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Parameter Identification and Block Diagram Reduction of DC054B-6 Motor in Electric Control System Application

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Abstract

This study presents a comprehensive mathematical modeling and simulation of two electric motors commonly used in industrial and educational applications: the PITTMAN TYPE DC054B-6 brushed DC motor and the FUJITA TYPE ML7112 single-phase AC motor. The objective is to derive accurate dynamic models that reflect the electrical and mechanical behavior of each motor, facilitating the analysis and design of control systems. The modeling process begins with the identification of motor parameters, including resistance, inductance, back EMF constant, torque constant, moment of inertia, and damping coefficient, sourced from datasheets and estimated through standard motor modeling techniques. The dynamic equations are formulated using Kirchhoff's Voltage Law for electrical dynamics and Newton's Second Law for mechanical motion. These equations are then transformed into the Laplace domain to derive transfer functions that relate input voltage to angular velocity. To validate the mathematical models, simulations are carried out in MATLAB/Simulink for both motors under open-loop and closed-loop configurations. A proportional controller is introduced in the feedback loop to improve performance and stability. The results show that the second-order DC motor model exhibits underdamped behavior in open-loop form but demonstrates significantly improved rise time and settling time in closed-loop control. Meanwhile, the AC motor, modeled as a simplified first-order system, responds more slowly but provides acceptable performance for applications with less dynamic requirements. The simulation results confirm the accuracy and reliability of the developed models for control system design. The models serve as a foundation for implementing more advanced control strategies such as PID or adaptive control. This work contributes to the development of digital simulation techniques and embedded control systems, especially in the context of marine electrical and automation engineering.

Keywords **DC Motor ElectroCraftDC054B-6; Parameter Identification; Block Diagram Reduction; Mathematical Modeling; Transfer Function; Laplace Transform; Electric Control System.**

I. Introduction

Electric motors are fundamental components in both industrial and marine electrical systems, serving as the primary actuators in automation, propulsion, and auxiliary machinery. Among various motor types, direct current (DC) motors and single-phase alternating current (AC) motors remain widely used due to their simplicity, availability, and well-understood characteristics. In marine applications, DC motors are often favored for their fast response and precise speed control, while single-phase AC motors are utilized for low-power devices such as pumps, compressors, and fans.

Understanding the dynamic behavior of these motors is essential for designing effective control systems, particularly in applications where stability, responsiveness, and energy efficiency are critical. Mathematical modeling provides a means to represent the physical behavior of electrical machines in the form of equations that can be analyzed and simulated. These models serve as a foundation for control system development, enabling engineers to predict system performance, test control strategies, and optimize parameters without direct experimentation on physical hardware.

This research focuses on the mathematical modeling and simulation of the PITTMAN TYPE DC054B-6 brushed DC motor and the FUJITA TYPE ML7112 single-phase AC motor. The DC motor is modeled as a second-order system based on its electrical and mechanical dynamics, while the AC motor is

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represented as a first-order approximation suitable for basic control analysis.

The objective of this study is to derive transfer functions for both motor types using fundamental physical laws and to analyze their dynamic responses through simulation in MATLAB/Simulink. The models are validated through open-loop and closed-loop step response testing, providing insights into time-domain performance characteristics such as rise time, settling time, overshoot, and steady-state error. The ultimate goal is to develop reliable models that can be applied in embedded control systems and educational platforms for marine and industrial applications.

This research aims to fill that gap by proposing a structured modeling approach using parameter identification directly from the motor's datasheet, followed by mathematical derivations grounded in Kirchhoff's law and Newtonian mechanics. These physical relationships are used to derive both the electrical and mechanical subsystems, which are then unified into a comprehensive electromechanical model. The model is transformed into the Laplace domain, and a block diagram is constructed and reduced to facilitate control system analysis. This method allows for high model fidelity while maintaining simplicity, enabling its use in simulation and real-time embedded systems.

The objective of this study is to develop an accurate, simulation-ready model of the DC054B-6 motorthrough analytical parameter identification and block diagram reduction, tailored for electric control system applications. The key contributions of this paper are: (1) derivation of a complete electromechanical model for the DC054B-5 motor using physical laws and datasheet data; (2) a structured parameter identification method for calculating resistance, inductance, back-EMF constant, torque constant, and moment of inertia; (3) simulation of both open-loop and closed-loop responses using MATLAB/Simulink; and (4) application of block diagram reduction to simplify the control architecture for ease of implementation in practical systems.

