Learning to Design Analog Circuits to Meet Threshold Specifications

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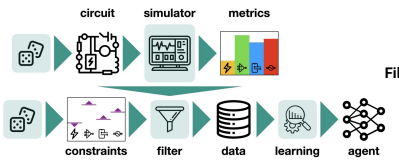
1. Motivation

Human circuit design lags behind co-design processes and struggles to predict exact circuit parameters. Introducing thresholds can alleviate this issue.

2. Contribution

Data-efficient method for dataset construction.
The most extensive evaluation on diverse set of analog and radio circuits.

3. ML Assisted Design



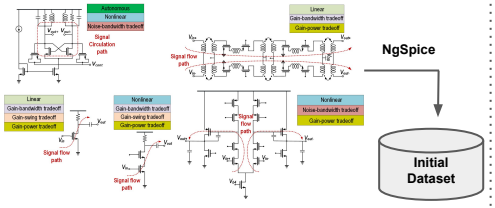
Simulation Phase:

- Specifying parameter space
- Simulating circuits using netlists
- Collecting simulated circuits

Filtering Phase:

- Adding optimization constraints
- Specifying thresholds
- Constructing dataset
- Training an agent on the dataset

4. Simulation Phase



5. Filtering Phase

- Multiplying every performance metric with $\boldsymbol{\lambda_i = -1}$ if it needs to be minimized

$$F(y; D_0) = \{(x, y') \in D_0 | \lambda y' \geq \lambda y\}$$

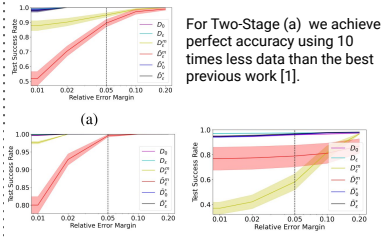
- Adding small perturbations

$$D_\epsilon = \{(x, (1 - \epsilon\lambda u)y) | (x, y) \in D_0, u \sim U^k \text{ i.i.d}\}$$

- Selecting the best available circuit

$$\tilde{D}^*_\epsilon = \{(x, \tilde{y}) | \tilde{y} \in D_\epsilon, x = \operatorname{argmax} F(\tilde{y}; D_0)\}$$

6. Experimental Results



For Two-Stage (a) we achieve perfect accuracy using 10 times less data than the best previous work [1].

For Low-Noise Amplifier (b) and Power Amplifier (c) all studied methods achieve perfect accuracy except in the ablation dataset.

Comparing results with the previous work

	Performance Metric	This Work (%)	Best Reported (%)	Related Works
CS	Gain	0.135±0.035	< 2.6	Devi et al. (2021)
	Bandwidth	0.048 ± 0.12		
	Power Consumption	0.0044± 0.002		
2-Stage Cascode	Gain	0.0471±0.02	≈ 1	Lourenço et al. (2019) Mina et al. (2022)
	Bandwidth	0.0433±0.01		
	Power Consumption	0.0222±0.007		
	Gain	0.0226±0.018	1.1	Fukuda et al. (2017a)
	Bandwidth	0.00001 ± 0.000003	NA	
	Power Consumption	0.0716±0.031	3.7	M.V. & Harish (2020a)
LNA	G_T	0.0028±0.001	< 5	Dumesnil et al. (2014)
	S_{11}	0.007±0.001		
	NF	0.002±0.0005		
PA	Power Gain	1.207 ± 0.14	NA	NA
	Drain Efficiency	1.361 ± 0.2		
	PAE	1.30 ± 0.19		
Mixer	Conversion Gain	0.005±0.0035	NA	NA
	Power Consumption	0.86±0.002		
	Swing	0.66± 0.005		
VCO	Power Consumption	0.017± 0.1423	NA	NA
	Output Power	0.1423±0.01		
	Tuning Range	3.226±0.6293		

6. References

[1] Fukuda, M. Op-amp sizing by inference of element values using machine learning.
[2] Devi, S. Automated design of analog circuits using machine learning techniques.
[3] Dumesnil, E. Rf-lna circuit synthesis by genetic algorithm-specified artificial neural network.
[4] Lourenço, Using Polynomial Regression and Artificial Neural Networks for Reusable Analog IC Sizing

7. Try it

Online Demo:
circuits.streamlit.app

Code and Data:
github.com/indylab/Circuit-Synthesis