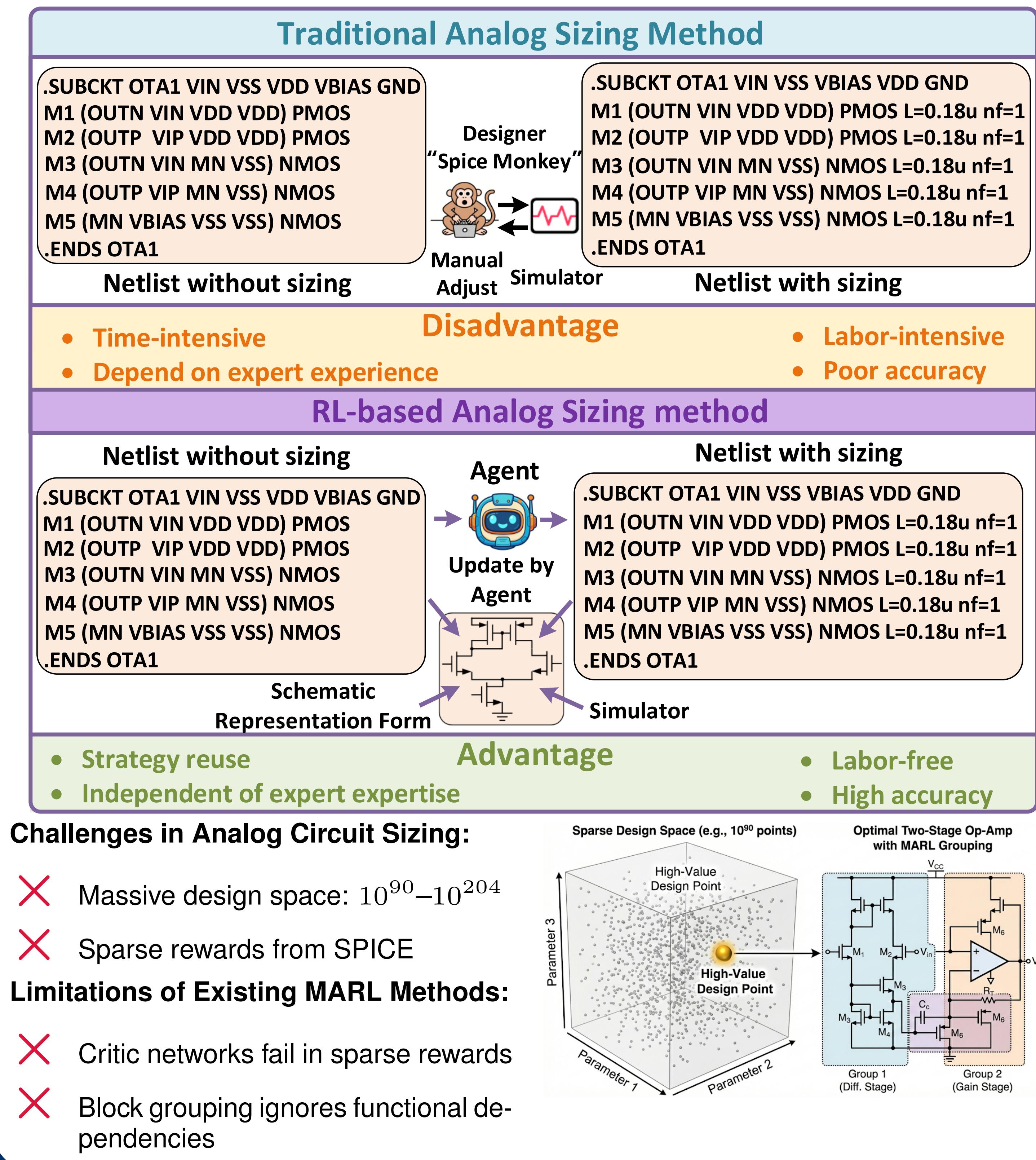


## FD-MAGRPO: Functionality-Driven Multi-Agent Group Relative Policy Optimization for Analog-LDO