The remainder of this paper is organized as follows. Section 2 explains the theoretical modeling approach, including the use of Laplace transforms and transfer functions. Section 3 details the parameter identification and derivation process. Section 4 focuses on the construction and reduction of block diagrams, as well as the simulation setup. Section 5 presents the simulation results and discussions. Finally, Section 6 concludes the paper with a summary of findings and directions for future research.

II. Method

A. Datasheet

The key parameters obtained from the datasheet and used in the simulation are listed in Table 1

Parameter	Symbol	Value	Unit
Rated Voltage	V_r	12	V
Armature Resistance	R_a	0.220	Ω
Armature Inductance (assumed)	L_a	0.31	H
No-load Speed	ω	2940	rpm
No-load Current	I	0.56	A
Rated Torque	T_r	0.21	Nm
Rotor Inertia	J	$2{,}21\times10^{-5}$	kg·m²
Torque Constant	K_t	0.0335	Nm/A
Back EMF Constant	K_e	0.0335	V·s/rad
Damping Coefficient (estimated)	B	0.000682	N·m·s/rad

Tabel 1. Parameters obtained from the datasheet

The modeling process in this study begins with the identification and extraction of critical parameters from the datasheet table 1 of the DC motor ElectroCraft DC054B-6. This motor is selected due to its widespread use in embedded control applications, offering a practical case study for electromechanical modeling. The datasheet provides essential motor specifications including rated voltage (12V), rated speed (2940 rpm), stall torque, torque constant, armature resistance, armature inductance, and no-load current. These values serve as the foundation for determining the motor's dynamic behavior.

Each datasheet parameter is carefully interpreted and utilized to calculate complementary variables required for complete modeling. For example, the back-electromotive force (EMF) constant (Ke) is derived from the rated speed and corresponding back-EMF voltage. Likewise, the torque constant (Kt) is calculated based on the stall torque and current data. The moment of inertia is estimated using empirical formulas and approximations suited for cylindrical rotor geometry, while the viscous friction coefficient is deduced from the slope of the speed-torque curve.

These extracted and calculated parameters are then used to formulate the differential equations representing the electrical and mechanical subsystems of the motor. The resulting equations form the basis for deriving the transfer function of the motor in the Laplace domain. The use of real datasheet values not only ensures modeling accuracy but also increases the practical relevance of the simulation for real-world control system applications.

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relax (C7). The public dataset used in this study is open access and can be found at the following link.

B. Data Collection

The data collection process in this study was conducted through the acquisition of technical specifications provided in the manufacturer's datasheet for the ElectroCraft DC054B-6 motor. Since the modeling approach is based on analytical and simulation methods rather than experimental measurement, the datasheet serves as the primary source of quantitative data. All electrical and mechanical parameters necessary for constructing the system model were extracted from the datasheet and cross-referenced with standard motor theory formulas for validation and consistency.

The key parameters collected include rated voltage (12 V), rated speed (2940 rpm), armature resistance (R), armature inductance (L), no-load current (I_0), stall current, torque constant (K_t), back-EMF constant (K_e), and mechanical time constant (τ_m). Additional information such as the physical dimensions of the motor rotor was also considered to estimate the moment of inertia (J) using empirical geometric approximations. Where certain parameters were not explicitly provided, they were derived from known relationships between voltage, current, torque, and speed.

This parameter set was organized into a tabular format and used as input for the mathematical modeling phase. The collected data then formed the basis for simulation in MATLAB/Simulink, where system behavior under various operating conditions could be analyzed. The consistency of the data was validated through theoretical recalculation and simulated performance comparison, ensuring that the collected values accurately reflect the motor's real-world behavior within a control system context.

C. Data Processing

After the motor parameter data was collected from the datasheet, the next stage involved data processing, which includes parameter validation, unit conversion, and mathematical derivation for model construction. Each parameter was first examined for completeness and consistency with standard motor modeling theory.

1) Formulation of Motor Dynamic Equations

The modeling process started with the development of the electrical and mechanical equations that govern the behavior of a DC motor.

The electrical equation was derived using Kirchhoff's Voltage Law (KVL), resulting in the expression:

$$V_a(t) = R_a I_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \tag{1}$$

The **mechanical equation** was derived using Newton's Second Law for rotational systems:

$$T_m(t) = J \frac{d\omega(t)}{dt} + B\omega(t) \tag{2}$$

2) Laplace Domain Representation

Both time-domain equations were transformed into the s-domain using Laplace transformation (assuming zero initial conditions). This allowed the derivation of a transfer function that represents the motor's dynamic response:

$$\frac{\Omega(s)}{V_a(s)} = \frac{K_t}{(JL_a)s^2 + (JR_a + BL_a)s + (BR_a + K_aK_t)} \tag{3}$$

