# Syllabus

| CODE | COURSE NAME | CATEGORY | L | T | P | CREDITS |
|---|---|---|---|---|---|---|
| EET292 | NETWORK ANALYSIS AND SYNTHESIS | Core (Honors) | 3 | 1 | 0 | 4 |

**Preamble** : This honors course is designed with the objective of expanding the student's knowledge in network analysis beyond the basic topics. It includes advanced topics in network analysis, basics of filter design and network synthesis concepts. This course would help students to explore more advanced concepts in the analysis of complex networks.

**Prerequisite** : **EET201 Circuits and Networks**

**Course Outcomes** : After the completion of the course the student will be able to:

| | |
|---|---|
| **CO 1** | Apply network topology concepts in the formulation and solution of electric network problems. |
| **CO 2** | Apply two-port network analysis in the design and analysis of filter and attenuator networks. |
| **CO 3** | Identify the properties and characteristics of network functions, and verify the mathematical constraints for their physical realisation. |
| **CO 4** | Synthesize passive one-port networks using standard Foster and Cauer forms. |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | 3 | | | | | | | | | | 2 |
| **CO 2** | 3 | 3 | | | | | | | | | | 2 |
| **CO 3** | 3 | 3 | | | | | | | | | | 2 |
| **CO 4** | 3 | 3 | | | | | | | | | | 2 |

## Assessment Pattern

| Bloom's Category | Continuous Assessment Tests | | End Semester Examination |
|---|---|---|---|
| | 1 | 2 | |
| Remember (K1) | 15 | 15 | 20 |
| Understand (K2) | 20 | 20 | 50 |
| Apply (K3) | 15 | 15 | 30 |
| Analyse (K4) | - | - | - |
| Evaluate (K5) | - | - | - |
| Create (K6) | - | - | - |

**End Semester Examination Pattern** : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Model Question Paper**



**Reg. No.:**

**Name:** **Pages: 4**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**
**FOURTH SEMESTER B. TECH DEGREE EXAMINATION, MONTH & YEAR**

Course Code: **EET292**

**Course Name: Network Analysis and Synthesis**

Max. Marks: 100 Time: 3 hrs

**Part A**

**Answer *all* questions. Each question carries 3 marks.**

1. Define subgraph, path and a tree, with proper examples.
2. Describe the properties of the complete incidence matrix.
3. What are dual graphs? What is the condition for a network graph to have a dual? Illustrate with an example.
4. Describe a cut-set with an example.
5. Show that the image impedances of a two-port network are given by $Z_{im1} = \sqrt{\frac{AB}{CD}}$ and $Z_{im2} = \sqrt{\frac{BD}{AC}}$.
6. Draw the frequency response curves for ideal and non-ideal low pass filter, band pass filter, band reject filter, and high pass filter respectively.
7. For the pole-zero plot shown in Fig. 1 below, for a network function, identify the function and find its impulse response.
8. List the properties of positive real functions.
9. What are the properties of LC immittance functions.
10. Draw the Foster and Cauer forms of RC networks. (10 x 3 = 30)

**Part B**

**Answer any one full question from each module.**
**Each question carries 14 Marks.**

**Module 1**

11. (a) Draw the oriented graph of the given network shown in Fig. 2, and identify one tree and its co-tree. Obtain the incidence matrix. (6)

    (b) Find all voltages and branch currents in the network shown in Fig. 3 by node analysis, and applying network graph principles. (8)

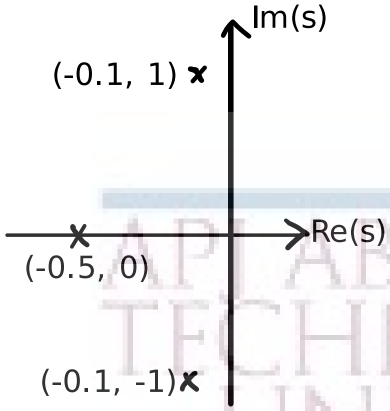


Figure 1: Pole Zero Plot

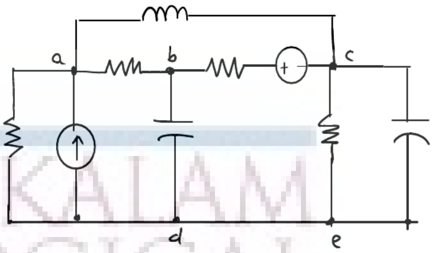


Figure 2: Figure for question 11 (a).

12. (a) The reduced incidence matrix A of an oriented graph is given below. (6)

$$A = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 & 1 & 0 & -1 \\ 1 & 0 & 1 & 0 & 0 & 0 & -1 & 0 \end{bmatrix}$$

Draw the graph of an electrical network represented by this matrix. The branches constituting the outer loop of are independent current sources branches. All the current sources have their branch current variable at 1 A. Find the currents in all other branches.

