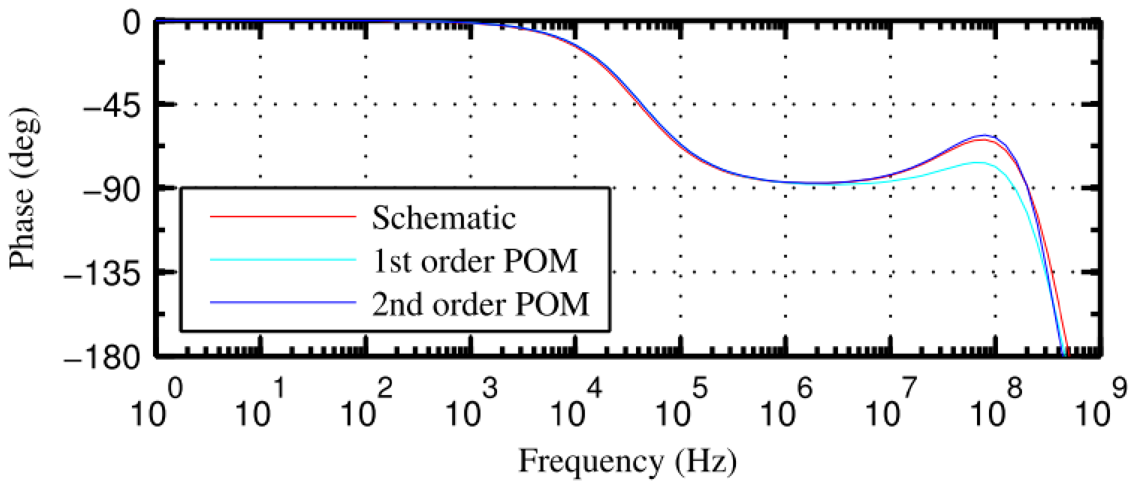
- **AC analyses**

Magnitude



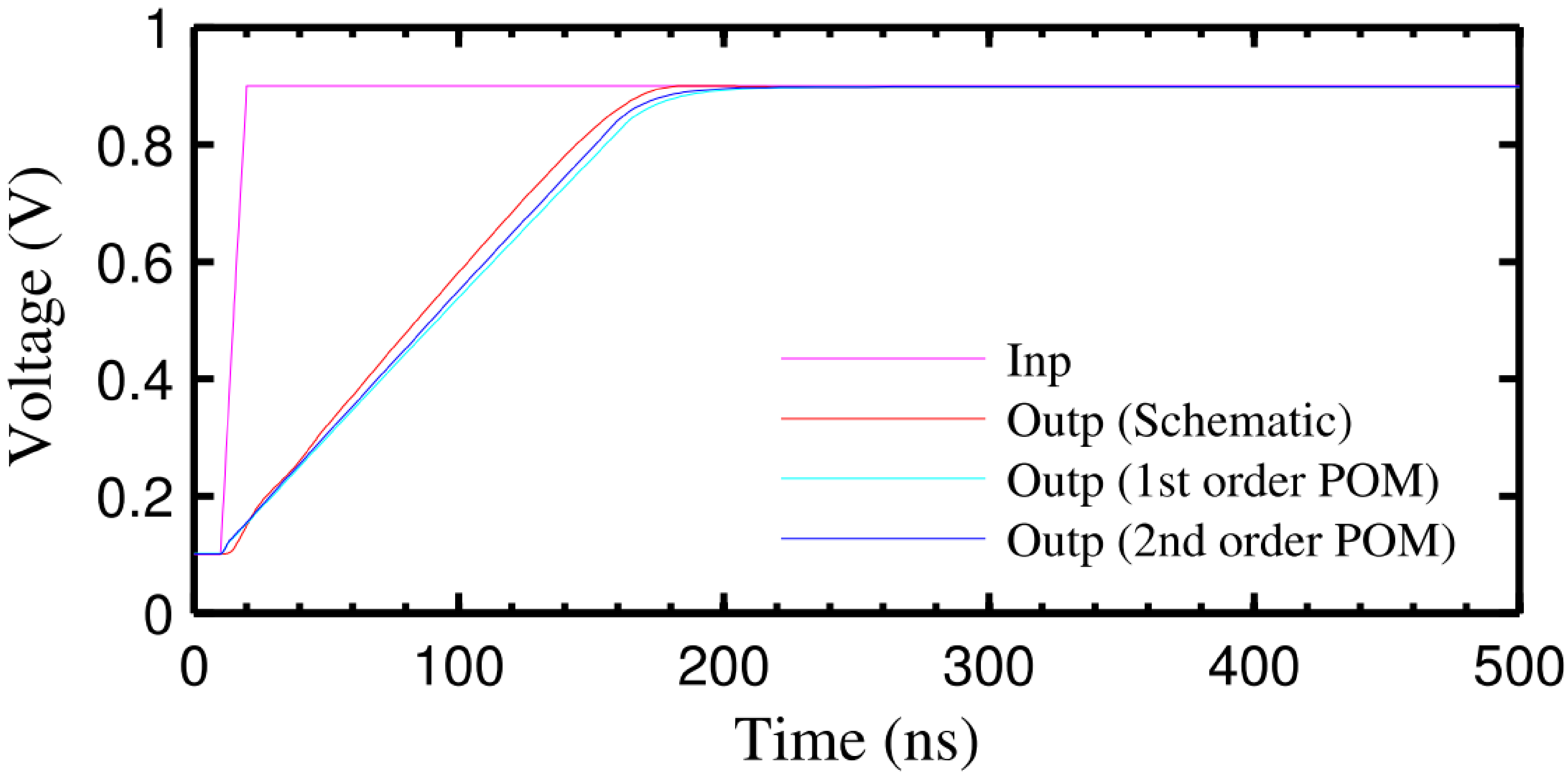
Frequency

Phase



SPICE vs Verilog-AMS-POM

❖ **Transient analysis**



Conclusions

- The proposed bottom-up optimization flow mitigates the flaw of the top-down approach
- Ultra-fast block-level op-amp optimization is achieved by using POMs
- Op-amp Verilog-AMS-POM has been constructed for accurate and efficient system-level optimization

Questions?

Thank You!!!