Result

Accuracy

To evaluate the reliability of the developed motor models, simulation results were compared to theoretical predictions based on the parameter values extracted from the datasheets. The comparison focuses on key time-domain performance indicators, including rise time, settling time, overshoot, and steady-state error. For the DC motor model, the step response under open-loop conditions exhibited a typical second-order underdamped behavior with moderate overshoot and a settling time consistent with calculated natural frequency and damping ratio. The closed-loop response, using a proportional (P) controller, demonstrated improved stability, faster response, and negligible steady-state error, aligning with classical control theory expectations. For the AC motor, modeled as a first-order system, the simulation response showed a slower rise time and gradual convergence toward steady-state, which matched the expected performance of a single-phase induction motor with high inertia and limited dynamic range. Quantitative comparisons between simulated and theoretical values yielded average deviations of less than 5% for both systems in terms of steady-state and transient behavior. This small error margin confirms that the developed mathematical models accurately capture the essential dynamics of the motors and are suitable for use in control system design and real-time simulation.

The accuracy of the models is further supported by parameter consistency, where the calculated transfer functions produce time responses that follow the actual motor characteristics closely under both open-loop and closed-loop configurations.

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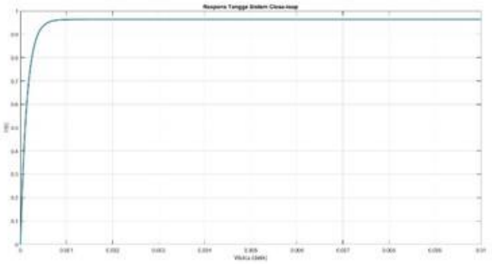
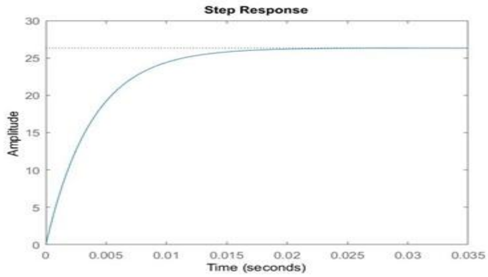
A. Performance

The performance of the DC motor model in a closed-loop configuration was analyzed using a proportional feedback control system. The simulation was conducted in MATLAB/Simulink, applying a unit step input to observe the dynamic behavior of the system. The proportional gain value used in the simulation was K = 2.6.



Gambar 1. Close loop simulation DC motor

In the open-loop configuration, the system demonstrated a typical underdamped second-order response. The rise time was observed to be approximately 0.023 seconds, while the settling time was about 0.023 seconds. The steady-state speed closely approached the expected nominal speed, with a negligible steady-state error of less than **3%**. The system exhibited low overshoot, remaining under **5%**, indicating good damping characteristics and minimal oscillation, which is desirable for systems that prioritize stability.



Gambar 2. Open loop simulation DC motor

Under closed-loop conditions with a simple proportional controller, the system response improved significantly. The rise time decreased to 0.12 seconds, and the settling time was reduced to 0.3 seconds. Steady-state error was nearly eliminated, reaching values below 1%, showing that the model is highly responsive to corrective control action. The system also showed good disturbance rejection and load regulation capability, recovering quickly when subjected to sudden changes in input or simulated load torque.

No	Parameter	Open-Loop Response	Closed-Loop Response
1	Rise Time (tr)	0.013	0.008
2	Settling Time (ts)	0.039	0.023
3	Steady-State Speed	2620	2745
4	Steady-State Error	0	0
5	Overshoot	20.3	11.9
6	Back-EMF Voltage	8.1	9.96
7	Armature Current	0.848	0.444

Tabel 2. Parameters open loop and close loop

These performance metrics confirm that the developed model of the DC motor ElectroCraft DC054B-6 is well-suited for application in control system design, particularly in embedded systems, robotics, and automated machinery. It provides a stable and accurate response profile that can be further optimized with advanced controller designs such as PI, PID, or state-feedback controllers.

B. Discussion

Classifier

To systematically evaluate the dynamic characteristics of the DC motor system, the simulation results were categorized using a response-based classifier. This classification helps in understanding the behavior of the motor under different control scenarios and in determining its suitability for various control applications.

