

Control Systems Assignment - Owen miller

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Design and Validation of a Closed-Loop Control System for a CIWS Turret

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I. Abstract

This report details the design, simulation, and analysis of a closed-loop control system for the angular positioning of a Close-In Weapon System (CIWS) turret.

Using a Proportional-Integral-Derivative (PID) controller implemented in MATLAB/Simulink, the system was tuned to meet the specific performance criteria of stability, a settling time of less than 2 seconds, and an overshoot of less than 5%. The results demonstrated that manual tuning achieved significant performance improvements over automatic tuning, delivering a rise time of 0.0675 seconds, a settling time of 0.247 seconds, and an overshoot of 2.16%, with all poles located in the left-half plane to confirm system stability.

While the designed control system is effective for static target engagement, it is not suitable as a standalone solution for gun-based CIWS like the Phalanx, which operate in dynamic environments with fast-moving targets. The system's limitations include an inability to predict and lead targets, handle hardware constraints during rapid turret movement, and account for complex disturbances such as recoil forces and environmental conditions.

The report concludes that although the presented system meets the criteria for a simplified CIWS application, significant enhancements are required for real-world implementation. Recommendations include the integration of feedforward control and state observers (e.g. Kalman filters). These improvements would enable the system to

track dynamic targets, manage disturbances, and operate within real-world mechanical and temporal constraints.

This study highlights the importance of advanced control strategies in defence systems, demonstrating how foundational designs can evolve into robust solutions capable of addressing the rigorous demands of modern CIWS applications.

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1. Introduction

1.1. Control systems are essential for managing the behaviour of dynamic systems, particularly in applications requiring precision and reliability. Close-In Weapon Systems (CIWS) rely on control systems to track and neutralise short-range threats, such as incoming missiles or aircraft. These systems are commonly deployed on naval platforms and must operate under strict performance requirements, including stability, minimal settling time, and accurate target tracking.

1.2. Closed-loop control systems, which use feedback to continuously adjust output, are used in CIWS applications. Proportional-Integral-Derivative (PID) controllers are a common choice for their simplicity and effectiveness in maintaining stability and minimising steady-state errors. However, achieving optimal performance requires careful tuning to meet specific requirements such as rise time, overshoot, and steady-state accuracy.

1.3. This report focuses on the design and validation of a closed-loop control system for a CIWS turret's angular positioning. Using MATLAB/Simulink, a PID controller was implemented and tuned to meet defined performance criteria. The results are analysed, including comparisons of automatic and manual tuning, and the system's limitations in handling real-world dynamic scenarios are discussed. Recommendations are provided to enhance the control system for practical applications, aligning it with the requirements of operational systems like the Phalanx CIWS.

2. Literature review

2.1. Control systems overview

Control systems manage the behaviour of dynamic systems to achieve a specific desired output by automatically adjusting input signals. They are broadly divided into open-loop and closed-loop systems. Open-loop systems execute commands without using feedback, which limits accuracy in variable environments. In contrast, closed-loop, or feedback, systems continuously monitor output, comparing it to a reference value and making adjustments as needed to reduce any deviation from the target [1].

2.1.1. Applications of control systems include:

- Manufacturing: Automated regulation of temperature, pressure, and machine speed.
- Automotive: Engine control, vehicle stability, and driver assistance functions.
- Aerospace and Defence: Stabilisation in aircraft, guided missile tracking, and precise turret positioning.
- Robotics: Control of movement, grip, and object manipulation.

Control systems are typically modelled by transfer functions, which mathematically express the relationship between input and output signals in the system. These transfer functions capture the system's dynamics, providing a basis for designing controllers that meet specific performance criteria such as stability, settling time, and overshoot limits. Through feedback and transfer

function analysis, control systems can achieve precise, adaptive control key for defence applications [2].

2.2. Close In Weapon Systems (CIWS)

2.2.1. CIWS are point-defence weapon systems designed to detect and destroy short-range threats, including incoming missiles and aircraft, that have bypassed a platform's outer defences. These systems, commonly deployed on naval vessels, are categorised into gun-based and missile-based types [3].

2.2.2. Gun-based CIWS, such as the Phalanx CIWS, rely on integrated radar tracking, automated aiming, and feedback control to engage high-speed threats. The control system features modules for tracking and targeting, proportional-integral control to minimise aiming errors, and noise filtering to maintain accuracy. Feedback mechanisms correct aim bias from environmental and mechanical factors, while time-delay compensation ensures stability during rapid engagements [4].

2.3. Transfer Functions and their role in Control System Dynamics

2.3.1. Transfer functions are key mathematical tools used to represent linear time-invariant systems, they describe the relationship between input $X(s)$ and output $Y(s)$ [5].

A general transfer function $G(s)$ is given by:

$$G(s) = Y(s)/X(s)$$

2.3.2. For a CIWS angular positioning system, the second-order transfer function is expressed as:

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$$G(s) = 1/(as^2 + bs + c)$$

where a, b, and c are system parameters determined from the physical setup.

This transfer function allows analysis of stability and performance metrics such as damping ratio (ζ), natural frequency (ω), and transient response.

Transfer functions help predict system behaviour and design control loops to ensure effective operation under dynamic conditions [5].

