Advanced Engineering Maths

A.Y. 2018-2019 - Spring Term

Advanced Engineering Mathematics

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Module info

Essential Details:

Credits: 10 Semester: Spring

Content Overview:

The module provides an introduction to a variety of mathematical techniques used in electrical and electronic engineering. Theory is directly related to topical applications. The content covers:

- *PDEs and their solution*
- *Matrices*
- *Signal processing*

Format:

12 weeks: 1/w 2-hr lecture (Tue. 4-6pm); 5 weeks: 1/w 2-hr lab (Fri. 11am-1pm)

Assessment:

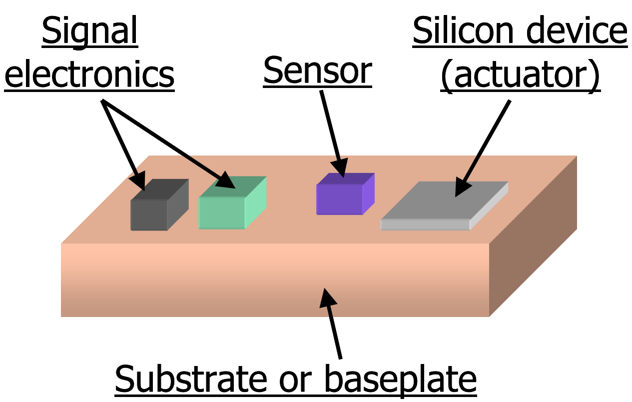
<u>75%</u>: 2 hr exam; <u>25%</u>: Coursework (2 pieces of coursework)

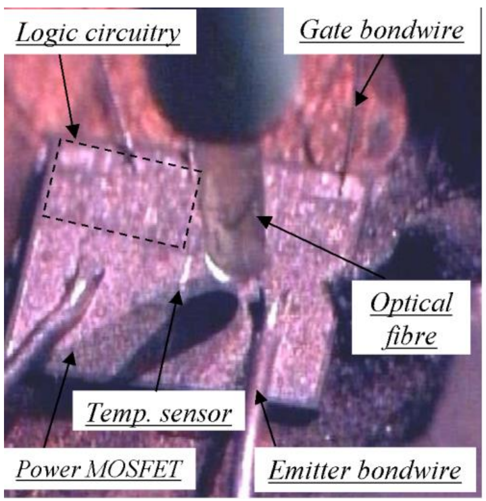
Pre-requisite:

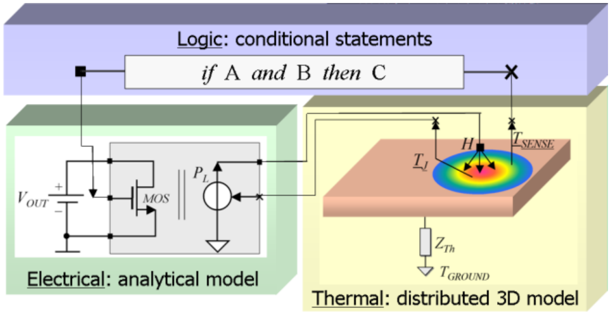
H61ENA (Eng. Maths.)
H62MMT (Modelling)
Suggested reading/textbooks/refs. Will be posted on Moodle. Lectures uploaded weekly

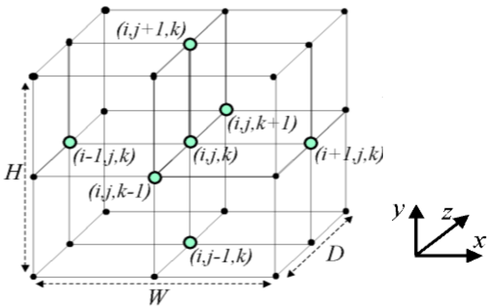
Partial Differential Equations (PDEs)

Ubiquitous relevance to engineering problem solving – example: advanced characterisation of SmartPower automotive device for design optimisation before series manufacturing and sale









Discretised heat-diffusion equation solution

Part I – Content

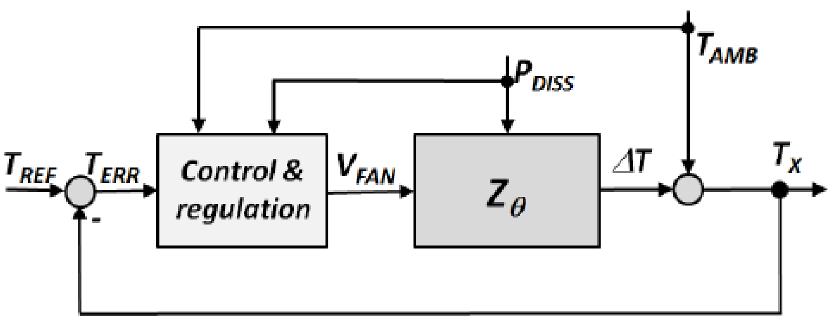
Partial Differential Equations (PDEs)

recap of PDEs;
space discretization methods (finite differences;
forward/backward/central derivation; solution stability and errors;
constant and non-constant meshes; adaptive and moving meshes;
hints of finite volumes; finite elements; method of moments);
time-discretisation methods; iterative solution;
Dirichlet and von Neumann boundary conditions;
multi physical domain coupled problems;
case-study/design exercise (smart-power electronic component) based on multi-level multi-domain coupled simulation (physical device models coupled with heat diffusion equation and control logic; inclusion of temperature sensor(s) to drive conditional statements)

