INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

COURSE NO: EE225 (For B. Tech. Students)   COURSE NAME: NETWORK THEORY

FIRST SEMESTER, ACADEMIC YEAR 2018-2019

COURSE OUTLINE AND RECOMMENDED REFERENCES

Course Structure (Lecture – Tutorial – Practical – Credits): 2 – 1 – 0 – 6

OBJECTIVES OF THE COURSE: This course is meant to provide a detailed insight into the principles and methods involved, in dealing with electrical networks. Typically, this course follows a basic course dealing with electrical circuits. Therefore, some elementary exposure to electrical circuits is assumed. This course is aimed at going further in the analysis of electrical networks, than what is learnt in an elementary course. The following main objectives are envisaged.

1. To deal with RLC (resistive, inductive and capacitive) circuits with arbitrary excitations using the Laplace domain approach, deriving phasor analysis as a special case. Further, to bring in ideal transformers and mutual inductance.
2. To build up the idea of network transfer functions, impulse responses, pole-zero descriptions and frequency domain methods in the analysis.
3. To develop formal techniques related to analysis of the graph underlying the electrical network, with the associated attributes.
4. To develop methods for analyzing the state variable behaviour in an electrical circuit.
5. To generalize the idea of network analysis to two-port, multi-port and multi-terminal elements.
6. To introduce passive filters and network synthesis.

COURSE CONTENTS: These contents are suggestive and describe the intended outline. However, they could be modified depending upon the class response and need in the course.

1. A review of the basic principles governing electrical networks:
   (a) Concept of an electrical network: lumped and distributed models.
   (b) Passive and active elements.
   (c) Attributes: linearity, time-invariance.

(d) Constraining relationships: Kirchoff's laws and their consequences.
(e) Behaviour of the individual RLC elements.
(f) Ideal transformers and mutual inductance.
(g) Direct and sinusoidal excitation and how to deal with them.
(h) Phasor diagrams.

2. Arbitrary excitation of circuits and related analysis:
   (a) Notion of eigenfunctions of electrical RLC circuits.
   (b) The Laplace Transform and its significance.
   (c) Generalized impedances and admittances of RLC elements.
   (d) Transforming time domain relations into Laplace domain relations.
   (e) Elementary analysis of Laplace domain circuits.
   (f) Transfer functions, poles and zeros.
   (g) State variables: an introduction.
   (h) The relation of state variables to poles and zeros.
   (i) Sinusoidal steady state excitation as a special case.
   (j) Frequency domain analysis of networks.
   (k) The step response of RLC circuits and corresponding impulse response.
   (l) Dealing with mutual inductance.

3. Systematic treatment of electrical circuits based on graph theory:
   (a) Paths, connectedness, circuits, cut-sets and trees.
   (b) Matrix representation of directed graphs.
   (c) Incidence, cut-set and circuit matrices, their properties.
   (d) Kirchoff's equations and their graph theoretic implications.
   (e) Systematic principles for handling electrical linear networks.
   (f) Nodal analysis, cut-set analysis, mesh analysis and their variants.
   (g) Duality.

(h) Generalized forms of the network theorems in the Laplace domain: Tellegen's Theorem, Thevenin-Norton Theorems, substitution theorem, reciprocity theorems, maximum power transfer.

4. Two port, multi-port and multi-terminal networks:
   (a) Two port networks and their parameters.
   (b) Interconnection of two port networks and the effect on their parameters.
   (c) Reciprocity and generalized reciprocity.
   (d) Multiport networks: their interconnection and representation.
   (e) Multi-terminal networks and the indefinite admittance matrix.
   (f) Star-delta and delta-star transformations: their generalization.

5. State equations for electrical circuits:
   (a) The notion of a state variable: inductor currents and capacitor voltages.
   (b) State equations by inspection.
   (c) Systematic construction of state equations for linear networks with no capacitor loops and no inductor cut-sets.
   (d) Solution of state equations for the case of distinct eigenvalues.

6. Elements of passive filter theory and network synthesis:
   (a) Lowpass, highpass, bandpass and bandstop filters.
   (b) RLC filter circuits: their analysis.
   (c) An introduction to network and filter synthesis.

   (The subject of network synthesis is very vast and the extent to which it can be handled in this course will depend upon the time available for that topic. This can only be dealt within the last segment of the course).

TEXTS AND REFERENCES: There is a wide variety of text books and reference books on the subject. In the first reference: M. E. Van Valkenburg, "Network Analysis" below, there is a very comprehensive list of references on the subject of electrical network theory towards the end. The list that follows herewith is not exhaustive, though it does provide some variety in selection. The instructor does not insist on any particular text/ reference and the student is welcome to select any that s/he finds suitable. Tutorial problem sets would be identified and provided to students of this course.

