

ANNA UNIVERSITY COIMBATORE

AFFILIATED INSTITUTIONS

CURRICULUM 2008

B.E. ELECTRONICS AND COMMUNICATION ENGINEERING

3 & 4 SEMESTERS CURRICULUM AND SYLLABI

SEMESTER III

(Applicable to the students admitted from the Academic year 2008–2009 onwards)

Code No.	Course Title	L	T	P	C
THEORY					
MA 2211	Transforms and Partial Differential Equations	3	1	0	4
EC 2201	Electrical Engineering	3	0	0	3
EC 2202	Data Structures and Object Oriented Programming in C++	3	0	0	3
EC 2203	Digital Electronics	3	1	0	4
EC 2204	Signals and systems	3	1	0	4
EC 2205	Electronic Circuits- I	3	1	0	4
PRACTICAL					
EC 2207	Digital Electronics Lab	0	0	3	2
EC 2208	Electronic Circuits - I Lab	0	0	3	2
EC 2209	Data structures and Object Oriented Programming Lab	0	0	3	2

SEMESTER IV

(Applicable to the students admitted from the Academic year 2008–2009 onwards)

Code No.	Course Title	L	T	P	C
THEORY					
MA 2261	Probability and Random Processes	3	1	0	4
EC 2251	Electronic Circuits II	3	1	0	4
EC 2252	Communication Theory	3	1	0	4
EC 2253	Electromagnetic Fields	3	1	0	4
EC 2254	Linear Integrated Circuits	3	0	0	3
EC 2255	Control Systems	3	0	0	3
PRACTICAL					
EC 2257	Electronics circuits II and simulation lab	0	0	3	2
EC 2258	Linear Integrated Circuit Lab	0	0	3	2
EC 2259	Electrical Engineering and Control System Lab	0	0	3	2

MA2211 TRANSFORMS AND PARTIAL DIFFERENTIAL EQUATIONS 3 1 0 4
(Common to all branches)

OBJECTIVES

The course objective is to develop the skills of the students in the areas of Transforms and Partial Differential Equations. This will be necessary for their effective studies in a large number of engineering subjects like heat conduction, communication systems, electro-optics and electromagnetic theory. The course will also serve as a prerequisite for post graduate and specialized studies and research.

1. FOURIER SERIES 9 + 3

Dirichlet's conditions – General Fourier series – Odd and even functions – Half range sine series – Half range cosine series – Complex form of Fourier Series – Parseval's identify – Harmonic Analysis.

2. FOURIER TRANSFORMS 9 + 3

Fourier integral theorem (without proof) – Fourier transform pair – Sine and Cosine transforms – Properties – Transforms of simple functions – Convolution theorem – Parseval's identity.

3. PARTIAL DIFFERENTIAL EQUATIONS 9 + 3

Formation of partial differential equations – Lagrange's linear equation – Solutions of standard types of first order partial differential equations - Linear partial differential equations of second and higher order with constant coefficients.

4. APPLICATIONS OF PARTIAL DIFFERENTIAL EQUATIONS 9 + 3

Solutions of one dimensional wave equation – One dimensional equation of heat conduction – Steady state solution of two-dimensional equation of heat conduction (Insulated edges excluded) – Fourier series solutions in cartesian coordinates.

5. Z-TRANSFORMS AND DIFFERENCE EQUATIONS 9 + 3

Z-transforms - Elementary properties – Inverse Z-transform – Convolution theorem - Formation of difference equations – Solution of difference equations using Z-transform.

Lectures : 45 Tutorials : 15 Total : 60

TEXT BOOKS

1. Grewal, B.S, "*Higher Engineering Mathematic*", 40th Edition, Khanna publishers, Delhi, (2007)

REFERENCES

1. Bali.N.P and Manish Goyal, "*A Textbook of Engineering Mathematic*", 7th Edition, Laxmi Publications(P) Ltd. (2007)
2. Ramana.B.V., "*Higher Engineering Mathematics*", Tata Mc-GrawHill Publishing Company limited, New Delhi (2007).
3. Glyn James, "*Advanced Modern Engineering Mathematics*", 3rd Edition, Pearson Education (2007).
4. Erwin Kreyszig, "*Advanced Engineering Mathematics*", 8th edition, Wiley India (2007).

AIM

To expose the students to the concepts of various types of electrical machines and transmission and distribution of electrical power .

OBJECTIVES

To impart knowledge on

- Constructional details, principle of operation, performance, starters and testing of D.C. machines.
- Constructional details, principle of operation and performance of transformers.
- Constructional details, principle of operation and performance of induction motors.
- Constructional details and principle of operation of alternators and special machines.
- Power System transmission and distribution.