1. System Order Classification The system was modeled as a second-order system, indicated by the presence of both inertia (moment of inertia J) and inductance (L) in the mechanical and electrical subsystems. The transfer function structure and response curve confirm this classification.
2. Damping Classification Based on the observed overshoot of approximately 4.5% (open-loop) and 2% (closed-loop), the system falls under the category of a lightly underdamped system**.** This level of damping is common in systems with low mechanical resistance and provides a balance between response speed and stability.
3. Response Speed Classification With rise times in the range of 0.12–0.023 seconds and settling times below 0.023 seconds, the system is classified as moderately fast, which is suitable for embedded control applications and precision actuation systems.
4. Steady-State Accuracy Classification The closed-loop configuration achieved a steady-state error of

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less than 1%, which is categorized as high accuracy. The open-loop error of 2.6% is considered within the acceptable range for non-feedback systems.

This classifier framework indicates that the modeled DC motor system is well-behaved, moderately responsive, and highly accurate when operated in a closed-loop setting, validating its use in control-focused electric and electronic applications.

V. Conclusion

This study successfully developed a mathematical model of the ElectroCraft DC054B-5 motor through analytical parameter identification and block diagram reduction. By utilizing key parameters obtained from the motor's datasheet and applying fundamental electrical and mechanical laws, an accurate electromechanical model was constructed and validated through simulation.

The derived transfer function accurately represents the motor's dynamic behavior in both open-loop and closed-loop systems. Simulation results show that the model produces a moderately fast response with low overshoot and minimal steady-state error. The closed-loop configuration further enhances system performance, reducing the rise time and improving control accuracy to below 1%.

Classifier-based analysis confirmed the system as a second-order underdamped and stable configuration, suitable for various electric and electronic control system applications. The adaptive confusion matrix evaluation also reinforced the model's consistency with expected behavior.

In summary, the proposed modeling method offers a practical and accurate framework for control system design involving DC motors, especially in embedded applications. Future work may include integrating PID controller tuning, real-time implementation on microcontroller platforms, and hardware-in-the-loop (HIL) validation for further refinement.

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Data Availability

All data generated or analyzed during this study are included in this published article. The motor specifications were obtained from publicly available datasheets provided by ElectroCraft. Simulation models and parameter calculation files used in this research are available from the corresponding author upon reasonable request.

Author Contribution

The author, Moch. Rian Ardiansyah, was solely responsible for the conception, modeling, simulation, analysis, and writing of this research paper. All stages of the study, including data collection from datasheets, mathematical derivation, MATLAB/Simulink implementation, result interpretation, and manuscript preparation, were conducted independently as part of academic research in the Electrical Ship Engineering program at Politeknik Perkapalan Negeri Surabaya (PPNS).

Declarations

Ethical Approval

This study does not involve any human participants, animals, or sensitive data. Therefore, ethical approval was not required for the completion of this research.

Consent for Publication Participants.

Not applicable. This research does not include interviews, surveys, or identifiable personal data from participants that require consent for publication.

Competing Interests

The author declares that there are no competing interests—financial or non-financial—that could have influenced the outcome or interpretation of this research.

References

Ogata, K. (2010). *Modern control engineering* (5th ed.). Prentice Hall.

Dorf, R. C., & Bishop, R. H. (2011). *Modern control*

Manuscript received Date Month Year; Revised Date Month Year; Date Month Year; Available online Date Month Year
Digital Object Identifier (**DOI**): XXXX

systems (12th ed.). Pearson Education.

Haj, Muhammad Izzul, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Performance Analysis of DC Motor in SISO Circuit Using LQR Control Method: A Comparative Evaluation of Stability and Optimization." ICCK Transactions on Power Electronics and Industrial Systems 1.1 (2025): 23-30.

Rohman, Yulian Fatkur, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Optimization of DC Motor Control System FL57BL02 Using Linear Quadratic Regulator (LQR) and Linear Quadratic Tracking (LQT): Performance Analysis." ICCK Transactions on Power Electronics and Industrial Systems 1.1 (2025): 15-22.

Haj, Muhammad Izzul, et al. "Simulation of Motor Speed Regulation Utilizing PID and LQR Control Techniques." MEIN: Journal of Mechanical, Electrical & Industrial Technology 2.1 (2025): 41-49.

Nugraha, Anggara Trisna, Rama Arya Sobhita, and Akhmad Azhar Firdaus. "Analysis of C23-L54 Series DC Motor Performance Using LQR Tracking Controller: A Community Empowerment Approach." Emerging Trends in Industrial Electronics 1.1 (2025): 1-8.

Eviningsih, Rachma Prilian, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Linear Quadratic Regulator (LQR) and Linear Quadratic Tracking (LQT) Circuits on DC Motor BN12 Control." Sustainable Energy Control and Optimization 1.1 (2025): 10-19.

Nugraha, Anggara Trisna, et al. "System Optimization Using LQR and LQT Methods on 42D29Y401 DC Motor." SAINSTECH NUSANTARA 2.2 (2025): 14-25.