2.4. PI Controllers and Alternative Control Methods

2.4.1. Proportional-Integral (PI) controllers stabilise systems and minimise steady-state errors [6]. The control law for a PI controller is:

$$u(t) = K_p e(t) + K_i \int e(t) dt$$

where:

- $u(t)$: control output
- $e(t)$: error signal
- K_p : proportional gain
- K_i : integral gain

The PI controller's transfer function is:

$$K_p + K_i \frac{1}{s} + K_d \frac{s}{\frac{1}{N}s + 1}$$

Where:

Kd: derivative gain

N: a constant used to filter the derivative term and prevent excessive noise amplification

This formula accounts for proportional, integral, and filtered derivative terms, making it flexible for various system requirements. While PI controllers are widely used, the inclusion of derivative terms (PID controllers) improves transient response and system stability by anticipating changes. The choice of controller depends on specific system requirements such as precision, computational complexity, and noise sensitivity [7].

3. Simulation Setup

The simulation focuses on designing and validating a closed-loop control system for a CIWS turret's angular positioning system. MATLAB/Simulink was used to model the system and verify its performance. Two models were developed: one for the complete control system and another for the simplified closed-loop transfer function. These models enable comparison of the system's response and ensure that the design meets performance criteria such as stability, settling time, and overshoot.

3.1. Simulink Models

3.1.1. Model with just process input: a model using only the plant transfer function

$$G(s) = \frac{1}{as^2 + bs + c}$$

was simulated to analyse the system's natural behaviour without a controller shown in figure 1.

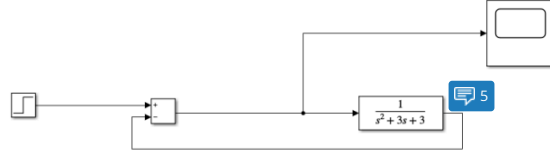


Figure 1 - process input block diagram

3.1.2. Control System Model: This model represents the full closed-loop system (figure 2), incorporating:

3.1.2.1. The plant transfer function:

$$G(s) = \frac{1}{as^2 + bs + c}$$

3.1.2.2. The PI controller transfer function:

$$K_p + K_i \frac{1}{s} + K_d \frac{s}{\frac{1}{N}s + 1}$$

3.1.2.3. A feedback loop that adjusts the system based on the error signal between the desired angular position and the actual output.

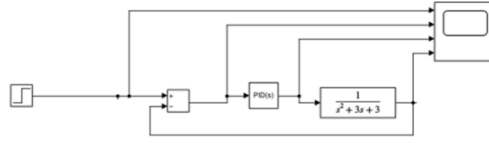


Figure 2 – Control system model configuration

3.1.3. Control system calculated model:

This model simulates the closed-loop system as a single transfer function using a block diagram as shown in figure 3.

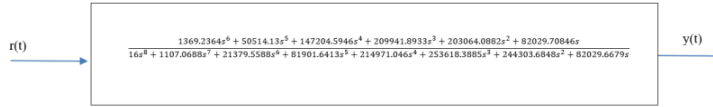


Figure 3 - Mathematically calculated block diagram

The model in figure 3 is used to validate the tuned response within the PID controller using mathematical calculation.

3.2. Simulation parameters

3.2.1. Plant Transfer Function Parameters:

$$G(s) = \frac{1}{1s^2 + 3s + 3}$$

3.2.2. PI Controller Gains:

Kp, Ki, and Kd are tuned during the simulation to achieve the desired performance.

Simulation Time: The system response is simulated over 5 seconds to evaluate stability and transient performance.

Sampling Time (block output intervals): 0.01 seconds

3.3.Simulink setup

3.3.1. The simulation environment was configured as follows:

Blocks Used:

- Transfer Function Block: Represents $G(s)$ and $T(s)$.
- PI Controller Block: Implements the $H(s)$ controller.
- Sum Block: Calculates the error between the desired and actual outputs.
- Scope: Visualises system responses, including settling time and overshoot.

Solver Settings:

- A fixed-step solver with a step size of 1 second was used

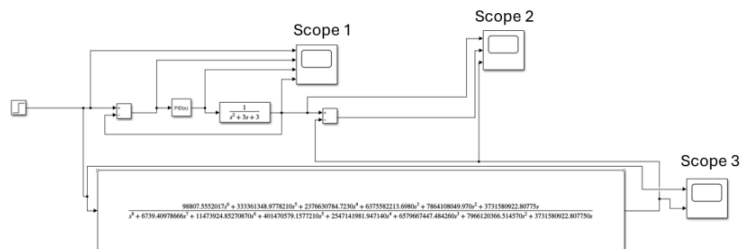


Figure 4 – Control system Model configuration including Single Block validation

- 3.3.2. Figure 4 shows the initial closed loop system with the addition of a second closed loop, replicating the PID controller and processor within a singular block with a calculated value to validate the results from the initial closed loop system. A full breakdown of the mathematical calculation is detailed in **Annex 1**.
- 3.3.3. Scopes are laid out interfacing separately with the PID system (Scope 1), the single block system (Scope 3) and the differentials between the two (Scope 2).
- 3.3.4. To achieve the specific requirements for the CIWS control system the following parameters needed to be met – general stability, a settling time of less than 2 seconds and an overshoot of less than 5% - the tuning tool within the PID controller was used to achieve these thresholds. This tool enabled the visualisation of these parameters on a graph and allowed for precise adjustments of the proportional, integral, derivative, and filter coefficients to meet the performance criteria effectively. The PID interface and tuning tool is shown in figures 5 & 6.

