STUDENT LAB SAFETY, HIRARC, DATASHEET VERIFICATION CHECKLIST, AND BRIEF REPORT SUBMISSION

EXPERIMENT KW9: CONTROL SYSTEM PERFORMANCE AND STABILITY (OPEN-ENDED)

STUDENT NAME : _____
MATRIC NO. : _____
GROUP : _____
DATE : _____

A. Equipment and System Verification Checklist

Item	Verification Requirement	✓
MATLAB / Simulink	Software opens correctly, and the Control System Toolbox is licensed and functional.	□
Model Units / Variables	Numerator and denominator coefficient vectors are verified against the specified transfer function before execution.	□
System Parameters	Plant transfer-function coefficients, stabiliser parameters, PID values and reference-input settings are specified correctly.	□
Baseline Simulink Model	The control-system model shown in Figure 1 is constructed according to the given block arrangement.	□
Stabiliser Simulink Model	The stabiliser block is inserted in the correct location according to Figure 2.	□
PID Controller Configuration	The PID Controller block is placed at an appropriate location, and the initial Proportional, Integral and Derivative parameters are verified.	□
Simulink Routing	Feedback loops, summing-junction signs, transfer-function blocks, Scope, Clock, Multiplexer and To Workspace signals are connected correctly.	□
Solver Settings	Solver type, step size, simulation duration and data-logging settings are checked before running the model.	□
Bode Plot Configuration	The transfer function $G(s) = 10/(s^2 + 2s + 10)$is defined correctly before generating the Bode Plot.	□
Nyquist Plot Configuration	The same transfer-function model is selected before generating the Nyquist diagram.	□
Root Locus Configuration	The same transfer-function model is selected before generating the Root Locus Plot.	□
File Management	MATLAB scripts, Simulink models, workspace data, plots and screenshots are saved using identifiable filenames.	□

B. HIRARC Checklist (OSH-Based Risk Assessment)

Hazard / Unsafe Condition	Potential Consequence	Control Measure	✓
Incorrect transfer-function coefficient ordering	Severe model error, invalid plots or incorrect stability conclusions	Double-check the descending powers of $s$in the numerator and denominator vectors before running MATLAB.	□
Incorrect transfer-function block parameters	Simulated response does not represent the specified control system	Verify every numerator and denominator entry against Figures 1, 2 and 3 before simulation.	□
Incorrect Simulink feedback routing	Incorrect response, positive feedback or uncontrolled signal	Check all signal paths, feedback connections and summing-junction signs before running the model.	□

	growth		
Incorrect stabiliser placement or parameters	Misleading comparison between the baseline and stabilised systems	Verify the stabiliser position and parameter values against Figure 2.	□
Excessive PID parameter values	Large overshoot, sustained oscillation or divergent output	Begin with controlled parameter values and vary P, I and D gradually while monitoring the Scope output.	□
Unstable simulated response	Rapid signal divergence and invalid performance measurements	Stop the simulation when the signal grows uncontrollably, then review the controller parameters and feedback configuration.	□
Incorrect solver type or step size	Numerical errors, inaccurate transient response or simulation failure	Review the solver algorithm, step-size limits and simulation duration before execution.	□
Incorrect performance-marker placement	Incorrect rise time, settling time, overshoot or steady-state error	Use a consistent step-response definition and confirm each measured point against the plotted response.	□
Incorrect Gain Margin or Phase Margin interpretation	Incorrect robustness and stability assessment	Identify the crossover frequencies carefully and record the corresponding margin values directly from the Bode Plot.	□
Incorrect Nyquist encirclement count	Incorrect closed-loop stability conclusion	Identify the critical point $(-, 10)$, count the encirclements and record the direction as clockwise or counter-clockwise.	□
Incorrect Root Locus interpretation	Incorrect conclusion regarding pole movement and stability	Identify the initial poles and observe whether the locus approaches or crosses the imaginary axis or enters the right-half plane.	□
Unsaved workspace variables or plots	Experimental results are lost between MATLAB or Simulink runs	Export the required signals using To Workspace and save scripts, models, plots and workspace data after every completed task.	□
Extended computer workstation use	Physical discomfort or eye strain	Maintain an ergonomically appropriate sitting posture and take short visual breaks.	□

