Syllabus

- **Lecture Information:**
  - Time: 9:10am-12noon, Tuesdays
  - Room: EE-MD231
  - Webpage: http://cc.ee.ntu.edu.tw/~fengli/Teaching/LinearSystems/

- **Instructor:**
  - Feng-Li Lian
  - Office: EE-MD717
  - E-mail: fengli@ntu.edu.tw, Phone: 02-3366-3606

- **Teaching Assistant:**
  - To be determined

- **Grading:**
  - Homework (30%) due in class, no late homework is accepted
  - Midterm exam (20+20%) on 10/23 and 11/27
  - Final exam (30%) on 1/15

- **Textbook:**
Homework and Exam

- **Homework Rules:**
  - No late homework will be graded!!!
  - 請註明：作業次別，姓名，學號，系級，日期
  - Problems
    - End-of-Chapter Problems
    - Special Problems

- **Exam Rules:**
  - 1-hour (midterm) & 2-hour (final) exam
  - Closed books and notes
  - No calculators are required
  - Coverage
    - Lecture notes: 1/3
    - End of Chapter Problems: 1/3
    - Special Problems: 1/3

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**What is Linear Systems about? – 1**

- In Algebra:

  \[ ax = b \]

- In Linear Algebra:

  \[ A x = B \]
In Differential Equation:

\[
\frac{dx(t)}{dt} = \dot{x}(t) = a \, x(t)
\]

\[
x(t_0) = x_0
\]

\[\Rightarrow x(t) = \]

In Differential Equations:

\[
\dot{x}(t) = a \, x(t) + b \, u(t)
\]

\[
x(t_0) = x_0
\]

\[\Rightarrow x(t) = \]
In Linear Systems:

\[ \dot{x}(t) = A \cdot x(t) + B \cdot u(t) \]
\[ x(t_0) = x_0 \]

\[ \Rightarrow x(t) = \]
Analysis & Design Philosophy of Engineering Systems

- Mathematics, Statistics:
  - Differential Equations,
  - Linear Algebra,
  - Probability, Stochastic Processes

- Physics, Chemistry:
  - Electronics, Electrical Circuits,
  - Electromagnetics, Dynamics,
  - Thermodynamics, Heat Transfer

- Linear v.s. Nonlinear

- Stability
- Controllability
- Observability
- Performance
- Robustness

- Hardware vs Software
- Optimization vs Control
  - Optimal Control, Robust Control,
  - Adaptive Control, Nonlinear Control
- Input-Output Model

- State-Space Model

An RLC Electrical Circuit – 1

At node A: \( C_2 \dot{x}_2 = x_3 \)

At node B: \( \frac{u - x_1}{R} = C_1 \dot{x}_1 + C_2 \dot{x}_2 \)

At RHS loop: \( L \dot{x}_3 = x_1 - x_2 \)

\( y = L \dot{x}_3 \)

\( \Rightarrow \hat{y}(s) = \hat{G}(s) \hat{u}(s) \)
An RLC Electrical Circuit – 2

\[
\begin{bmatrix}
\dot{x}_1 \\
\dot{x}_2 \\
\dot{x}_3 
\end{bmatrix} =
\begin{bmatrix}
-1/RC_1 & 0 & -1/RC_1 \\
0 & 0 & 1/C_2 \\
1/L & -1/L & 0
\end{bmatrix}
\begin{bmatrix}
x_1 \\
x_2 \\
x_3
\end{bmatrix} +
\begin{bmatrix}
-1/RC_1 \\
0 \\
0
\end{bmatrix} u
\]

- Let \( x := \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \)

\[ \Rightarrow \dot{x} = Ax + Bu \]

- \( y = L\dot{x}_3 = x_1 - x_2 = [1 \quad -1 \quad 0]x + 0 \cdot u \)

\[ \Rightarrow y = Cx + Du \]

- In general, \( \dot{x}(t) = A(t)x(t) + B(t)u(t) \)
  \[
  y(t) = C(t)x(t) + D(t)u(t)
  \]

Another RLC Electrical Circuit

\[
\begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
x_4
\end{bmatrix} :=
\begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
x_4
\end{bmatrix}
\]

- Solution
- Stability
- Controllability
- Observability
- Minimal Form
- State Feedback
- State Estimation
Course Outline

- Mathematical Description of Systems (Ch 02)
- Linear Algebra (Ch 03)
- State-Space Solutions and Realizations (Ch 04)
- Stability (Ch 05)
- Controllability & Observability (Ch 06)
- Minimal Realization (Ch 07)
- State Feedback and State Estimation (Ch 08)