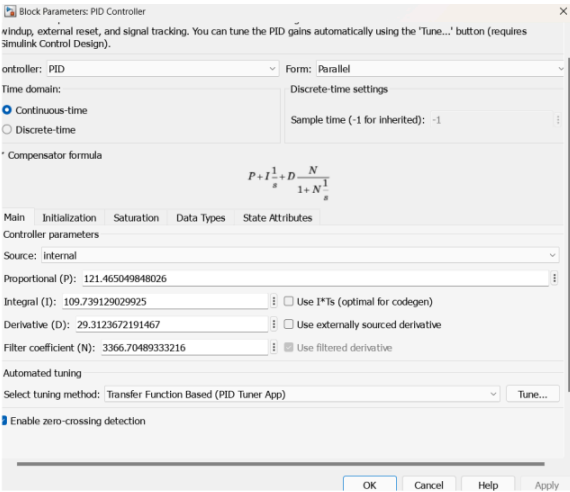


Figure 5 – PID Controller Interface

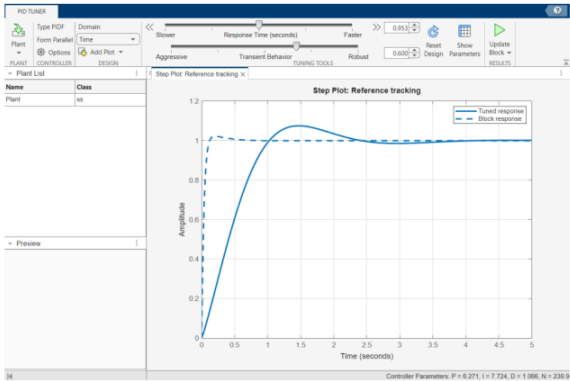


Figure 6 – PID Controller Parameter Tuning Tool

4. Results

This section presents the simulation results for the CIWS control system, beginning with the natural response of the system without a controller. The responses from the initially tuned (automatic) and manually tuned PID controller parameters are then detailed. Finally, a comparison of the full PID controller loop with the single calculated block loop is provided, alongside a pole-zero map to validate system stability.

4.1. Open-Loop Response (Natural System Behaviour)

4.1.1. The open-loop response of the plant transfer function was simulated to analyse the system's natural behaviour without a controller. The performance was as follows:

- Rise Time: 0.08 seconds
- Settling Time: 3.96 seconds (not accurate as the system settles at approximately 0.78, below the target value of 1)
- Overshoot: No overshoot as the system does not reach a value of 1
- Closed-Loop Stability: Marginally stable but does not meet performance criteria

The response plot (figure 7) shows the system's inability to stabilise at the desired value of 1, presenting the need for a feedback control system to regulate the system effectively.

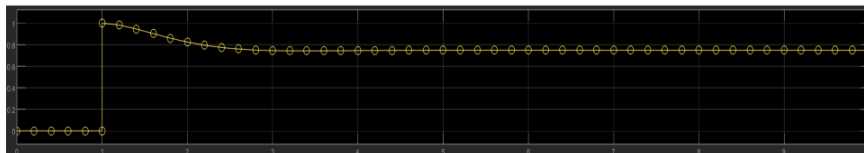


Figure 7 – Open-Loop Response plot

4.2. Initially Tuned Block Response (Automatic Tuning)

4.2.1. The PID controller's automatic tuning function was used to generate an initial response for the closed-loop system. The performance metrics were as follows:

- Rise Time: 0.74 seconds
- Settling Time: 2.15 seconds
- Overshoot: 7.44%
- Peak Value: 1.07
- Closed-Loop Stability: Stable

While the system was stable, the settling time exceeded the requirement of 2 seconds, and the overshoot was above the target of 5%.

4.3. Manually Tuned Block Response

4.3.1. Manual adjustments to the PID controller parameters (K_p , K_i , K_d and N) were performed to meet the system requirements. The manually tuned response achieved significant performance improvements:

- Rise Time: 0.0675 seconds
- Settling Time: 0.247 seconds
- Overshoot: 2.16%
- Peak Value: 1.02
- Closed-Loop Stability: Stable

The manually tuned response met all the specified criteria, with minimal overshoot and a significantly reduced settling time compared to the initial automatic tuning. The response plot is shown in figure 7.

4.3.2. The exact K_p , K_i , K_d and N are as follows:

K_p : 121.465049848026

K_i : 109.739129029925

K_d : 29.3123672191467

N : 3366.70489333216

4.4. Response analysis

4.4.1. In regard to Scope 1 shown in figure 7 each port shows:

- Port 1 - This port carries the reference signal. In this case, it is the step input which represents the desired angular position for the system. As the step input has an amplitude of 1, this is fed into the subtract block as the target value [8].
- Port 2 - This port carries the error signal, which is the difference between the reference signal (step input) and the actual output (feedback from the process) [9].
- Port 3 - This port carries the control signal generated by the PID controller. The control signal adjusts the process to reduce the error and bring the system output closer to the reference signal [10].