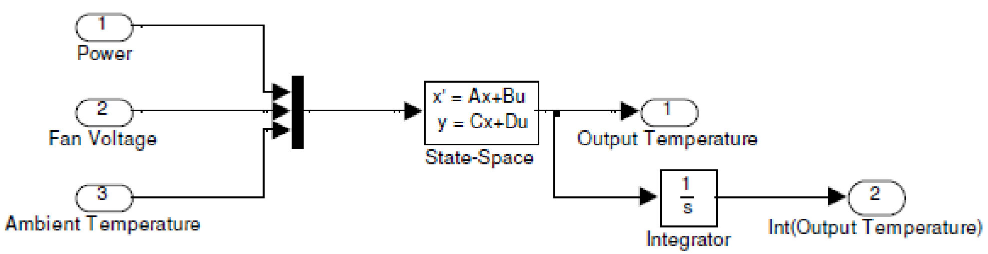
Part II – Description

Matrices

Standard underpinning mathematical tools for handling multi-state (multiple inputs, multiple outputs) problems – example: feedback and feedforward control of linear systems

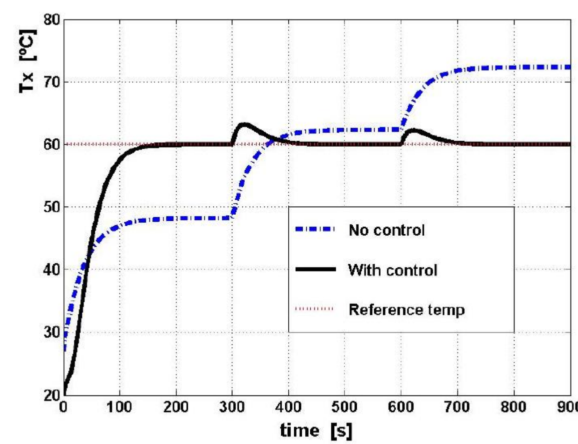


<u>Time and frequency domain matrix description of plant for use in Matlab/Simulink study to achieve desired dynamic response</u>



$$\dot{\hat{\underline{x}}} = A\hat{\underline{x}} + B\underline{u} + L(\underline{v} - \hat{\underline{v}})$$

$$\hat{\underline{v}} = C\hat{\underline{x}} + D\underline{u}$$



Part II – Content

Matrices

1.Deterministic and random matrices. Review of basic matrix notation and operations.

2. Special structures and methods using the triangular form (LU, QR).

3. Calculation of eigenvalues and eigenvectors, eigen-decomposition and spectral theorem.

4. Rectangular systems from under/overdetermined systems. Inversion. Concept of generalized inverse and SVD decomposition.

5. Sparse versus dense problems. Solution by iterative techniques.

6. Large and dense matrices with statistical fluctuations. Random matrix theory. Universal ensembles from symmetry and rotations.

7. Gaussian Orthogonal and Gaussian Unitary Ensemble. Probability distribution of eigenvalues and eigenvectors.

Part III – Description

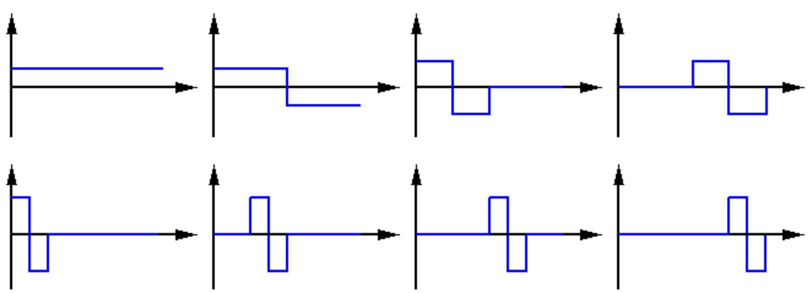
Signal processing

In many applications we wish to store signals and images minimising storage requirements – lossy compression

e.g. Using Fourier Transform

Above compression based on using cosines as basis functions to model the underlying image. However, other basis functions may be more suitable

e.g. wavelets



We will look at the mathematics behind fixed and data-adaptive basis functions that are applied to lossy data compression

Part III – Content

Signal processing

Transforms allow data to be represented in different ways; Useful if more efficient – or enhances some aspect of the data; Recap Discrete Fourier Transform; Other Discrete Transforms (Hartley, Haar, Discrete Cosine); Karhunen Loeve Transform / Principal Component Analysis; KLT / PCA; Empirical Mode Decomposition (Hilbert Huang transform).

Applications to signal compression and tracking signals with changing frequency

Representing signals as cosine/sine waves: Discrete Fourier Transform, Discrete Cosine Transform, Discrete Hartley Transform, Short-Time Fourier Transform

Representing Signals with Sharp Edges: Wavelet (Haar) Transform

Eigenvectors and Eigenvalues – compression adaptive to signal

Empirical Mode Decomposition – Signals with several frequency components