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Parameter Estimation Techniques for Circuit Models: Methods and Applications

Dr. Ananya R. Menon
Assistant Professor
Department of Electrical & Electronics Engineering,
Don Bosco Institute of Technology, Mumbai, Maharashtra, India
Email: *ananya.menon.param@dbit.ac.in*

Rohit P. Nair
Assistant Professor
Department of Electronics & Communication Engineering,
Sree Narayana Gurukulam College of Engineering, Kottiyam, Kerala, India
Email: *rohit.nair.circuit@gmail.com*

Abstract

Accurate parameter estimation is essential for reliable circuit modeling and simulation. Parameter estimation techniques are used to extract component values and system characteristics from measured data to create precise models for SPICE simulations, real-time control, and fault diagnosis. This paper reviews techniques such as least squares, optimization-based methods, neural networks, and hybrid approaches for parameter estimation in analog, digital, and power electronic circuits. Challenges like measurement noise, nonlinearity, and computational complexity are discussed. Indian contributions from smaller institutions are highlighted. Tables and 2D figures illustrate estimation workflows, methods, and circuit-level applications.

Keywords: *Parameter estimation, Circuit modeling, Optimization, Least squares, Neural networks, Electrical circuits, SPICE*

INTRODUCTION

Parameter estimation is the process of determining unknown parameters of a circuit model using measured data. Accurate parameter estimation is critical for:

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- Predictive simulations in SPICE or other tools
- Real-time control and hardware-in-the-loop simulations
- Fault detection and predictive maintenance

Traditional parameter estimation relies on analytical techniques, while modern approaches increasingly use AI and optimization algorithms.

2. Techniques for Parameter Estimation

2.1 Least Squares Method

- Minimizes the sum of squared differences between measured and simulated signals
- Commonly used for linear systems and simple RC, RL, RLC circuits
- Can be extended to nonlinear systems using iterative methods

Mathematical Formulation:

θ^=argminθ∑i=1N(yi−f(xi,θ))2\hat{\theta} = \arg \min_{\theta} \sum_{i=1}^{N} (y_i - f(x_i, \theta))^2θ^=argθmini=1∑N(yi−f(xi,θ))2

where yiy_iyi is measured data, f(xi,θ)f(x_i, \theta)f(xi,θ) is the model response, and θ\thetaθ is the parameter vector.

2.2 Optimization-Based Methods

- Treats parameter estimation as an optimization problem
- Evolutionary algorithms (GA, PSO, DE) are often used for complex or nonlinear circuits
- Suitable for multi-objective optimization, e.g., balancing power, gain, and bandwidth

2.3 Neural Network Approaches

- Feedforward and recurrent neural networks can learn the mapping from measured data to circuit parameters
- Effective for systems with high nonlinearity and noisy measurements
- Can be integrated with SPICE or digital twin models

2.4 Hybrid Methods

- Combine analytical methods, optimization algorithms, and machine learning

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- Improve accuracy and convergence speed
- Useful for real-time or large-scale systems

Table 1: Comparison of Parameter Estimation Techniques

Technique	Advantages	Limitations	Applications
Least Squares	Simple, analytical solution	Sensitive to noise, linear systems	RC, RL, RLC circuits
Optimization	Handles nonlinear, multi-objective	Computationally intensive	Power electronics, mixed-signal circuits
Neural Networks	Adaptive, handles noise	Requires training data, black-box	Nonlinear circuits, motor drives
Hybrid	High accuracy, robust	Complexity, integration effort	Real-time estimation, industrial systems

3. Parameter Estimation Workflow

Circuit Data Acquisition

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Preprocessing (Filtering, Noise Reduction)

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Selection of Estimation Technique

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Parameter Estimation (Least Squares / Optimization / AI)

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Model Validation (Simulation / HIL Testing)

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Updated Circuit Model

Figure 1: General Workflow for Circuit Parameter Estimation

Steps:

- Acquire voltage, current, or other signals from the circuit
- Preprocess signals to remove noise and normalize data
- Choose an appropriate estimation technique based on circuit complexity

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- Estimate parameters and validate against measured data
- Update the circuit model and iterate if necessary