- This port carries the feedback signal. It represents the actual output of the system after passing through the system. This signal is fed back into the subtract block to compute the error, forming the closed-loop feedback system [11].

4.4.2. Scope 1: PID Controller Loop Response

4.4.2.1. The step response of the complete PID controller loop with the manually tuned parameters demonstrates stability, a fast rise time, and minimal overshoot. The response plot shown in figure 7. Numerical results are outlined in 4.3.

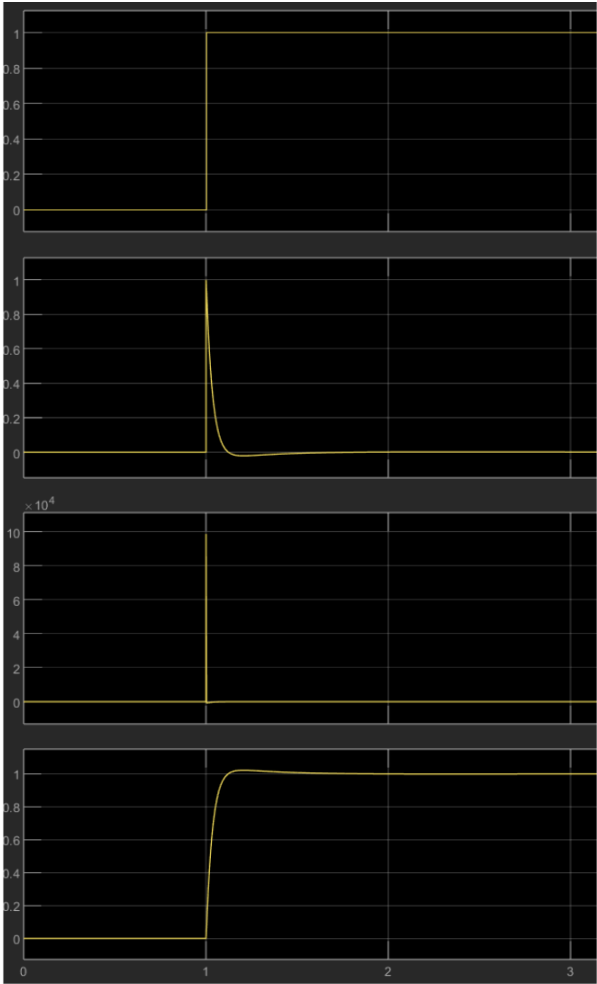


Figure 7 – Initially Tuned Block Response plot

4.4.3. Scope 3: Single Calculated Block Loop Response

The response for the single block representing the closed-loop transfer function was simulated to validate its equivalence with the detailed PID controller loop. The performance closely matched that of the complete system (figure 8).

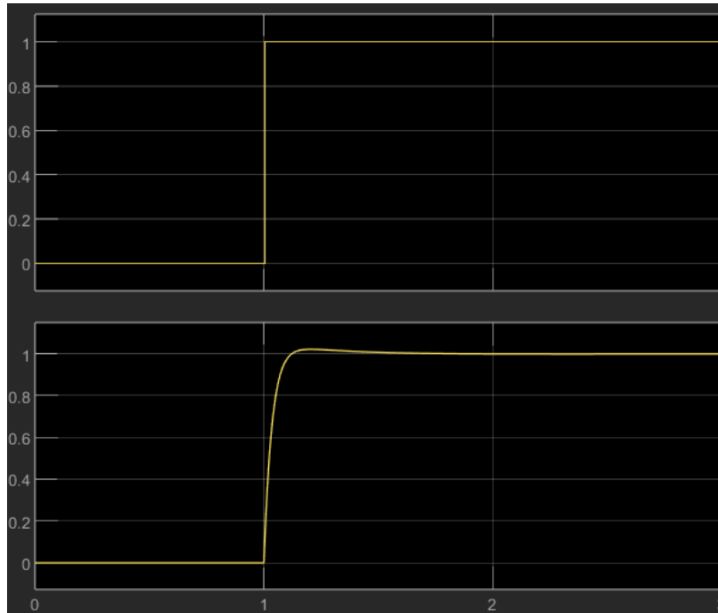


Figure 8 – Single Calculated Block Loop Response plot (scope 3)

4.4.4. Scope 2: Comparison of both responses

A direct comparison of the PID controller loop response and the single calculated block loop response is provided in Scope 2. Figure 9 confirms the

equivalence of the two responses as port 2s maximum variance is 10×10^{-5} , a negligible amount and is most likely due to rounding completed in calculation.

This validates the accuracy of both models.