(b) Find the total power dissipated in the circuit shown in Fig. 4 by node analysis (graph based). (8)

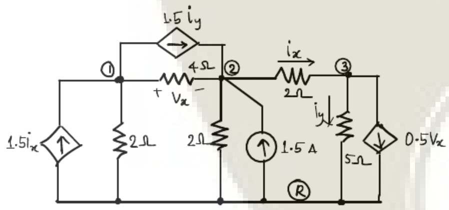

Figure 3: Figure for question 11 (b).

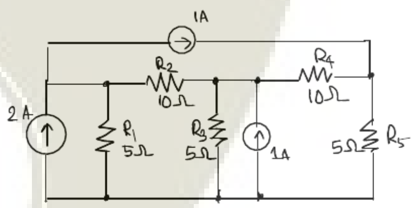

Figure 4: Figure for question 12 (b).

## Module 2

13. (a) Find the power delivered by the independent voltage sources in the network shown in Fig. 5 by loop analysis (use graph theory). Prepare the network graph using the reference directions marked in the figure. (8)

(b) A connected network has the fundamental circuit matrix given as, (6)

$$B_f = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 1 & 0 \\ 1 & -1 & -1 & 0 & 0 & 1 \end{bmatrix}$$

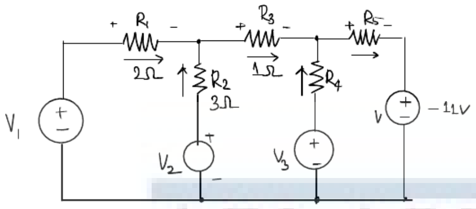


Figure 5: Figure for question 13 (a).

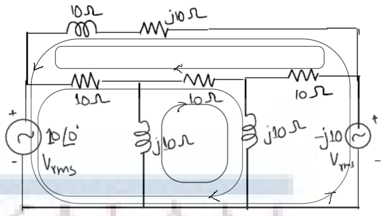


Figure 6: Figure for question 14 (a).

for some choice of tree. Obtain the f-cut-set matrix for the same tree.

14. (a) For the network shown in Fig. 6assign reference directions and draw the network graph. Obtain the connection matrix between branch currents and the loop currents in the three loops shown in the network diagram. Determine the loop impedance matrix of the network. (8)

(b) For the graph shown in Fig. 7, write the cut-set (KCL) equations for the following cut-sets: {1, 6}, {1,2,7,8}, {5, 6, 8, 9} and {2, 5, 7, 9}. Will this set of equations form an independent set of equations? If not why? (6)

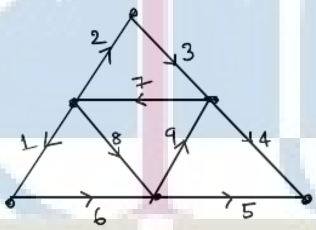


Figure 7: Figure for question 14 (b).

## Module 3

15. (a) Design a prototype T-section low-pass filter to cut-off at 100 Hz with a load resistance of 75Ω. Calculate the attenuation in Np and in dB at 200 Hz and 1 kHz. Also find the phase shift suffered by the output signal for 10 Hz and 50 Hz. (7)

(b) Design an m-derived high pass filter having a design impedance of 300 Ω, cut-off frequency of 2000 Hz and infinite attenuation at 1700 Hz. (7)

16. (a) The open-circuit voltage observed across a signal source varies between $\pm 100\ mV$. The voltage across a 60Ω resistance connected across this source is found to vary between $\pm 50\ mV$. Design a T-section attenuator such that the voltage across a 600 Ω load connected across the output of the attenuator varies between $\pm 5\ mV$. (7)

(b) Design the T-section and p-section of a constant K-type BPF that has a pass band from 1500 to 5500 Hz and characteristic resistance of 200 Ω. Further, find resonant frequency of series and shunt arms. (7)

## Module 4

17. (a) Test the following polynomials for the Hurwitz property: (6)
   (i). $s^3 + s^2 + 2s + 2$
   (ii). $s^7 + s^5 + s^3 + s$
   (iii). $s^7 + 2s^6 + 2s^5 + s^4 + 4s^3 + 8s^2 + 8s + 4$

   (b) Determine whether the following functions are positive real or not: (8)
   (i). $F(s) = \dfrac{2s^2 + 2s + 4}{(s+1)(s^2+2)}$
   (ii). $F(s) = \dfrac{5s^2 + s}{s^2 + 1}$

18. (a) Find the limits of K so that the polynomial $s^3 + 14s^2 + 56s + K$ may be Hurwitz. (6)

   (b) Find the driving point impedance Z(s) in the form $K\dfrac{N(s)}{D(s)}$ for the network shown in Fig. 8. Verify that Z(s) is positive real and that the polynomial D(s)+KN(s) is Hurwitz. (8)

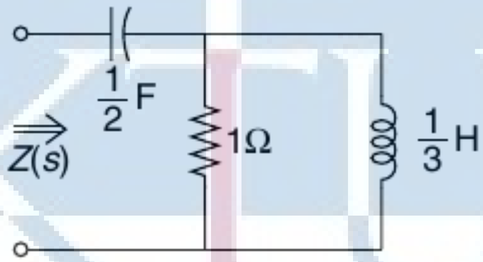


Figure 8: Figure for question 18 (b).

