LED BRIGHTNESS CONTROL USING PID CONTROLLER

Report

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EE326 - Linear Control Theory

by

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ABSTRACT

The aim of this report is to show the application of a Proportional-Integral-Derivative (PID) controller in regulating LED brightness, which uses control system analysis tools and plots such as: Bode, Nyquist, and Root Locus plots. The study aims to design an efficient control system that ensures rapid response, minimal overshoot, and steady-state accuracy in maintaining desired LED luminance levels.

The methodology involves constructing Bode plots to assess the system's frequency response, Nyquist plots to evaluate stability and robustness, and Root Locus plots to visualize the closed-loop poles' movement with varying controller parameters. These graphical tools contribute to a comprehensive understanding of the system dynamics and guide PID controller tuning.

Also, the report shows a simulation model with a detailed block diagram, offering insights into the practical implementation of the PID controller. The simulation explores the controller's performance under varying coefficients of the pid controller, providing a quantitative analysis of key parameters such as rise time, settling time, and overshoot.

This study aims to demonstrate the applications of PID controllers in led brightness control systems. The software tools used for demonstration and obtaining the results include: MATLAB, Simulink.

Keywords: MATLAB, Simulink, PID, led, Nyquist, Bode, root locus.

INTRODUCTION

Light Emitting Diodes (LEDs) have become ubiquitous in various applications, from everyday lighting to sophisticated display systems. Efficient control of LED brightness is pivotal for optimizing energy consumption, ensuring visual comfort, and extending the lifespan of LED devices. This project delves into the development and optimization of a Proportional-Integral-Derivative (PID) controller for precise and dynamic LED brightness regulation.

The objective is to design a PID control system that not only achieves accurate and rapid response to brightness adjustments but also minimizes overshoot and settles quickly to the desired luminance levels. To achieve this, the project employs analysis tools such as Bode, Nyquist, and Root Locus plots to comprehensively understand the dynamic behavior of the LED brightness control system.

The Bode plots provide insights into the frequency response of the system, allowing for the identification of optimal control parameters (kp, kd, ki). The Nyquist plots are utilized to assess the system's stability and robustness, ensuring the PID controller performs reliably under various conditions. Finally, the Root Locus plots offer a graphical representation of how the system's poles move as the PID controller parameters vary, guiding the tuning process for enhanced performance.

In addition to the theoretical analysis, the project includes simulation of the LED brightness control system. A detailed block diagram illustrates the implementation of the PID controller in a simulated environment, allowing for a quantitative evaluation of key performance metrics, such as rise time, settling time, and overshoot.

By the project's conclusion, it is anticipated that the findings will not only contribute to the theoretical understanding of PID-controlled LED brightness systems but also provide practical insights for the design and implementation of efficient and reliable LED lighting control in real-world applications. This research aligns with the broader goal of advancing energy-efficient and visually optimized LED technologies for diverse domains.

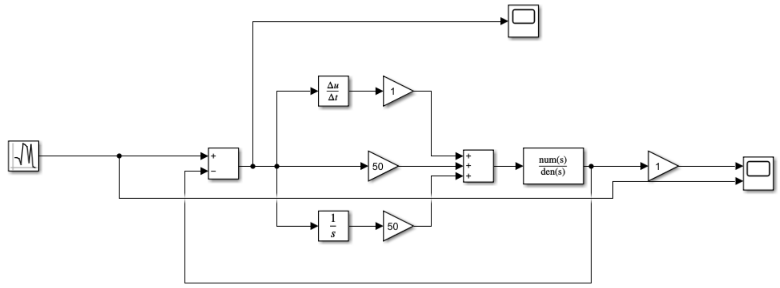
METHODOLOGY

We initially identify and determine the parameters for the LED brightness control system. This involves understanding the characteristics of the LED, determining the input and output response desired. We then collect relevant specifications and data, such as the LED's response time and dynamic behavior.

Then we can design the Proportional-Integral-Derivative (PID) controller based on the system parameters. Consider the desired performance criteria, such as settling time, overshoot, and steady-state error. And also to use the control systems tools/plots for determining the transfer function and the PID parameters.