C. Engineering Practice Verification

Requirement	✓
The baseline control-system model in Figure 1 is constructed and simulated correctly.	□
The baseline step-response curve is generated and recorded.	□
Peak amplitude, rise time, settling time, percentage overshoot and steady-state error are obtained from the baseline response.	□
The stabiliser is inserted according to Figure 2, and the modified system is simulated.	□
The stabilised-system response parameters are measured and recorded.	□
The PID Controller block is inserted at an appropriate location in the Figure 1 model.	□
P, I and D parameters are tuned using the specified trial-and-error method.	□
The PID values that produce the best selected performance are recorded.	□
The baseline, stabiliser and PID-controlled responses are compared using the same performance criteria.	□
The transfer function $G(s) = 10/(s^2 + 2s + 10)$ is created correctly in MATLAB.	□
The Bode Plot is generated, and its Gain Margin, Phase Margin and associated frequencies are recorded.	□

The Nyquist Plot is generated, and the encirclement of the critical point $(-, 10)$is evaluated.	□
The Nyquist stability criterion is applied to determine closed-loop stability.	□
The Root Locus Plot is generated, and changes in pole location with gain are evaluated.	□
All MATLAB commands, Simulink models, plots, measurements, observations and engineering conclusions are recorded.	□

D. Student Declaration

I confirm that I have completed the above verification and HIRARC checks, verified the MATLAB/Simulink workspace and model settings, and will report any software, workstation or laboratory issue to the demonstrator/technician.

Student Signature : _____

Date : _____

E. Experiment Data Results and Discussion

In Lab Task (During Lab)

Task 1: Test 1 — Control System Performance in Simulink Data Sheet
Table E1.1: Simulink Model and Output Verification

Procedure / Question	Model / Controller Configuration	Output / Observation / Analysis	Key System Parameter Value / Description	Simulink / Scope Output
Construction of Baseline Model	Figure 1			
Baseline Step Response	Figure 1 without additional controller			
Construction of Stabilised Model	Figure 2			
Stabilised Step Response	Figure 2 with stabiliser			
PID Controller Insertion	Figure 1 + PID Controller			
PID Trial 1	P = _____, I = _____, D = _____			
PID Trial 2	P = _____, I = _____, D = _____			
PID Trial 3	P = _____, I = _____, D = _____			
Best PID Performance	P = _____, I = _____, D = _____			

Table E1.2: Step-Response Performance Comparison

Configuration	System	PID Parameters	Peak Amplitude	Rise Time, t_r	Settling Time, t_s	Overshoot, %OS	Steady-State Error, e_{ss}
Baseline	Figure 1	N/A					
With Stabiliser	Figure 2	N/A					
With PID, Best Performance	Figure 1 + PID	P = _____					
		I = _____					
		D = _____					

Task 2: Test 2 — System Stability Using MATLAB Data Sheet

The KW9 stability analysis uses the following system:

$$G(s) = \frac{10}{s^2 + 2s + 10}$$

Table E2.1: MATLAB Stability Analysis

Procedure / Question	MATLAB Command Used	Output / Observation / Analysis	Key Stability Parameter / Description	MATLAB Figure / Command Window Output
Transfer Function Creation			Numerator: _____ Denominator: _____	
Bode Plot Generation			Gain and phase response	
Gain Margin Determination			GM = _____	
Phase Margin Determination			PM = _____	
Nyquist Plot Generation			Encirclement of $(-, 10)$	
Nyquist Stability Assessment			P = _____, N = _____, Z = _____	
Root Locus Generation			Pole movement as gain varies	
Root Locus Stability Assessment			Imaginary-axis crossing / RHP entry	

Task 3: Detailed Performance and Stability Data Sheets

Table E3.1: Bode Plot Analysis

Parameter	Value from Plot	Frequency, ω	Observation / Stability Significance
Gain Margin, GM			
Phase Margin, PM			

Gain-Crossover Frequency			
Phase-Crossover Frequency			
Overall Bode Stability Assessment			

