Introduction to Control Engineering

XMUT315 Control System Engineering

Topics

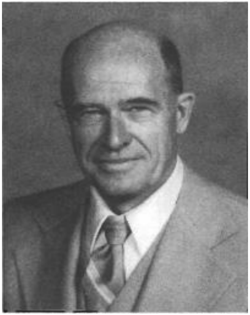
- Classical control.
- Feedback control systems.
- Graphical techniques.
- System topologies and notations.
- Compensator design.

Classical Control

- Classical control was developed in the 1930's (H. W. Bode and H. Nyquist) and 1940's (W. R. Evans).
- It allows effective control system design without use of the computers.

Hendrik W. Bode

Harry Nyquist



Walter R. Evans

Classical Control

- Classical control is most useful for systems:
  - Linear Time Invariant (LTI).
  - Single Input, Single Output (SISO).
- For other systems, use multivariable control systems or nonlinear control systems.
- Subsequent ECEN415 Advanced Control Engineering course at VUW covers these other systems and also digital control systems and applications of further control system techniques.

Classical Control

- We will also continue to consider only continuous time systems, though these tools can all be used in discrete time.
- The various techniques provide *insight* into the system behaviour.
- These techniques typically do not yield a single “correct” compensator design.
- They require a level of engineering judgement.

Topics in Classical Control

- Classical knowledge and skills in control systems:
  - Physical and conceptual modelling skills.
  - Mathematical and transformation skills.
  - System characteristic and performance identification, measurement, and analysis.
  - Troubleshooting and fault finding.
  - Use of control system software and relevant equipment and tool.

Topics in Classical Control

Specific knowledge and skills covered in course:

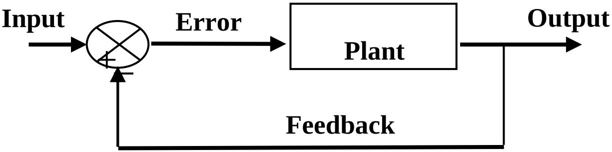
- Modelling systems from physical entities.
- Feedback control systems.
- Stability analysis.
- Transient and steady-state analysis.
- Time domain analysis.
- Frequency response analysis.
- Compensation and solution design.

Modelling Physical System

- Identification of physical components of the system.
- Modelling of the physical system (block diagram).
- Derivation of differential equation of the system.
- Application of Laplace transform to simplify the calculation, solving and domain transformation of the differential equations.
- Assuming some knowledge on simple electrical and mechanical systems.

Feedback Control Systems

Feedback control systems (closed loop) improves the characteristic and performance of the system:



Notations:

- Feedback = Output
- Error = Input - Feedback
- Output = Error x Plant

Feedback Control Systems

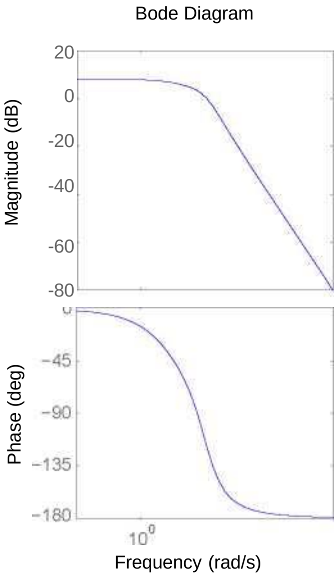
Advantages:

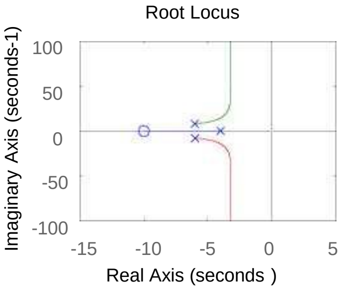
- Plant more responsive to changes in input.
- Eliminate noise.

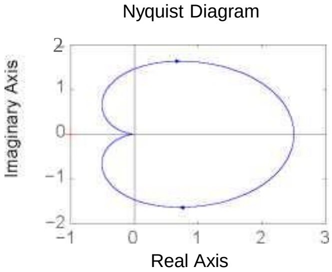
Disadvantages:

- Added cost and complexities to implement.
- Could lead to issues in performance and stability.