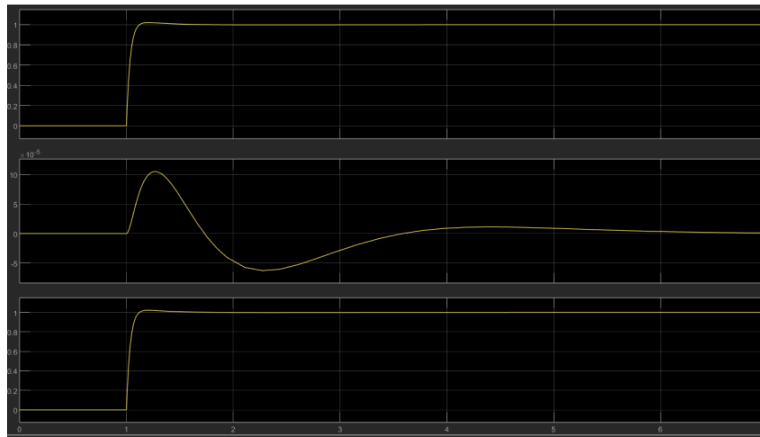


Figure 9 – Comparison of Both Responses Block Loop plot (scope 2)

4.5. Pole-Zero Plot

A pole-zero plot is a graphical representation of the poles and zeros of a system's transfer function in the complex plane. It provides a view of system stability [12].

4.5.1. Poles: The values of s that cause the denominator of the transfer function $G(s)$ to become zero. Poles determine the system's stability and transient response.

4.5.2. Zeros: The values of s that cause the numerator of the transfer function $G(s)$ to become zero. Zeros affect the shape of the system's response but do not directly determine stability [12].

4.5.3. A pole zero plot can be used to loosely measure stability by [13]:

- Stable System: All poles lie in the Left-hand (negative) plane.
- Unstable System: At least one pole lies in the right-half (positive) plane.
- Marginally Stable System: Poles are on the imaginary axis (and no poles are in the right-hand Plane).

4.5.4. The pole-zero map of the system is shown in figure 10, this contains the following components:

- Top Left: The poles and zeros of the process alone.
- Top Right: The poles and zeros of the controller alone.
- Bottom Left: The combination of the process and controller.
- Bottom Right: The complete system, including the feedback loop.

All poles and zeros in the plot are negatively valued, indicating that the system is stable.

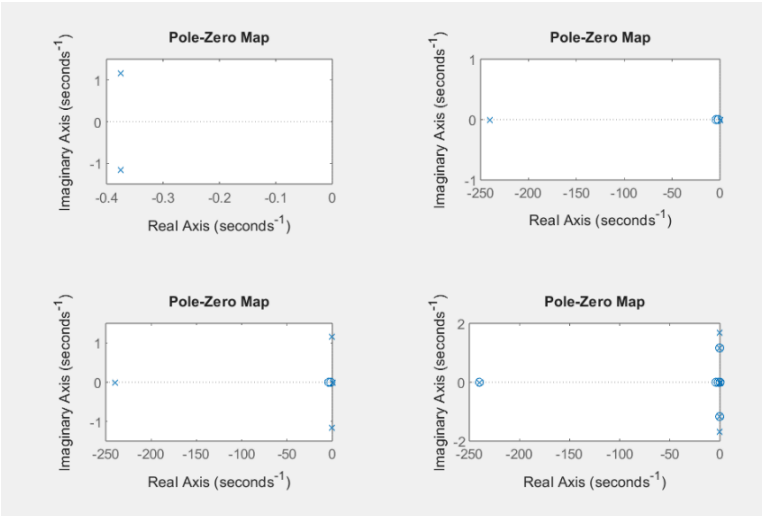


Figure 10 – pole zero plot

5. Discussion

5.1.Result efficiency within a CWIS system

5.1.1. The simulation results confirm that the designed control system successfully meets the performance criteria outlined for the CIWS. The manually tuned PID controller achieved the metrics outlined in 4.3.1.

5.1.2. The results demonstrate that the manual tuning of the PID controller provided significant improvements over the automatic tuning, especially in terms of rise time and overshoot. While the initial tuning offered a stable system, the overshoot of 7.44% and settling time of 2.15 seconds were outside the specified limits, highlighting the importance of manual adjustments for optimising performance.

5.1.3. The designed control system demonstrates several key characteristics that align with the requirements for a CIWS angular positioning system:

5.1.3.1.Rapid Response:

With a rise time of 0.0675 seconds and a settling time of 0.247 seconds (post-tuning), the system exhibits a fast transient response, which is critical in CIWS applications where threats must be detected and engaged in minimal time. The quick stabilisation of the turret ensures accurate targeting without delay.

5.1.3.2.High Stability:

The pole-zero plot confirms that the system is stable under the tuned parameters, with all poles in the left-half plane. However, this only shows the system targeting a stable target, not taking the wider system e.g. firing system or gyroscopic into account.

5.1.3.3.Minimal Overshoot:

An overshoot of 2.16% minimises unnecessary oscillations around the target position, which is vital for maintaining accuracy and preventing turret movement from exceeding its intended path. This characteristic is particularly useful in high-precision engagements where even slight deviations can compromise performance.

5.1.3.4.Accurate Target Tracking:

The system achieves a peak value of 1.02 with minimal steady-state error, ensuring the turret aligns closely with the intended target. This accuracy is essential for CIWS, as it directly impacts the ability to neutralise incoming threats effectively.

5.2. Comparison to operational Phalanx CIWS^{Sp.}

While the designed control system effectively meets the specifications for targeting a static object, it would not be suitable as a standalone system for a gun-based CIWS like the Phalanx [14].