4. Applications in Electrical Circuits

4.1 Analog Circuit Modeling

- Estimation of transistor parameters (β, Vth, capacitances)
- Passive component identification for RC, RL, RLC networks

4.2 Digital Circuits

- Estimation of timing parameters and logic delays
- Power and energy modeling for digital gates

4.3 Power Electronics

- Estimation of switching device parameters
- Converter and inverter modeling for SPICE simulations and real-time HIL

Table 2: Example Parameters for Estimation in Different Circuit Types

Circuit Type	Parameters Estimated	Application
RC / RL / RLC	R, L, C values	Filter design, signal processing
Op-amp / Amplifier	Gain, bandwidth, bias currents	Analog design optimization
MOSFET / IGBT	Threshold voltage, capacitances	Converter simulation, HIL testing
Digital Logic	Propagation delay, setup/hold times	FPGA / ASIC timing analysis

5. Challenges in Parameter Estimation

- **Measurement Noise:** Reduces accuracy and reliability
- **Nonlinearity:** Complex circuits require iterative or AI-based methods
- **Computational Cost:** Optimization and neural network methods may require high computation
- **Real-Time Constraints:** Parameter estimation for HIL or live systems must be fast and accurate
- **Model Validation:** Ensuring the estimated parameters reflect actual physical behavior

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6. Indian Research Contributions

- **Don Bosco Institute of Technology, Mumbai:** Optimization-based parameter estimation for power electronic converters
- **Sree Narayana Gurukulam College of Engineering, Kottiyam:** Neural network-based estimation for motor drive models
- **Rajalakshmi Engineering College, Chennai:** Hybrid estimation techniques combining least squares and AI for analog circuits

These contributions demonstrate practical solutions for accurate circuit modeling and real-time implementation.

7. Future Trends

- **AI-Enhanced Parameter Estimation:** Using machine learning for adaptive and robust estimation
- **Integration with Digital Twins:** Real-time model updates using sensor data
- **Edge Computing for Estimation:** Performing parameter estimation locally for fast decision-making
- **Multi-Objective Estimation:** Simultaneously estimating multiple circuit parameters under constraints

Circuit Sensors & Data

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Preprocessing

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Neural Network / Optimization

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Estimated Parameters

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Updated Circuit Model

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Real-Time Simulation / Control

Figure 2: AI-Integrated Parameter Estimation Framework

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CONCLUSION

Parameter estimation is vital for accurate modeling, simulation, and control of electrical circuits. Techniques such as least squares, optimization algorithms, neural networks, and hybrid approaches provide tools to handle linear, nonlinear, and large-scale circuits. Indian research demonstrates successful applications in analog, digital, and power electronics systems. Future work integrating AI, digital twins, and edge computing will enhance real-time parameter estimation and improve system reliability.

REFERENCES

1. A. R. Menon, R. P. Nair, "Parameter Estimation Techniques for Electrical Circuit Models," *International Journal of Circuit Modeling and Simulation*, vol. 10, pp. 45–62, 2025.
2. L. Ljung, *System Identification: Theory for the User*, 2nd Edition, Prentice Hall, 1999, pp. 45–120.
3. S. Haykin, *Neural Networks and Learning Machines*, 3rd Edition, Pearson, 2009, pp. 210–310.
4. K. Deb, *Multi-Objective Optimization Using Evolutionary Algorithms*, Wiley, 2001, pp. 12–89.
5. R. Storn, K. Price, "Differential Evolution – A Simple and Efficient Heuristic for Global Optimization," *Journal of Global Optimization*, vol. 11, pp. 341–359, 1997.
6. P. Rashid et al., "Optimization-Based Parameter Estimation for Power Electronics Circuits," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 4, pp. 3567–3578, 2022.
7. S. P. Menon et al., "Neural Network-Based Parameter Estimation for Motor Drive Models," *International Journal of Electrical Engineering Simulation*, vol. 11, pp. 77–93, 2024.
8. R. K. Sharma et al., "Hybrid Parameter Estimation Methods for Analog Circuits," *Journal of Circuit Systems and Simulation*, vol. 16, pp. 33–50, 2025.

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