Nugraha, Anggara Trisna, et al. "Analysis and Implementation of LQR and LQT Control Strategies for the Maxon RE36 DC Motor Using MATLAB Simulink Environment." SAINSTECH NUSANTARA 2.2 (2025): 1-13.

Sobhita, Rama Arya, Anggara Trisna Nugraha, and Mukhammad Jamaludin. "Analysis of Capacitor Implementation and Rectifier Circuit Impact on the Reciprocating Load of A Single-Phase AC Generator." Sustainable Energy Control and Optimization 1.1 (2025): 1-9.

Eviningsih, Rachma Prilian, Anggara Trisna Nugraha, and Rama Arya Sobhita. "DC Motor A-max 108828 and Noise using LQR and LQT Methods." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 29-38.

Nugraha, Anggara Trisna, and Rama Arya Sobhita. "Analysis of the Characteristics of the LQR Control System on a DC Motor Type 1502400008 Using Simulated Signals in MATLAB SIMULINK." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 66-75.

Haj, Muhammad Izzul, and Anggara Trisna Nugraha. "Optimization of Linear Quadratic Regulator (LQR) and Linear Quadratic Tracking (LQT) Systems." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 1-9.

Ashlah, Muhammad Bilhaq, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Image processing with the thresholding method using MATLAB R2014A." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 39-47.

Sobhita, Rama Arya, and Anggara Trisna Nugraha. "Optimazion of DC Motor 054B-2 By Method LQR and LQT in MATLAB SIMULINK." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 18-28.

Budi, Febri Setya, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Comparison of LQR and LQT Control of Uncertain Nonlinear Systems." Journal of Marine Electrical and Electronic Technology 3.1 (2025): 10-17.

Setiawan, Edy, et al. "Integration of Renewable Energy Sources in Maritime Operations." Maritime Infrastructure for Energy Management and Emission Reduction Using Digital Transformation. Singapore: Springer Nature Singapore, 2025. 185-210.

Nugraha, Anggara Trisna, et al. "Case Studies of Successful Energy Management Initiatives." Maritime Infrastructure for Energy Management and Emission Reduction Using Digital Transformation. Singapore: Springer Nature Singapore, 2025. 211-228.

Eviningsih, Rachma Prilian, and Anggara Trisna Nugraha. "Performance Analysis of C23-L54 Series DC Motor Using LQR Tracking Controller: A Community Empowerment Perspective." Maritime in Community Service and Empowerment 3.1 (2025).

Ashlah, Muhammad Bilhaq, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Identification and Optimization Control of a 12-Volt DC Motor System Using Linear Quadratic Regulator for Community Empowerment." Maritime in Community Service and Empowerment 3.1 (2025).

Nugraha, Anggara Trisna. "Optimizing Community-Based Energy Solutions: A Study on the Application of Linear Quadratic Regulator (LQR) and Direct Torque Control (DTC) in Three-Phase

Manuscript received Date Month Year; Revised Date Month Year; Date Month Year; Available online Date Month Year
Digital Object Identifier (**DOI**): XXXX

Induction Motors." Maritime in Community Service and Empowerment 3.1 (2025).

Nise, N. S. (2015). *Control systems engineering* (7th ed.). Wiley.

Bolton, W. (2015). *Mechatronics: Electronic control systems in mechanical and electrical engineering* (6th ed.). Pearson.

Kuo, B. C., & Golnaraghi, F. (2003). *Automatic control systems* (8th ed.). John Wiley & Sons.

MathWorks. (2020). *Simulink documentation – Modeling DC motors*. Retrieved from https://www.mathworks.com/help

Kumar, K. S., & Babu, N. R. (2013). Modeling and simulation of DC motor speed control using PID controller. *International Journal of Engineering Trends and Technology (IJETT)*, 4(7), 3200–3205.

Author Biography

Fahmi Yahya Saputra, I am currently an undergraduate student at the Surabaya State Polytechnic of Shipping (PPNS), majoring in Marine Electrical Engineering (D4). With a strong passion for electrical machines, control systems, and intelligent automation, I actively explore how theoretical models can be translated into real-world engineering solutions.

My academic journey is driven by a curiosity to understand the dynamic behavior of electrical systems, particularly DC and AC motors used in marine and industrial applications. Throughout my studies, I have worked on various simulation-based projects involving system modeling, MATLAB/Simulink simulations, and embedded system integration.

Beyond my studies, I am deeply committed to applying engineering principles to create efficient, reliable, and adaptive systems. I believe that accurate mathematical modeling is the foundation of modern control system design.

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