5.2.1. Targeting Dynamics

This control system assumes a static target, while gun-based CIWS like the Phalanx are primarily designed to engage fast-moving objects, such as missiles or aircraft, traveling at high speeds. Tracking dynamic targets requires predictive algorithms to account for the target's velocity, acceleration, and trajectory, which this system does not address. A CIWS must lead the target or, in cases where the object is incoming, adjust to fire in patterns such as a spiral to maximise interception chances. The presented system lacks the predictive control mechanisms required for these scenarios.

5.2.2. Hardware Constraints

Presented control system directly tracks the target position without consideration for hardware limitations. In a real-world application, attempting to move the turret at the speeds dictated by this system could exceed the mechanical capabilities of the turret actuators and structure. The rapid accelerations and decelerations would generate excessive momentum,

potentially leading to hardware damage, such as motor overheating or structural fatigue [14].

5.2.3. Need for Multiple Control Systems

The Phalanx CIWS integrates multiple specialised control systems to manage real-world target engagement, including:

5.2.3.1.Inner and Outer Feedback Loops:

The inner loop manages real-time tracking of targets, ensuring the turret aligns accurately with the predicted trajectory.

The outer loop compensates for aim bias caused by factors such as barrel heating, environmental conditions, or mechanical misalignments, maintaining accuracy under varying conditions [14].

5.2.3.2.Disturbance Rejection:

Vibrations, recoil forces, and other disturbances are rejected using layered feedback mechanisms. This ensures stable and precise turret movement, even during continuous firing.

5.2.3.3.Noise Filtering:

Targeting measurements, often affected by sensor noise, require advanced noise-filtering techniques to ensure reliability. The Phalanx

employs filters within its control loops to mitigate the impact of noise on targeting accuracy.



5.2.3.4. Dynamic Control Strategies:

The Phalanx employs adaptive control strategies that adjust between tracking, aiming, and firing modes based on the engagement phase. A singular PID-based control system, such as the one presented, cannot provide the flexibility required to handle these transitions effectively [14].

5.2.4. Time Delay Management

In a real-world gun-based CIWS, factors such as bullet flight time, actuator delays, and feedback processing must be accounted for. The Phalanx system incorporates control systems specifically designed to manage these delays, ensuring adjustments to the turret's position without overshoot or instability. The presented system does not address such time delays, further limiting its practical application.

5.2.5. Overall, when compared to the Phalanx CIWS this control system provides a simplified approach to angular positioning but fails to meet the demands of real-world dynamic engagement scenarios.

5.3. How could the system be improved

To effectively function as a gun-based-CWIZ the system needs a more layered control system to account for multiple variables.

5.3.1. Observer-Based Control (State Estimation)

Introducing a state observer, such as a Kalman filter, could improve the system's ability to track high-speed targets accurately by estimating unmeasured states or reducing the effects of noise [15].

This would be particularly effective in environments with sensor inaccuracies or limited target resolution.

5.3.2. Integration of Multiple Control Layers

Learning from the Phalanx system [14], integrating multiple control layers would improve the overall system performance:

- Inner Loop: High-speed tracking of targets with minimal delay.
- Outer Loop: Compensation for aim bias and external disturbances, such as wind or barrel heating.
- Disturbance Rejection: Dedicated feedback systems to handle vibrations and recoil forces.

This hierarchy of control approach ensures stability and precision at multiple operation levels.

6. Conclusion

6.1. Overall, the system utilised a PID controller to meet specific performance requirements, including stability, a settling time of less than 2 seconds, and an overshoot of less than 5%. The results demonstrated that the manually tuned PID controller significantly improved system performance, achieving a rise time of 0.0675 seconds, a settling time of 0.247 seconds, and an overshoot of 2.16%. The stability of the system was validated through time-domain simulations and pole-zero analysis, confirming its ability to reliably track static targets.

6.2. While the designed system is effective for a simplified CIWS application, it lacks the complexity and adaptability required for real-world gun-based systems like the Phalanx CIWS. This limitation arises from the system's assumption of static target engagement and its inability to handle the dynamic tracking, predictive targeting, and mechanical constraints inherent in high-speed engagements. The Phalanx CIWS exemplifies the necessity of integrating multiple control systems, including inner and outer loops, disturbance rejection mechanisms, and noise filtering, to manage these challenges.

6.3. To bridge the gap between the presented design and a fully functional gun-based CIWS, two enhancements are recommended. These include incorporating

feedforward control, observer-based estimation (e.g. Kalman filters), multiple control layers. Such improvements would enable the system to handle dynamic target scenarios, reduce the impact of disturbances, and account for real-world constraints like time delays and mechanical limitations.

6.4. In conclusion, the presented control system successfully meets the defined performance criteria for a simplified CIWS angular positioning task. However, to function effectively in real-world applications, particularly as a gun-based system, it requires significant enhancements. By integrating advanced control strategies and layered systems, the design could evolve into a robust solution capable of meeting the rigorous demands of dynamic engagement environments like those encountered by the Phalanx CIWS. This progression would ensure precise, stable, and reliable performance, aligning with the operational requirements of modern defence systems.