We employ Bode, Nyquist and root-locus plots and check the system behaviour for varying parameters of the PID controller.Employ MATLAB or a similar tool to generate Bode plots of the open-loop and closed-loop systems. Analyze the frequency response to ensure stability and determine the parameters such as: phase and gain margin. Adjust PID parameters as needed to optimize the system's performance. Generate Nyquist plots to assess the system's stability and robustness. Examine the plot for encirclements of the critical point (-1, j0) to evaluate stability margins. Adjust PID parameters based on the Nyquist analysis to enhance stability. Utilize Root Locus plots to visualize the movement of the system's poles as PID parameters vary. Analyze the plot to understand the impact of parameter changes on closed-loop stability and transient response. Fine-tune PID parameters to achieve desired pole locations.

Next we analyse the output behaviour and observe the simulation waveform for a step input. We can also obtain the step input parameters such as settling time, peak time and rise time.

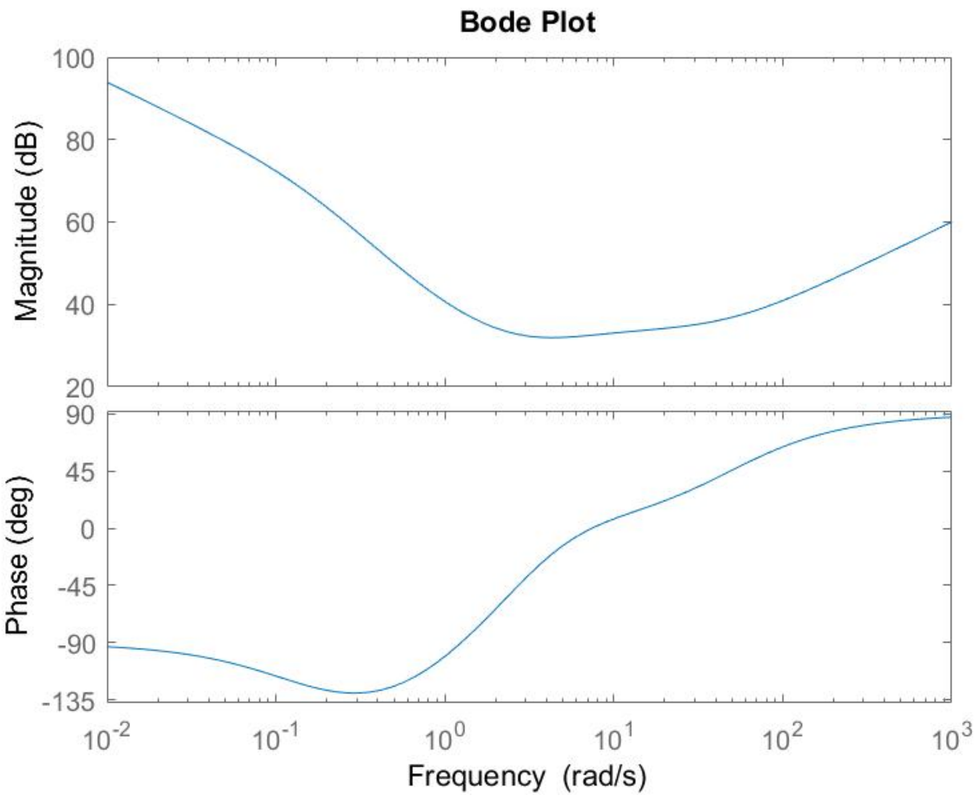


RESULTS

For the simulation the results were obtained from Simulink and the parameters for the PID controller and transfer function were determined based on the practical requirements of an LED brightness controller and the bode, nyquist and root locus plots.