Graphical Techniques - A Preview



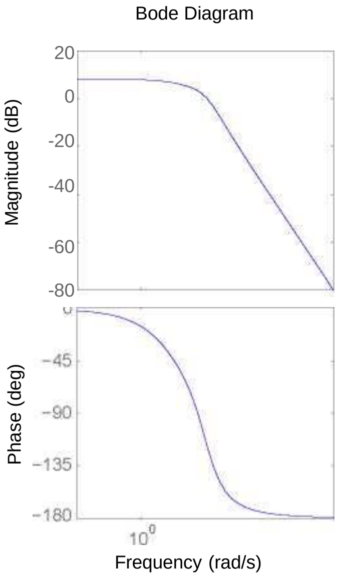




Graphical Techniques - A Preview

Bode plots:

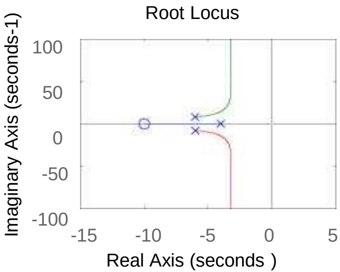
- Consisted of magnitude and phase plots.
- Analysis and design of system based on frequency response of the system.



Graphical Techniques - A Preview

Root locus diagram:

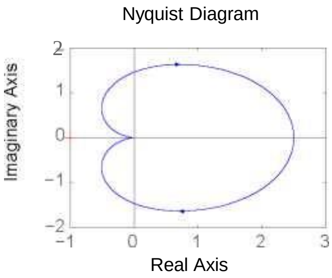
- Based on the transfer function (output/ input) of the system.
- Analysis and design of system performance and stability using the poles/zeros of the system transfer function.



Graphical Techniques - A Preview

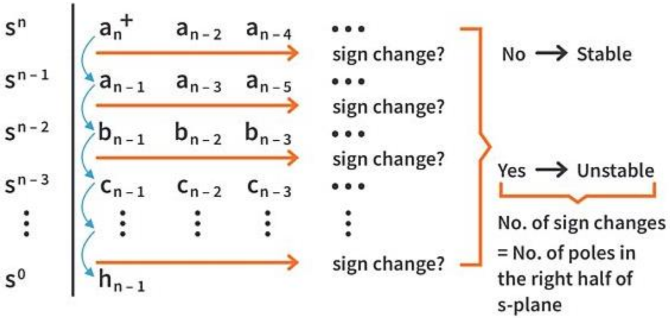
Nyquist plot:

- Based on polar plots of frequency response of the system.
- Further analysis and design of system stability.



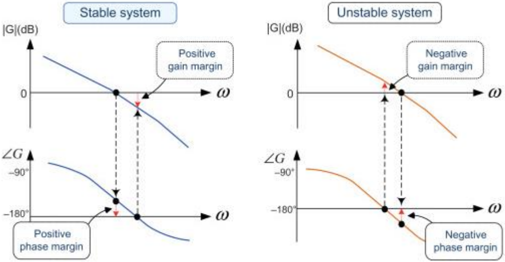
Stability Analysis

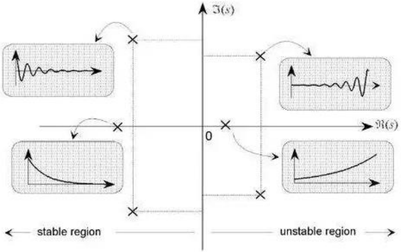
- Stability analysis is important to do first, before further (more specific type of) analysis and design.
- Stability analysis with generic Routh-Hurwitz criterion method.



Stability Analysis

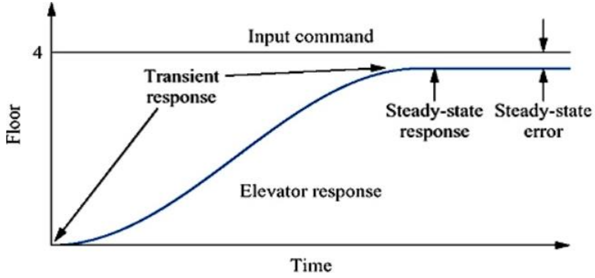
- Stability analysis with relevant graphical techniques e.g. frequency response plots and pole-zero diagram.