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8. Appendix 1

$$G(s) = \frac{1}{as^2 + bs + c}$$

Taking $a = 1$, $b = 3$, $c = 3$ transfer function now becomes:

$$G(s) = \frac{1}{1s^2 + 3s + 3}$$

Using the PID tuner in MATLAB, the following values were obtained:

Kp: 121.465049848026

Ki: 109.739129029925

Kd: 29.3123672191467

N: 3366.70489333216

So the transfer function of the PID controller will be:

$$K_p + K_i \frac{1}{s} + K_d \frac{s}{N s + 1}$$

$$121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \frac{s}{3366.70489333216 s + 1}$$

To calculate the forward path transfer function of the system, the controller's transfer function must be multiplied by the transfer function of the process.

$$\left(121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \frac{s}{3366.70489333216 s + 1} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right)$$

$$\left(121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \frac{s}{3366.70489333216 s + 1} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right)$$

$$\left(121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \left(s \div \frac{s + 3366.70489333216}{3366.70489333216} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right) \right)$$

$$\left(121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \left(s \left(\frac{3366.70489333216}{s + 3366.70489333216} \right) \right) \times \left(\frac{1}{s^2 + 3s + 3} \right) \right)$$

$$\left(121.465049848026 + \frac{109.739129029925}{s} + 29.3123672191467 \left(\left(\frac{3366.70489333216s}{s + 3366.70489333216} \right) \right) \times \left(\frac{1}{s^2 + 3s + 3} \right) \right)$$

$$\left(121.465049848026 + \frac{109.739129029925}{s} + \left(\frac{98686.0901519s}{s + 3366.70489333216} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right) \right)$$

$$\left(\frac{((s(s + 3366.70489333216)) \times 121.465049848026) + (s + 3366.70489333216)109.739129029925 + s(98686.0901519s)}{s(s + 3366.70489333216)} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right)$$

$$\left(\frac{121.465049848026s^2 + 408936.977692s + 109.739129029925s + 369459.262695 + 98686.0901519s^2}{s^2 + 3366.70489333216s} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right)$$

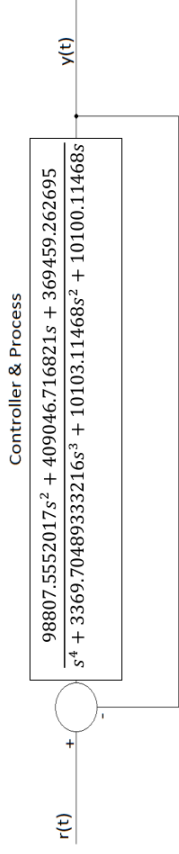
$$\left(\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^2 + 3366.7048933216s} \right) \times \left(\frac{1}{s^2 + 3s + 3} \right)$$

$$\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{(s^2 + 3366.7048933216s)(s^2 + 3s + 3)}$$

$$\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3s^3 + 3s^2 + 3366.7048933216s^3 + 10100.11468s^2 + 10100.11468s}$$

$$\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.7048933216s^3 + 10103.11468s^2 + 10100.11468s}$$

The block diagram can now be redrawn as:



Now remove the feedback loop and calculate the transfer function of the system as a whole.

Using:

$$TF = \frac{G}{1 + GH}$$

Where TF is the transfer function of the whole system, G is the forward path transfer function, and H is the transfer function of the feedback loop, in this case $H = 1$

$$TF = \frac{\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 33369.70489333216s^3 + 10103.11468s^2 + 10100.11468s}}{1 + \left(\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 33369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} \right) \times 1}$$

TF

$$= \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} + \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} + \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s}$$

TF

$$= \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} + \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s}$$

$TF =$

$$\frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} + \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s}$$

$$TF = \frac{98807.5552017s^2 + 409046.716821s + 369459.262695}{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s} \times \frac{s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s}{s^4 + 3369.70489333216s^3 + 108910.6698817s^2 + 419146.831501s + 369459.262695}$$

$$TF = \frac{(98807.5552017s^2 + 409046.716821s + 369459.262695)(s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s)}{(s^4 + 3369.70489333216s^3 + 10103.11468s^2 + 10100.11468s)(s^4 + 3369.70489333216s^3 + 108910.6698817s^2 + 419146.831501s + 369459.262695)}$$
$$TF = \frac{98807.5552017s^6 + 32952302.261s^5 + 998264661.453s^4 + 997967638.788s^3 + 469046.716821s^2 + 1378566723.27s + 1244968685.390230s^5 + 419146.831501s^4 + 369459.262695s^3 + 11324911.088147s^2 + 360996817.26844800s + 1412401129.133590s + 1244968685.390230s^4 + 10103.11468s^3 + 369459.262695s^2 + 1244968685.39s + 3731580922.81s}{s^8 + 3404511.975920s^7 + 110833087.6884800s^6 + 423488056.432400s^5 + 372489388.558300s^4 + 10100.1146800s^3 + 36034405.8064120s^2 + 1108010255.6097000s + 423431065.0187800s + 3731580922.807750s}$$

Collecting like terms...