Sizing

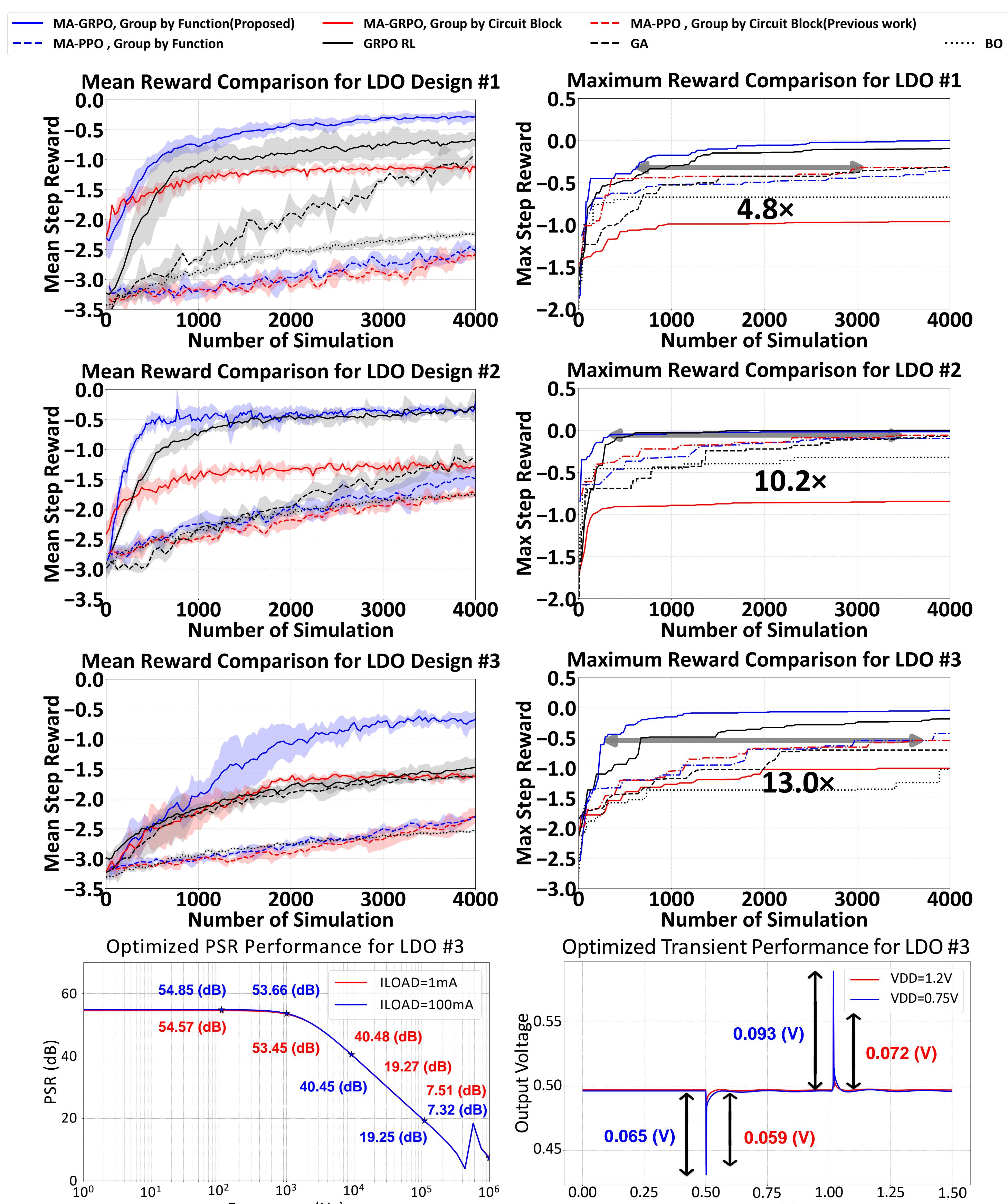
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### Background and Motivation