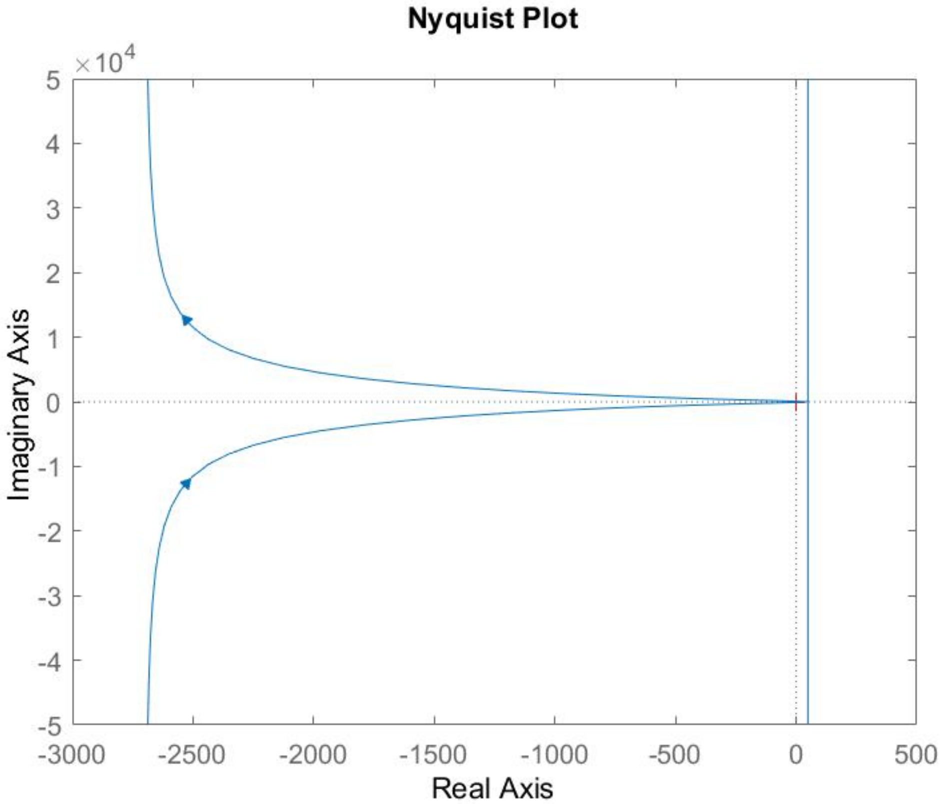
Bode Plot

The Bode plot illustrated the frequency response of the open-loop system, providing insights into system bandwidth, phase margin, and gain margin. This analysis guided the PID controller design for stability and performance.



