

## Filter Design

Course Objective:

To familiarize student with the concept of analog filter design: passive filters, RC active filters and switched-capacitor filters.

### 1. Introduction [4 hours]

- a. Filter and its importance in communication
- b. Kinds of filters in terms of frequency response
- c. Ideal response and response of practical filters
- d. Normalization and denormalization in filter design
- e. Impedance (magnitude) scaling and frequency scaling
- f. History of filter design and available filter technologies

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### 2. Approximation Methods [8 hours]

- a. Approximation and its importance in filter design
- b. Lowpass approximations methods
- c. Butterworth response, Butterworth pole locations, Butterworth filter design from specifications
- d. Chebyshev and inverse Chebyshev characteristics, network functions and pole zero locations
- e. Characteristics of Cauer (elliptic) response
- f. Bessel-Thomson approximation of constant delay
- g. Delay Equalization

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### 3. Frequency transformation [2 hours]

- a. Frequency transformation and its importance in filter design
- b. Lowpass to highpass transformation
- c. Lowpass to bandpass transformation and
- d. Lowpass to bandstop transformation

### 4. Properties and Synthesis of Passive Networks [7 hours]

- a. One-port passive circuits
  - i. Properties of passive circuits, positive real functions
  - ii. Properties of lossless circuits
  - iii. Synthesis of LC one-port circuits, Foster and Cauer circuits
  - iv. Properties and synthesis of RC one-port circuits
- b. Two-port Passive Circuits
  - i. Properties of passive two-port circuits, residue condition, transmission zeros
  - ii. Synthesis of two-port LC and RC ladder circuits based on zero-shifting by partial pole removal

### 5. Design of Resistively-Terminated Lossless Filter [4 hours]

- a. Properties of resistively-terminated lossless ladder circuits, transmission and reflection coefficients
- b. Synthesis of LC ladder circuits to realize all-pole lowpass functions
- c. Synthesis of LC ladder circuits to realize functions with finite transmission zeros

## 6. Active Filter[7 hours]

- a. Fundamentals of Active Filter Circuits
  - i. Active filter and passive filter
  - ii. Ideal and real operational amplifiers, gain-bandwidth product
  - iii. Active building blocks: amplifiers, summers, integrators
  - iv. First order active sections using inverting and non-inverting op-amp configuration
- b. Second order active sections (biquads)
  - i. Tow-Thomas biquad circuit, design of active filter using Tow-Thomas biquad
  - ii. Sallen-Key biquad circuit and Multiple-feedback biquad (MFB) circuit
  - iii. Gain reduction and gain enhancement
  - iv. RC-CR transformation

## 7. Sensitivity[3 hours]

- a. Sensitivity and importance of sensitivity analysis
- b. Definition of single parameter sensitivity
- c. Centre frequency and Q-factor sensitivity
- d. Sensitivity properties of biquads
- e. Sensitivity of passive circuits

## 8. Design of High-Order Active Filters[6 hours]

- a. Cascade of biquads
  - i. Sequencing of filter blocks, center frequency, Q-factor and gain
- b. Active simulation of passive filters
  - i. Ladder design with simulated inductors
  - ii. Ladder design with frequency-dependent negative resistors (FDNR)
  - iii. Leapfrog simulation of ladders

## 9. Switched-Capacitor Filters[4 hours]

- a. The MOS switch and switched capacitor
- b. Simulation of resistor by switched capacitor
- c. Switched-capacitor circuits for analog operations: addition, subtraction, multiplication and integration
- d. First-order and second-order switched-capacitor circuits

### Practical:

The laboratory experiments consist computer simulation as well hardware realization for analysis and design of passive and active filters which include.

1. Analysis and design of passive & active filter circuits using computer simulation
2. Design of active filters using biquad circuits
3. Design of higher order active filters using inductor simulation
4. Design of higher order active filters using functional simulation

### References:

1. Design of Analog Filters By: Rolf Schaumann, Mac E. Van Valkenburg
2. Passive and Active Filters (Theory and Implementations) By: Wai-Kai Chen
3. Analog Filter, Kendal L Su

- e. Protection Mechanisms
- f. Authentication
- g. OS Design Considerations For Security
- h. Access Control Lists And OS Support

9. System administration (4 hours)

- a. Administration Tasks
- b. User Account Management
- c. Start And Shutdown Procedures
- d. Setting up Operational Environment for a New User
- e. AWK tool, Search, Sort tools, Shell scripts, Make tool

Practical:

1. Shell commands, shell programming: write simple functions, basic tests, loops, patterns, expansions, substitutions
2. Programs using the following system calls of UNIX operating system: fork, exec, getpid, exit, wait, close, stat, opendir, readdir
3. Programs using the I/O system calls of UNIX operating system
4. Implement the Producer – Consumer problem using semaphores.
5. Implement some memory management schemes

Reference Books:

1. Andrew S. Tanenbaum, "Modern Operating Systems", 3rd Edition, PHI
2. Stallings William, "Operating Systems", 6th Edition, Pearson Education
3. Silberschatz A., Galvin P., Gagne G., "Operating System Concepts", 8th Edition, John Wiley and Sons,
4. Milan Milenkovic, "Operating Systems Concepts and Design", TMGH
5. Das Sumitabha, "Unix Concepts and Applications", 3rd Edition, Tata McGraw Hill, 2003
6. M. J. Bach, "The Design of The Unix Operating System", PHI.
7. Charles Crowley, "Operating Systems: A Design-oriented Approach", TMH.

**Evaluation Scheme:**

Unit	Hour	Marks Distribution*
1	4	7
2	8	14
3	2	4
4	7	13
5	4	7
6	7	12
7	3	5
8	6	11
9	4	7
Total	45	80

**\*Note: There may be minor deviation in marks distribution.**