### Experimental Results & Validation



Specification	Reported	Optimized	Improv.
IQ( $\mu\text{A}$ )	8.00	7.91	1%
Line Reg. <sup>1</sup> (mV/V)	4.50	1.80	60%
Line Reg. <sup>2</sup> (mV/V)	7.80	1.96	75%
Load Reg.(V/A)	0.12	0.002	98%
Overshoot <sup>3</sup> (V)	0.11	0.092	16%
Undershoot <sup>3</sup> (V)	0.077	0.065	16%
Overshoot <sup>4</sup> (V)	0.072	0.072	0%
Undershoot <sup>4</sup> (V)	0.062	0.059	5%
PSR@100Hz <sup>2</sup> (dB)	51.0	54.9	8%
PSR@1kHz <sup>2</sup> (dB)	45.0	53.7	19%
PSR@10kHz <sup>2</sup> (dB)	25.0	40.5	62%
PSR@100kHz <sup>2</sup> (dB)	3.0	19.3	542%
PSR@1MHz <sup>2</sup> (dB)	0	7.3	∞
PSR@100Hz <sup>1</sup> (dB)	50.0	54.6	9%
PSR@1kHz <sup>1</sup> (dB)	45.0	53.5	19%
PSR@10kHz <sup>1</sup> (dB)	25.0	40.5	62%
PSR@100kHz <sup>1</sup> (dB)	5.0	19.3	285%
PSR@1MHz <sup>1</sup> (dB)	0	7.5	∞
FoM(fFV/A)	0.588	0.581	1%

<sup>1</sup>  $I_{LOAD}=1\text{mA}$ , <sup>2</sup>  $I_{LOAD}=100\text{mA}$ , <sup>3</sup>  $VDD=0.75\text{V}$ , <sup>4</sup>  $VDD=1.2\text{V}$

$$\text{FoM: FoM} = \frac{I_Q C_L \Delta V_{OUT}}{\Delta I_{LOAD}^2}$$

#### Gradient SNR Comparison (Functionality vs. Block):

Step	LDO #1				LDO #2				LDO #3			
	Func.-based		Block-based		Func.-based		Block-based		Func.-based		Block-based	
	GSNR	GSNR <sub>h</sub>										
1	0.222	0.211	0.199	0.197	0.227	0.219	0.221	0.208	0.232	0.224	0.197	0.189
5	0.198	0.186	0.171	0.168	0.223	0.216	0.202	0.202	0.198	0.196	0.148	0.145
10	0.248	0.247	0.214	0.208	0.225	0.220	0.199	0.197	0.224	0.219	0.220	0.214
20	0.293	0.272	0.217	0.205	0.245	0.239	0.194	0.190	0.244	0.238	0.209	0.203
40	0.296	0.283	0.205	0.186	0.215	0.209	0.204	0.187	0.226	0.219	0.187	0.184

Note:  $\overline{\text{GSNR}_h}$  denotes harmonic mean GSNR. Functionality-based grouping achieves consistently higher GSNR  $\Rightarrow$  clearer credit assignment  $\Rightarrow$  faster convergence.

#### Key Achievements:

- Rapid convergence: 800–3000 simulations across three LDO topologies
- Significant speedup:  $4.8\times\text{--}13.0\times$  faster than SOTA RL methods
- Scalability: Optimizes circuits with up to 179 parameters in  $10^{204}$  design space

### References

- Shao et al., "DeepSeekMath: Pushing the Limits of Mathematical Reasoning," arXiv:2402.03300, 2024.
- Bao et al., "Multiagent Based RL: An Automated Designer for Complex Analog Circuits," IEEE TCAD, vol. 43, no. 12, 2024.
- Ahmadvazee & Gielen, "Using Probabilistic Model Rollouts to Boost Sample Efficiency of RL," DAC, 2024.
- Schulman et al., "Proximal Policy Optimization Algorithms," arXiv:1707.06347, 2017.