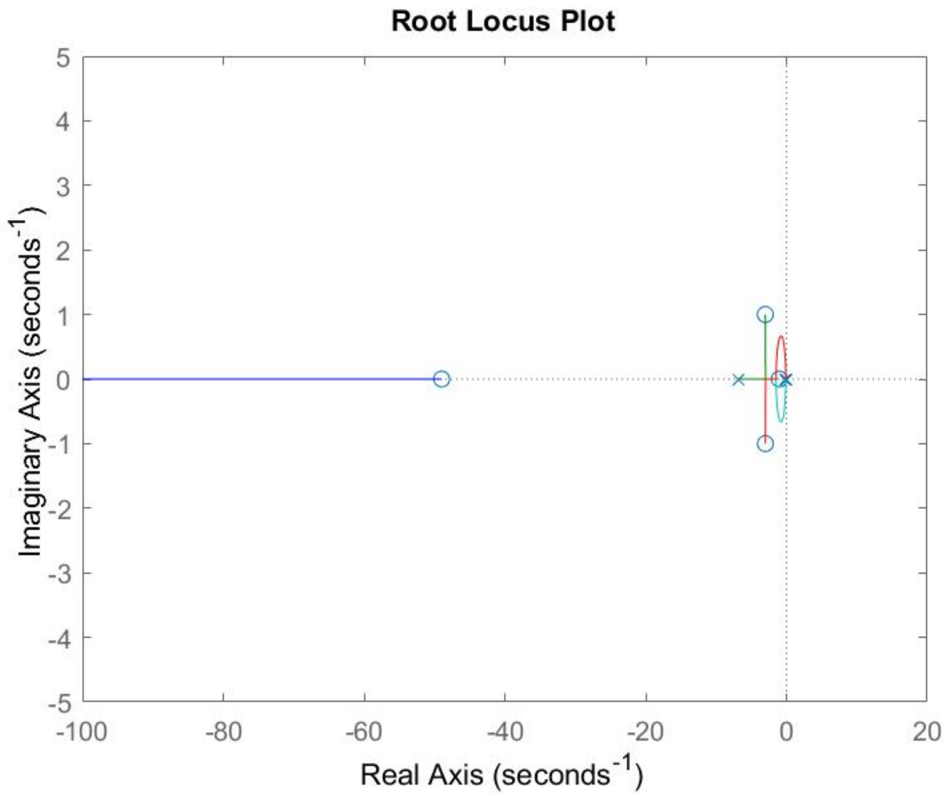
Nyquist Plot

The Nyquist plot assessed system stability and robustness. Analysis of encirclements and phase margins ensured a stable and well-performing LED brightness control system.



Root Locus

The Root Locus plot visualized the movement of system poles, aiding in PID parameter tuning for stability and transient response. The plot provided valuable insights into the impact of parameter changes on system behavior.


Root Locus Plot
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Real Axis (seconds^-1)
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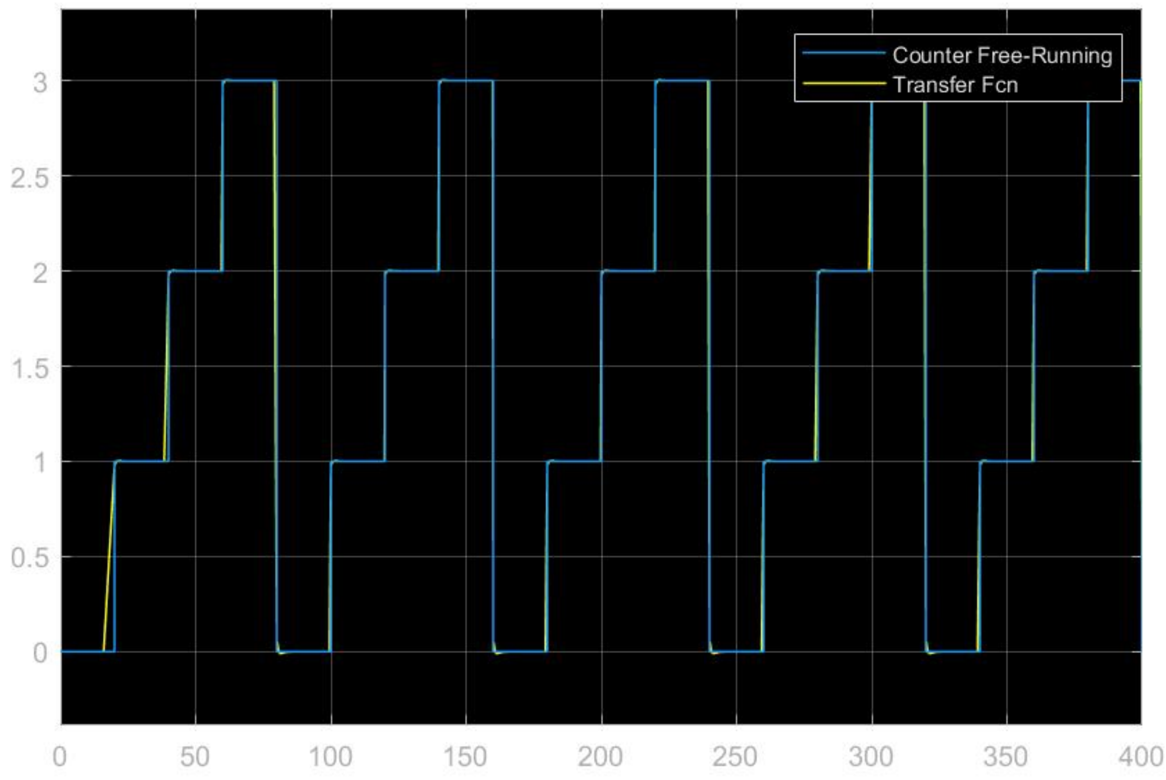
-80
-60
-40
-20
0
20


Counter Free-Running
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3
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