Design and Optimization of Low-Dropout Voltage Regulator Using Relational Graph Neural Network and Reinforcement Learning in Open-Source SKY130 Process

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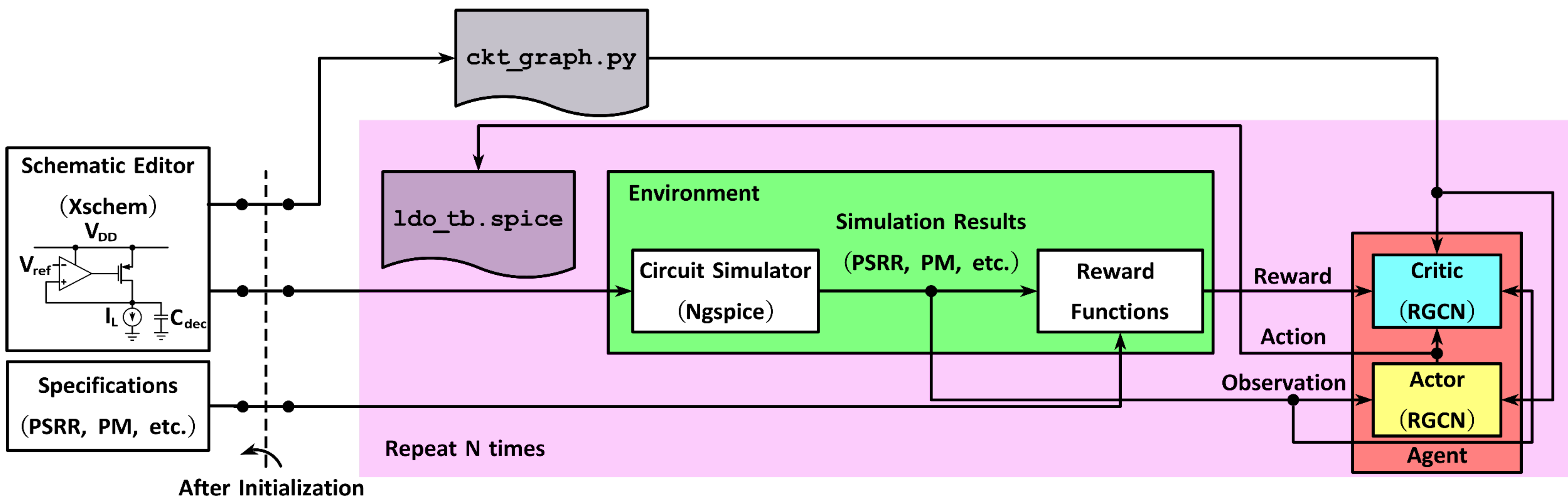
IEEE/ACM 2023 INTERNATIONAL CONFERENCE ON COMPUTER-AIDED DESIGN ICCAD 42nd Edition

Overview



Objectives

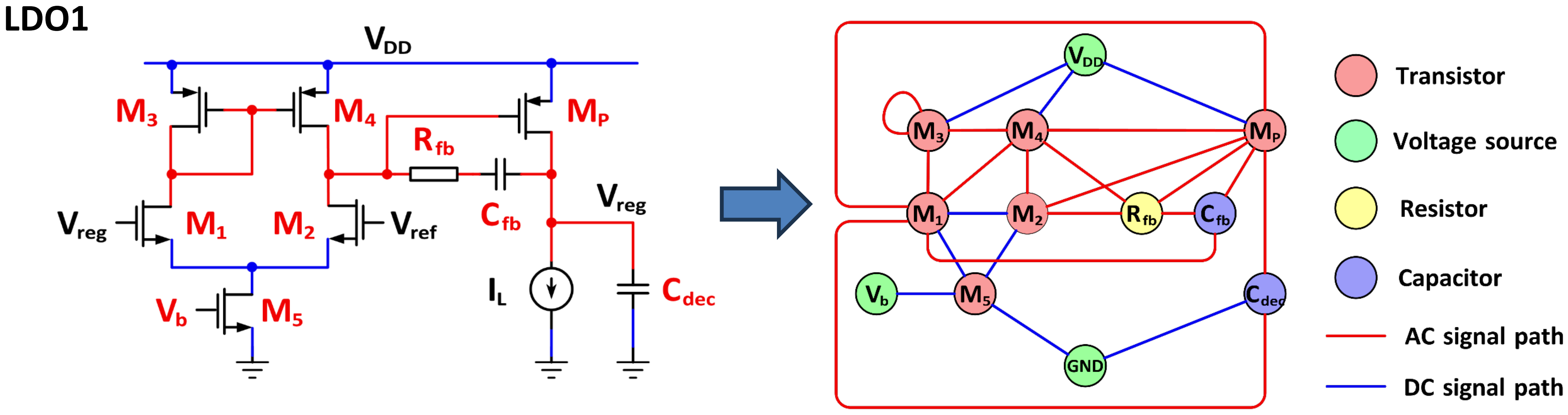
- In analog IC design, sizing circuit components for a given circuit to meet specifications can be challenging.
- Reinforcement learning (RL) has been introduced as an alternative approach to optimize analog circuits.
- **In the domain of ML, reproducibility is crucial. However, commercial PDKs come with NDA, no public access to the dataset. In addition, trained RL agents cannot be publicized, exacerbate their reusability.**
- **We demonstrate the use of relational graph convolutional network (RGCN) and reinforcement learning (RL) to optimize analog LDOs using the open-source SKY130 PDK.**