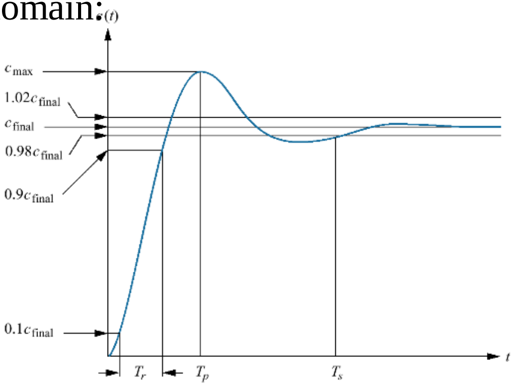
Transient and Steady-State Analysis

- Transient analysis is about analysis of the initial response of the system.
- Steady-state analysis is about analysis of the response of the system after a (long) period of time of the settling down.



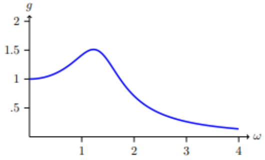
Time Domain Analysis

- Time domain analysis is a more specific analysis of the system in the time domain:
  - Time period (τ).
  - Damping factor (ζ).
  - Rise time (T_r).
  - Time-to-peak (T_p).
  - Settling time (T_s).
  - Percentage overshoot ($\%OS$).

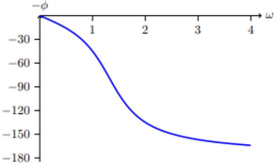


Frequency Response Analysis

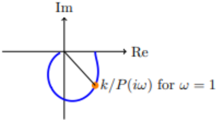
- Frequency response analysis is about analysis of the system based on its response in the frequency domain.
- Its analysis is based on the parameters of frequency response of the system:
    - Gain of the system.
    - Phase shift of the system.



Bode gain plot



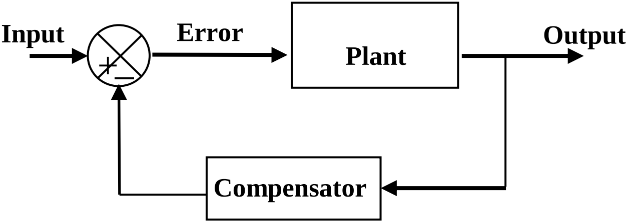
Bode phase plot (in degrees)



Nyquist plot

Compensator Design

- System with issue and problem $\rightarrow$ application of compensator.
- We will generally implement compensator in the feedback path, but it could be placed in the forward path.
- Compensator work to improve the performance of the control system.



Compensator Design

There are many approaches to designing a compensator.

1. Choose a compensator structure and then tune manually.
2. Choose a compensator model and tune using a "recipe" (e.g. Ziegler-Nichols).
3. Use a model and solve for desired pole locations.
4. Measure the system performance and use a graphical technique.
5. Use a mathematical model with a graphical technique.

Compensator Design

6. Use mathematical tools to achieve optimal performance (see ECEN415 - Advanced Control Engineering).

In the remaining lectures, we will concentrate on the use of graphical methods which form the heart of classical control (items 4 and 5 in the list):

- Measure the system performance and use a graphical technique.
- Use a mathematical model with relevant graphical techniques.

Example for Tutorial

A Segway Human Transporter (HT) as shown in here is a two wheeled vehicle in which the human operator stands vertical on a platform.

As the driver leans left, right, forward, or backward, a set of sensitive gyroscopic sensors sense the desired input.

Example for Tutorial

a. Describe the functionalities of gyroscope that works behind the human transporter. [2 marks]

b. A conventional gyroscope would be cumbersome and difficult to maintain practically, describe how Segway’s engineers invent the same effect with a more practical mechanism. [2 marks]

c. Draw a functional block diagram of the system that keeps the system in a vertical position. [4 marks]

d. Indicate and describe briefly the I/O signals, intermediate signals, and subsystems. [6 marks]