Table E3.2: Nyquist Plot Analysis

Parameter	**Value**	**Stability Assessment**
Number of Open-Loop Poles in RHP, P		
Number of Encirclements of $(-, 10)$**,** N		CW / CCW / None
Number of Closed-Loop Poles in RHP, $Z = N + P$		
Closed-Loop Stability Conclusion		Stable / Unstable

Table E3.3: Root Locus Plot Analysis

Observation	**Location of Poles at Low Gain,** $K \approx 0$	**Location of Poles at High Gain,** $K \to \infty$
Initial Pole Location		
Pole Movement / Locus Path		
Imaginary-Axis Crossing		
Poles Crossing into RHP		
Stability Assessment		

Task 4: In-Lab Analytical & Open-Ended Questions

Q1. PID Controller Tuning and Performance Analysis

Question / Task	**Key Concept to Discuss**	**Analysis / Explanation Requirement**
Q1 in Test 1	**PID control and step-response performance**	State the selected P, I and D values. Explain the trial-and-error tuning sequence and how changes to each term affected rise time, settling time, percentage overshoot and steady-state error. Compare the best PID response with Figure 1 and Figure 2.

Answer:

Q1(a). Transient-Response Comparison

Question / Task	**Key Concept to Discuss**	**Analysis / Explanation Requirement**
Baseline, stabiliser and PID comparison	**Transient-response characteristics**	Compare peak amplitude, rise time, settling time and percentage overshoot for all three configurations. Identify the controller that provides the best transient response and justify the conclusion using the measured values.

Answer:

Q1(b). Steady-State Performance Comparison

Question / Task	Key Concept to Discuss	Analysis / Explanation Requirement
Steady-state error comparison	**Accuracy and Integral action**	Compare the steady-state errors of the three configurations. Explain whether the Integral term eliminated or reduced the steady-state error in the PID-controlled system.

Answer:

Q2. Bode Plot Stability Analysis

Question / Task	Key Concept to Discuss	Analysis / Explanation Requirement
Q2 in System Stability Using MATLAB	**Gain Margin and Phase Margin**	Identify the Gain Margin and Phase Margin and record the frequencies at which the margins occur. Discuss how the measured margins relate to system stability and robustness.

Answer:

Q3. Nyquist Plot Stability Analysis

Question / Task	Key Concept to Discuss	Analysis / Explanation Requirement
Q3 in System Stability Using MATLAB	**Nyquist Stability Criterion**	Determine the number and direction of encirclements of the critical point $(-, 10)$. Record P, $N$and Z, apply $Z = N + P$, and conclude whether the closed-loop system is stable.

Answer:

Q4. Root Locus and Pole-Movement Analysis

Question / Task	Key Concept to Discuss	Analysis / Explanation Requirement
Q4 in System Stability Using MATLAB	**Closed-loop pole location and stability**	Identify the pole locations as gain varies. Explain how pole movement influences system stability and describe the significance of poles approaching or crossing the imaginary axis and entering the right-half plane.

Answer:

Task 5: Experimental Results and Overall Discussion

Analysis Area	Required Discussion	Student Findings
Baseline Performance	Discuss the Figure 1 response using peak amplitude, rise time, settling time, overshoot and steady-state error.	
Stabiliser Performance	Explain how the stabiliser changes the response relative to the baseline system.	
PID Performance	Explain how the best PID parameters improve or affect transient and steady-state performance.	
Controller Comparison	Identify the best overall controller configuration using the experimental data.	
Bode Plot	Discuss Gain Margin, Phase Margin and relative stability.	
Nyquist Plot	Discuss the critical-point encirclement and closed-loop stability result.	
Root Locus	Discuss pole movement as gain varies and relate the movement to stability.	
Engineering Recommendation	Recommend the most suitable controller configuration or design improvement based on the results.	
Limitations	Identify model, simulation, measurement or tuning limitations that affected the results.	

DISCUSSION:

CONCLUSION:

LAB LECTURER **INSTRUCTOR**

SIGNATURE : _____ **SIGNATURE :** _____

DATE : _____ **DATE :** _____