## Module 5

19. Realise the impedance $Z(s) = \dfrac{2(s^2+1)(s^2+0)}{s(s^2+4)}$ in three different ways. (14)

20. (a) For the network function $Y(s) = \dfrac{2(s+1)(s+3)}{(s+2)(s+4)}$, synthesise a Foster form and a Cauer form realisations. (10)

   (b) Check whether the driving point impedance $Z(s) = \dfrac{s^4 + s^2 + 1}{s^3 + 2s^2 - 2s + 10}$ represents a passive network or not. (4)

## Course Level Assessment Questions

**Course Outcome 1 (CO1):**

[K1]: Questions on Network topology terminology, definitions.

[K2}: Questions on identification of graphs, paths, sub-paths, etc., Questions on incidence matrix.

[K2, K3] Understand level and application level numerical problems on application of Kirchoff's laws in matrix formulation, nodal analysis.

[K2, K3]. Numerical problems on graph theory based network analysis, cut-set, circuit matrices, nodal and loop analysis.

**Course Outcome 2 (CO2):** [K1, K2] Questions on definitions and properties of filters.

[K2, K3]. Numerical problems on constant-k and m-derived filter design and analysis.

**Course Outcome 3 (CO3):** [K1] Questions on the properties of network functions and realizability of passive impedance functions.

[K2, K3]. Numerical problems on the realizability of network functions, testing of positive real functions and Hurwitz polynomials.

**Course Outcome 4 (CO4):** [K1]. Questions to describe Foster and Cauer forms and the properties of immittance functions.

[K2, K3]. Numerical problems to synthesise networks in Foster and Cauer forms.

## Syllabus



**Module 1**

Network Topology (8 hours)

Linear Oriented Graphs -incidence matrix of a linear oriented graph –Kirchoff's Laws in incidence matrix formulation –nodal analysis of networks (independent and dependent sources) – Circuit matrix of linear oriented graph –Kirchoff's laws in fundamental circuit matrix formulation.

**Module 2** (8 hours)

Loop analysis of electric networks (with independent and dependent sources) - Planar graphs –Mesh analysis- Duality –Cut set matrix -Fundamental cut set matrix –Relation between circuit, cut set and incidence matrices –Kirchoff's laws in fundamental cut-set formulation –Node-pair analysis – Analysis using generalized branch model (node, loop and node pair analysis) –Tellegen's theorem.

**Module 3:** (12 hours)

Modeling Two-port networks-application examples-amplifiers, transmission lines, passive filters.

Review of network parameter sets for two-port networks (z, y, h, g, T parameters, equivalent circuits and inter-relationship between parameters). (Review may be done using assignments/homeworks).

Image parameter description of a reciprocal two-port network -- Image impedance -Characteristic impedance - propagation constant—derivation of characteristic impedance and propagation constant for T and Pi networks under sinusoidal steady state --Attenuation constant and phase constant.

Filter terminology: Low pass, high pass, band-pass and band-reject filters.

Constant k and m-derived filters -- low pass, high pass, band-pass and band-stop filters --design--effect of cascading multiple sections. Resistive T, Pi and lattice attenuators.

**Module 4**

Network Functions (10 hours)

Review of Network functions for one port and two port networks: – pole zero location for driving point and transfer functions-Impulse response of Network functions from pole-zero plots- Sinusoidal steady-state frequency response from pole-zero plots.

Hurwitz polynomials –properties - Positive real functions –Properties of positive real functions – passivity-necessary and sufficient conditions for positive real functions-physical realizability.

**Module 5**

Synthesis of one port networks (8 hours)

Synthesis of reactive one-ports by Foster's and Cauer methods (forms I and II) -Synthesis of LC, RC and RL driving-point functions.