Relational Graph Convolutional Network (RGCN)

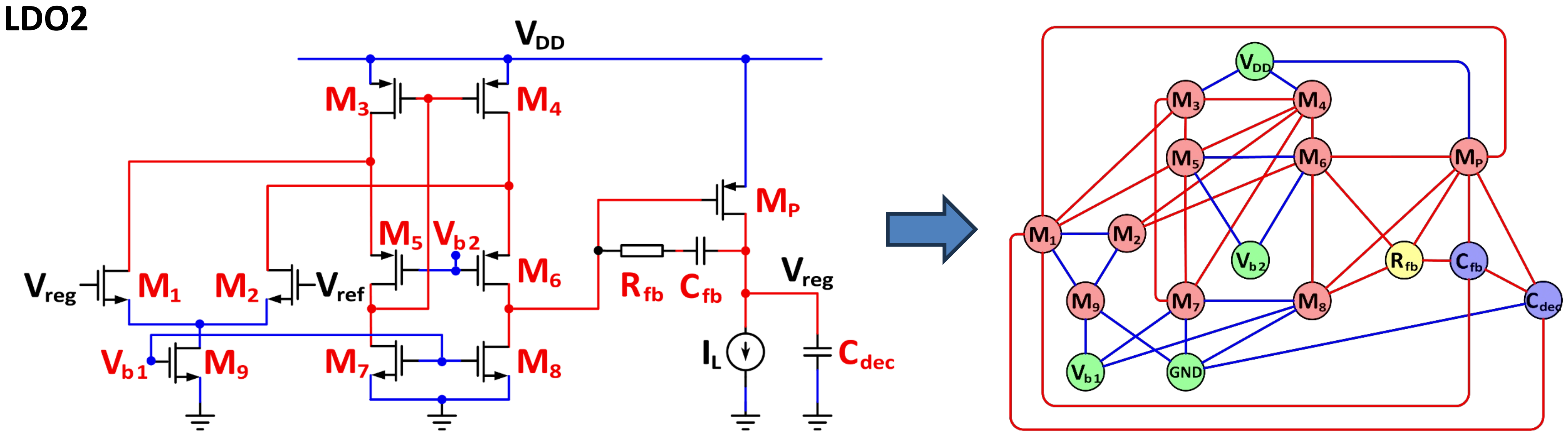
- Recently, using graph neural network (GNN) as the function approximator is getting popular, such as graph convolutional neural network (GCN).
- We explore applying a heterogeneous GNN called relational graph convolutional neural network (RGCN).
- **A big difference between homogeneous and heterogeneous GNN is the latter allows different edge types.**
- **As an example, we could categorize a circuit net based on the signals they are carrying: AC and DC signals.**

