# CONTROL SYSTEMS

## Complete Multipage Master Handbook & Problem Solver | GATE ECE 2027

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| **Target Exam:** | GATE 2027 Electronics & Communication (EC) |
| **Organizing Institute:** | IIT Madras |
| **Syllabus Standard:** | 100% Complete Syllabus + 2027 Revisions |
| **Edition:** | Comprehensive Multipage Textbook & Problem Solver |

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# CHAPTER 1: SYSTEM MODELING & BLOCK DIAGRAMS

## 1.1 Mason's Gain Formula

Mason's gain formula evaluates closed-loop transfer function T(s) directly from signal flow graphs.

- **Formula:** T(s) = (1 / Delta) * sum P_k * Delta_k.
- **Determinant Delta:** Delta = 1 - sum L_1 + sum L_2 - sum L_3 + ...

# CHAPTER 2: TIME DOMAIN PERFORMANCE & STEADY-STATE ERROR

## 2.1 2nd Order Transient Specifications & e_ss

Standard 2nd order system T(s) = omega_n^2 / (s^2 + 2*zeta*omega_n*s + omega_n^2).

- **Peak Overshoot M_p:** % M_p = exp(-pi*zeta / sqrt(1 - zeta^2)) * 100%.
- **Settling Time t_s:** t_s = 4 / (zeta * omega_n) (2% tolerance band).
- **Steady-State Error e_ss:** e_ss = lim s R(s) / (1 + G(s)H(s)) as s -> 0.

# CHAPTER 3: STABILITY ANALYSIS & ROOT LOCUS

## 3.1 Routh-Hurwitz & Root Locus Rules

Routh-Hurwitz determines absolute stability without factoring characteristic polynomial.

- **Routh Criterion:** System stable if no sign changes in 1st column.
- **Root Locus Asymptotes Angle:** $\phi_a = (2k + 1) * 180° / (P - Z)$.

# CHAPTER 4: FREQUENCY DOMAIN & COMPENSATORS

## 4.1 Bode Plots & Lead/Lag Compensators

Bode plots evaluate open-loop frequency response magnitude and phase.

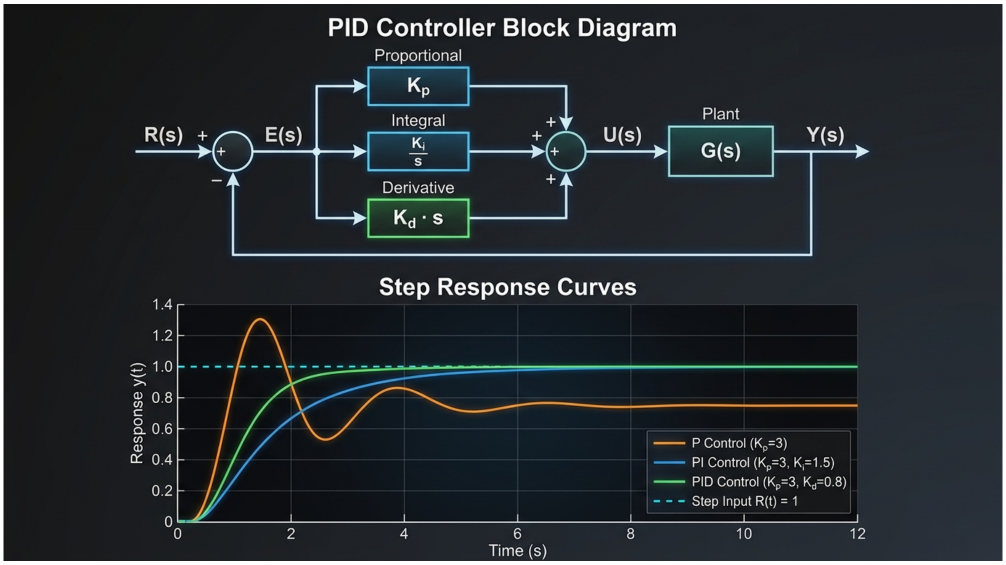
- **Phase Margin:** PM = 180° + angle(G(j*omega_gc)H(j*omega_gc)).
- **Lead Compensator:** Phase lead phi_m = sin^-1((1-alpha)/(1+alpha)). Speeds up response.

# CHAPTER 5: PID CONTROLLERS & STATE-SPACE ANALYSIS

## 5.1 PID Controllers (NEW FOR GATE 2027)

PID controllers combine proportional, integral, and derivative control actions.

- **Transfer Function:** G_c(s) = K_p + K_i / s + K_d s.
- **Integral Control (K_i):** Eliminates steady-state error completely (e_ss -> 0).
- **Derivative Control (K_d):** Increases damping, reduces peak overshoot M_p, improves transient stability.




**WORKED GATE NUMERICAL: PD Controller Parameter Design**

**Problem:** Plant G(s) = 1/s^2 controlled by G_c(s) = K_p + K_d s. Target poles s = -2 +/- j2.

**Step-by-Step Derivation & Solution:**

1. Target characteristic eq: (s+2)^2 + 4 = s^2 + 4s + 8 = 0
2. Actual characteristic eq: s^2 + K_d s + K_p = 0
3. Comparing coefficients: **K_d = 4, K_p = 8**.