**Text Books**


1. K. S. Suresh Kumar, "Electric Circuit Analysis", Pearson Publications, 2013.
2. Ravish R. Singh, "Network Analysis and Synthesis", McGraw-Hill Education, 2013


**References**


1. Franklin Kuo, "Network Analysis and Synthesis", 2nd Ed.,Wiley India.
2. Van Valkenburg M.E., "Introduction to Modern Network Synthesis," Wiley Eastern, 1960 (reprint 1986).
3. Van Valkenburg M.E, "Network Analysis," Prentice Hall India, 2014.
4. Charles A. Desoer and Ernest S. Kuh, "Basic Circuit Theory," Tata McGraw Hill Edition.
5. Chakrabarti, A., "Circuit Theory Analysis and Synthesis", DhanpatRai& Co., Seventh - Revised edition, 2018
6. S. K. Bhattacharya, "Network Analysis and Synthesis," Pearson Education India.

**Course Contents and Lecture Schedule:**



| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Network Topology (8 hours)** | |
| 1.1 | Linear Oriented Graphs - Connected Graph, sub graphs, paths, The incidence matrix of a linear oriented graph – Path matrix, its relation to incidence matrix. | 2 |
| 1.2 | Kirchoff's Laws in incidence matrix formulation – nodal analysis of networks (independent and dependent sources) principle of v-shifting. | 2 |
| 1.3 | Circuit matrix of linear oriented graph – Fundamental Circuit matrix $B_f$. Relation between All incidence matrix and All Circuit matrix. | 2 |
| 1.4 | Kirchoff's laws in fundamental circuit matrix formulation - | 2 |
| **2** | **(8 hours)** | |
| 2.1 | Loop analysis of electric networks (with independent and dependent sources) -- Planar graphs –Mesh analysis- Duality. | 2 |
| 2.2 | Cut set matrix -Fundamental cut set matrix –Relation between circuit, cut set and incidence matrices – Orthogonality relation. | 2 |
| 2.3 | Kirchoff's laws in fundamental cut-set formulation –Node-pair analysis. i-shifting. | 2 |
| 2.4 | Analysis using generalized branch model (node, loop and node pair analysis) –Tellegen's theorem. | 2 |
| **3** | **(13 hours)** | |
| 3.1 | Modeling Two-port networks - application examples-amplifiers, transmission lines, passive filters.<br><br>Review of network parameter sets for two-port networks (z, y, h, g, T parameters, equivalent circuits and inter-relationship between parameters, Standard T- and pi networks. (Review may be done using assignments/homeworks). | 2 |
| 3.2 | Image parameter description of a reciprocal two-port network - Image impedance. | 1 |
| 3.3 | Characteristic impedance - propagation constant—derivation of characteristic impedance and propagation constant for T and Pi networks under sinusoidal steady state -- Attenuation constant and phase constant. | 2 |

| | | |
|---|---|---|
| 3.4 | Filter terminology: Low pass, high pass, band-pass and band-reject filters. Gain characteristics.<br><br>Constant k-derived low pass filter -- Comparison with ideal low-pass filter -- Prototype Low pass filter design. | 2 |
| 3.5 | m-derived low pass filter sections, m-derived half-sections for filter termination. m-derived half-sections for input termination. Half-pi termination for pi section filters. | 2 |
| 3.6 | Constant k- and m-derived high pass filters --Design.<br><br>Constant k- band-pass filter -- Design of prototype bandpass filter -- Constant-k band-stop filter-effect of cascading multiple sections. | 2 |
| 3.7 | Resistive attenuators-Symmetric T and Pi section attenuators -- Lattice-section attenuator- Symmetrical bridged T-section attenuator -Asymmetrical T-Section and Pi-section attenuator. | 2 |
| **4** | **Network Functions (7 hours)** | |
| 4.1 | Review of Network functions for one port and two port networks: – calculation of network functions for ladder and general networks-poles and zeros for network functions-pole zero location for driving point and transfer functions. | 2 |
| | Impulse response of Network functions from pole-zero plots- Sinusoidal steady-state frequency response from pole-zero plots. | 2 |
| | Hurwitz polynomials – properties - Positive real functions – Properties of positive real functions – passivity-necessary and sufficient conditions for positive real functions - physical realizability. | 3 |
| **5** | **Synthesis of one port networks (9 hours)** | |
| 5.1 | Synthesis of reactive one - ports by Foster's and Cauer methods (forms I and II):<br><br>Synthesis of R–C Network -- Properties of the R–C Impedance or R–L Admittance Function -- Foster Form-I of R–C Network -- Foster Form-II of R–C Network, Cauer Forms of R–C Network. | 3 |
| 5.2 | Synthesis of R–L Network -- Properties of R–L Function/R–C Admittance Function -- Foster Form-I of R–L Network -- Foster Form-II of R–L Network -- Cauer Form-I of R–L Network -- Cauer Form-II R–L Network. | 3 |
| 5.3 | Synthesis of L–C Networks -- Properties of L–C Immittance -- Foster Form-I of L–C Network -- Foster Form-II of L–C Network -- Cauer Form-I of L–C Network -- Cauer Form-II of L–C Network. | 3 |