Low-Dropout (LDO) Regulator

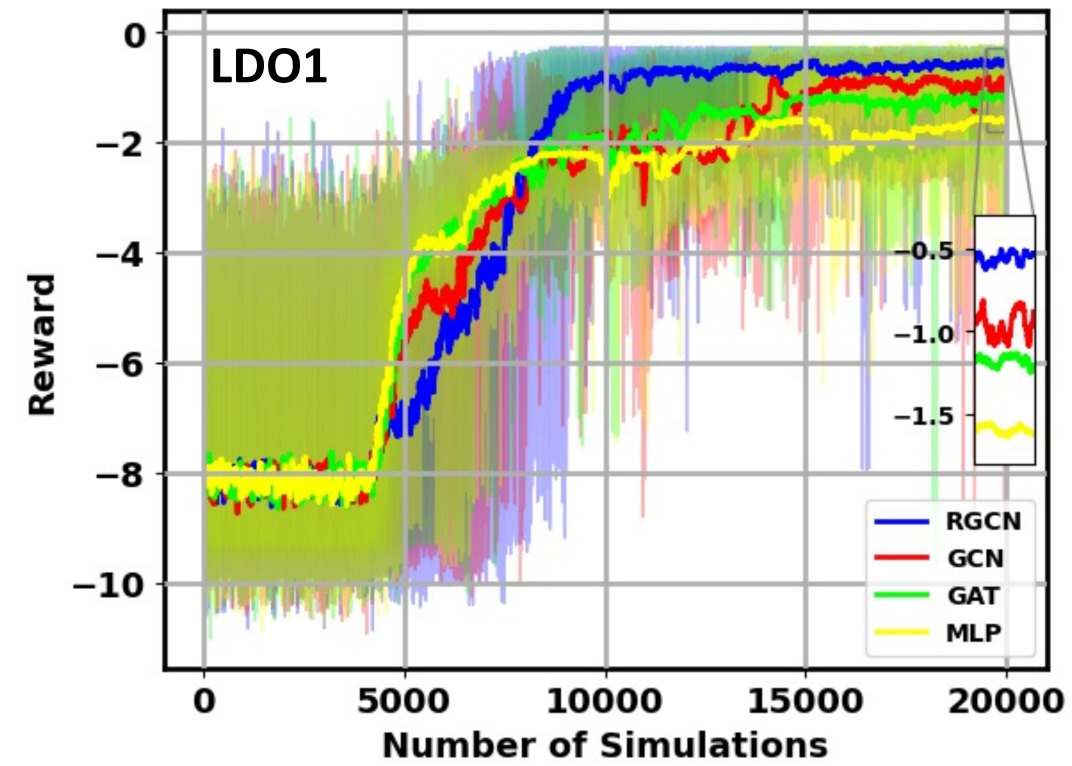
LDO1



LDO2



Results



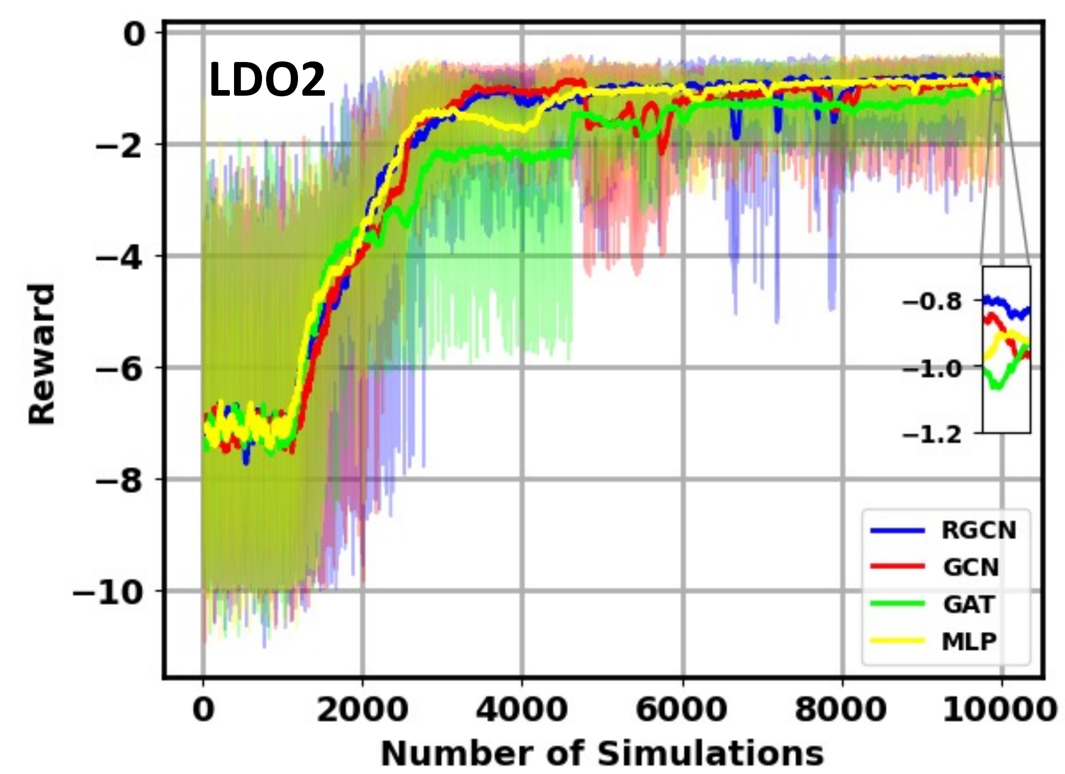


Table I: Optimization Results

		V_{reg} (V)	V_{drop} (mV)	I_L	PSRR(dB)			PM	I_q (μA)
					≤ 10kHz	≤ 1MHz	≥ 1MHz		
Specs.		1.8	≤ 200	[10μA, 10mA]	≤ −30	≤ −20	≤ −5	≥ 60°	≤ 200
LDO1	$I_{L,min}$	1.83	170	[10μA, 10mA]	**−29.3**	−22	−25.75	**54.4°**	175.32
	$I_{L,max}$	1.8	200		−34	−23.2	**−0.32**	61°	
LDO2	$I_{L,min}$	1.86	140	[10μA, 10mA]	−53.53	−25.2	−25.86	61.2	398 (≤ 400)
	$I_{L,max}$	1.81	190		−44.1	−20	**−0.9**	78.2	

Conclusion

- We have demonstrated an open-source RL framework for designing and optimizing vanilla LDO circuits in the open-source SKY130 process.
- We believe that our proposed framework can be generalized to other analog circuits.
- In the future, we plan to expand our model to include post-layout simulation.
- By leveraging the ability of transfer learning, we will explore how the trained RL agent could be applied to other technology nodes.
- **Linked to the GitHub:** https://github.com/ChrisZonghaoLi/sky130_ldo_rl