1. M. E. Van Valkenburg, "Network Analysis", Prentice Hall of India Private Limited, New Delhi – 110 001, Eastern Economy Edition, 1997 or later.
2. K. V. V. Murthy and M. S. Kamath, "Basic Circuit Analysis", Tata Mc-Graw Hill Publishing Company Limited, 1989.
3. Charles A. Desoer and Ernest S. Kuh, "Basic Circuit Theory", Mc-Graw Hill Book Company, 1969. (Could be rather expensive to purchase – would serve as a good library reference).
4. Donald E. Scott, "An introduction to circuit analysis – a systems approach", Tata Mc-Graw Hill Publishing Company Limited.
5. John O'Malley, "Basic Circuit Analysis", Schaum's Outlines: a kind of workbook, Tata Mc Graw Hill Publishing Company Limited.
6. A. Bruce Carlson, "Circuits", Thomson Brooks/ Cole, c 2000, Thomson Learning Inc., Indian Edition.
7. Lawrence Huelsman, "Basic Circuit Theory", Prentice Hall of India Private Limited, New Delhi – 110 001, Eastern Economy Edition.
8. William Hayt, Jack Kemmerly, "Engineering Circuit Analysis", International Student Edition, Tata Mc-Graw Hill Publishing Company Limited.
9. Ernst A. Guillemin, "Introductory Circuit Theory", John Wiley and Sons, Inc. (This book is rather rigorous in its approach. It may make difficult 'first reading'. It would, however, provide deep insight.)
10. Russell M. Mersereau, Joel R. Jackson, "Circuit Analysis – A Systems Approach", Pearson Education, Low Price Edition, 2007, ISBN 81-317-0712-1.
11. N. Balabanian, T.A. Bickart, S. Seshu, "Electrical Network Theory", John Wiley and Sons, Inc. (now Matrix Publishers), 1969.

12. L. O. Chua, C. A. Desoer, E. S. Kuh, “Linear and non-linear circuits”, McGraw Hill International Edition, 1987.
13. Franklin F. Kuo, “Network Analysis and Synthesis”, Second Edition, 1962, 1966, Wiley Singapore Edition, John Wiley and Sons (Asia) Pte. Ltd.
14. M. E. Van Valkenburg, “Introduction to Modern Network Synthesis”, Wiley Eastern Limited”.

COURSE ORGANIZATION AND EVALUATION: The course would involve, on an average, three contact hours per week. Typically, two of these are lecture hours and one is a tutorial hour. We may, once in a while, deviate from this norm, though we would adhere to this plan on an average.

Tutorial sheets would be provided to the students for reference. We shall discuss tutorial problems in the class and then groups of students would be required to put down a solution, have it reviewed and submit it for general reference. The instructor strongly encourages student participation in lectures and tutorials. In some of the contact hours, there could be an unannounced class test administered.

The **overall performance** of the student in the course will be ascertained based on the following components of evaluation, upon a total of 200 marks:

Class participation: Class tests, assignments, tutorial submissions, general classroom participation, attendance, course presentation/ term paper: 80 marks (40 percent weight)

Mid-semester examination: 50 marks (25 percent weight)

Semester-end examination: 70 marks (35 percent weight)

Overall student performance and award of grades: In evaluating the students, **two scores for class participation** will be computed **for every student**: one **saturated**, where the class participation marks upon 200 are limited to 80, even if the student has earned more than 80 marks and the other **unsaturated**, which means that the student can earn any number of marks in this component without a limit. Accordingly, two overall scores shall be computed for every student in the course: a **saturated score upon 200** and an **unsaturated score, which can well exceed 200** to any extent. There will be separate grading for the whole class based upon the saturated scores and upon the unsaturated scores. Thus, each student will initially be eligible for two grades, one based upon the saturated score that s/he has earned and one, upon the unsaturated score that s/he has earned. **Each student will then be finally be awarded the better of these two grades**, for which s/he is eligible.

In effect, the instructor would like to reward any exceptional efforts by a student during the semester in the course, during the award of grades, over and above the performance in regular examinations through this mechanism. The instructor believes that attendance in classes is very important and cannot be compromised, in general, other than for genuine exigencies.

Instructor: Prof. Vikram M. Gadre, Department of Electrical Engineering, IIT Bombay. Students are welcome to discuss issues/ difficulties pertaining to the course with the Instructor at mutually convenient times.

Welcome to the beautiful and fundamental subject of network theory!