$$TF = \frac{98807.5552017s^6 + 333361348.9778210s^5 + 23766530784.7230s^4 + 6375582213.6980s^3 + 7864108049.970s^2 + 3731580922.80775s}{s^8 + 6739.40978666s^7 + 11473924.85270870s^6 + 401470579.1577210s^5 + 2547141981.947140s^4 + 6579667447.484260s^3 + 7966120366.514570s^2 + 3731580922.807750s}$$

The block diagram can now be redrawn again as a single block.

$$\frac{98807.5552017s^6 + 33336.13489778210s^5 + 2376630784.7230s^4 + 6375582213.6980s^3 + 7864108049970s^2 + 3731580922.80775s^8 + 6739.40978666s^7 + 11473924.85270870s^6 + 401470579.1577210s^5 + 2547141981.947140s^4 + 6579667447.484260s^3 + 7966120366.514570s^2 + 3731580922.807750s}{s^8 + 6739.40978666s^7 + 11473924.85270870s^6 + 401470579.1577210s^5 + 2547141981.947140s^4 + 6579667447.484260s^3 + 7966120366.514570s^2 + 3731580922.807750s}$$

Control Systems Assignment - Owen miller

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

69/100

PAGE 1

PAGE 2



Comment 1

This is very quick.

PAGE 3



Comment 2

This would be part of a different system, the system which provides the setpoint to the control system I have asked you to design.



Comment 3

Your control system should manage disturbances naturally - that is what the feedback is for.

PAGE 4

PAGE 5



Comment 4

Bold statements like this should have a reference to back them up.

PAGE 6

PAGE 7

PAGE 8



Use Eqn editor

You should use the equation editor in word to insert your equations - this way you will create a far more professional looking report.

PAGE 9

PAGE 10



Comment 5

This scope does not monitor the output of the process, it monitors the input

PAGE 11

PAGE 12



Comment 6

H(s) is normally the transfer function of the feedback circuit.

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QM

Sp.

Spelling error



Comment 7

The purpose of this assignment is to develop the azimuth control sus-system for a CWIS, and to contextualise the use of industrial control systems in terms of WOME. The azimuth control sus-system would generally be sent angular data for a given target from a target tracking computer. This would not be the only thing controlling the turret.



Comment 8

That is the responsibility of the system above this one. The responsibility of this system is to ensure the gun is pointing in the direction it is told to.



Comment 9

And knowing this, you still designed it that way. You could have designed it to have a settling time of 2 seconds - this would be more in line with the capabilities of systems like Phalanx, Goalkeeper, or DARDO.

PAGE 27

PAGE 28



Comment 10

You PID controller has a filter in it. That is what the N coefficient is for.

PAGE 29

PAGE 30

PAGE 31



Comment 11

I would have thought you'd want me to mark the abstract as it was quite good. A little long, but quite good.

I opened your report in word and that quotes the word count as 3386 including your 252 word abstract. This is 35.4% OVER the word count limit. Without including the abstract that takes it to 25.4% over the word limit. Both of these should result in a deduction of 10 marks from your final mark as per university regulation 7.7 paragraph (ii)

<https://www.uwtsd.ac.uk/sites/default/files/2024-01/Academic-Quality-Handbook-2023-24---complete-document.pdf>

I think this a bit harsh, so I will use the category below which stipulates work between 10% and 25% above the word limit shall see a deduction of 5 marks.

Please adhere to the word limit - it is part of the challenge of the assessment.

PAGE 32

QM

Refs missing info

Some of your references are missing information. To understand what information should be included, see the university IEEE referencing handbook on the library website.

https://uwtsd.ac.uk/media/uwtsd-website/content-assets/documents/library-and-learning-resources/infoskills/IEEE-eng_v.1.2.pdf

PAGE 33

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

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GRADING FORM: SMU GENERIC_SMOSEY

OWEN MILLER

74.10

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.

8.5

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.

-  Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.

22.5

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.

21.9

Your comments on the suitability of your control system are very negative. This control system is intended to be the very bottom layer of a complex hierarchy of target identification and tracking systems. Your report seemed to labour the idea that this control system would not be enough on its own missing the point that I didn't ask you about the target identification and tracking. You wasted a lot of words on this point.

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



"An advanced application of a range of methods, materials, tools and/or techniques.
The context of the application is well considered, with extensive use of relevant examples.
Application and deployment extend beyond established conventions. Innovation and creativity evident throughout

14

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate professionally and, confidently in a suitable format.
Work is coherent, very fluent and is presented professionally.

7.2

I opened your report in word and that quotes the word count as 3386 including your 252 word abstract. This is 35.4% OVER the word count limit. Without including the abstract that takes it to 25.4% over the word limit. Both of these should result in a deduction of 10 marks from your final mark as per university regulation 7.7 paragraph (ii)

<https://www.uwtsd.ac.uk/sites/default/files/2024-01/Academic-Quality-Handbook-2023-24---complete-document.pdf>

I think this a bit harsh, so I will use the category below which stipulates work between 10% and 25% above the word limit shall see a deduction of 5 marks.

Please adhere to the word limit - it is part of the challenge of the assessment.

You would have scored 74.1% for this report, but as you were 35.4% over the word limit I have subtracted 5% from your final mark meaning you score 69.1%