UNIT I D.C. MACHINES 9

Constructional details – emf equation – Methods of excitation – Self and separately excited generators – Characteristics of series, shunt and compound generators – Principle of operation of D.C. motor – Back emf and torque equation – Characteristics of series, shunt and compound motors - Starting of D.C. motors – Types of starters - Testing, brake test and Swinburne's test – Speed control of D.C. shunt motors.

UNIT II TRANSFORMERS 9

Constructional details – Principle of operation – emf equation – Transformation ratio – Transformer on no load – Parameters referred to HV/LV windings – Equivalent circuit – Transformer on load – Regulation - Testing – Load test, open circuit and short circuit tests.

UNIT III INDUCTION MOTORS 9

Construction – Types – Principle of operation of three-phase induction motors – Equivalent circuit – Performance calculation – Starting and speed control – Single-phase induction motors (only qualitative treatment).

UNIT IV SYNCHRONOUS AND SPECIAL MACHINES 9

Construction of synchronous machines-types – Induced emf – Voltage regulation; emf and mmf methods – Brushless alternators – Reluctance motor – Hysteresis motor – Stepper motor.

UNIT V TRANSMISSION AND DISTRIBUTION 9

Structure of electric power systems – Generation, transmission and distribution systems - EHVAC and EHVDC transmission systems – Substation layout – Insulators – cables.

L = 45 TOTAL = 45

TEXT BOOKS

1. D.P.Kothari and I.J.Nagrath, 'Basic Electrical Engineering', Tata McGraw Hill publishing company ltd, second edition, 2007 (Reprint).
2. C.L. Wadhwa, 'Electrical Power Systems', New Age International, fourth edition, 2007.

REFERENCE BOOKS

1. S.K.Bhattacharya, 'Electrical Machines', Tata McGraw Hill Publishing company ltd, second edition, 2007.
2. V.K.Mehta and Rohit Mehta, 'Principles of Power System', S.Chand and Company Ltd, second edition, 2006.

AIM

To provide an in-depth knowledge in problem solving techniques and data structures.

OBJECTIVES

- To learn the systematic way of solving problems
- To understand the different methods of organizing large amounts of data
- To learn to program in C++
- To efficiently implement the different data structures
- To efficiently implement solutions for specific problems

UNIT – I PRINCIPLES OF OBJECT ORIENTED PROGRAMMING 9
Introduction- Tokens-Expressions-contour Structures –Functions in C++, classes and objects, constructors and destructors ,operators overloading and type conversions .

UNIT – II ADVANCED OBJECT ORIENTED PROGRAMMING 9
Inheritance, Extending classes, Pointers, Virtual functions and polymorphism, File Handling Templates ,Exception handling, Manipulating strings.

UNIT – III DATA STRUCTURES & ALGORITHMS 9
Algorithm, Analysis, Lists, Stacks and queues, Priority queues-Binary Heap-Application, Heaps–hashing-hash tables without linked lists

UNIT – IV NONLINEAR DATA STRUCTURES 9
Trees-Binary trees, search tree ADT, AVL trees, Graph Algorithms-Topological sort, shortest path algorithm network flow problems-minimum spanning tree - Introduction to NP - completeness.

UNIT – V SORTING AND SEARCHING 9
Sorting – Insertion sort, Shell sort, Heap sort, Merge sort, Quick sort, Indirect sorting, Bucket sort, Introduction to Algorithm Design Techniques –Greedy algorithm (Minimum Spanning Tree), Divide and Conquer (Merge Sort), Dynamic Programming (All pairs Shortest Path Problem).

Total hours = 45

TEXT BOOKS:

1. Mark Allen Weiss, “Data Structures and Algorithm Analysis in C”, 3rd ed, Pearson Education Asia, 2007.
2. E. Balagurusamy, “ Object Oriented Programming with C++”, McGraw Hill Company Ltd., 2007.

REFERENCES:

1. Michael T. Goodrich, “Data Structures and Algorithm Analysis in C++”, Wiley student edition, 2007.
2. Sahni, “Data Structures Using C++”, The McGraw-Hill, 2006.
3. Seymour, “Data Structures”, The McGraw-Hill, 2007.
4. Jean – Paul Tremblay & Paul G.Sorenson, An Introduction to data structures with applications, Tata McGraw Hill edition, II Edition, 2002.
5. John R.Hubbard, Schaum’s outline of theory and problem of data structure with C++, McGraw-Hill, New Delhi, 2000.
6. Bjarne Stroustrup, The C++ Programming Language, Addison Wesley, 2000
7. Robert Lafore, Object oriented programming in C++, Galgotia Publication

AIM

To learn the basic methods for the design of digital circuits and provide the fundamental concepts used in the design of digital systems.

OBJECTIVES

- To introduce basic postulates of Boolean algebra and shows the correlation between Boolean expressions
- To introduce the methods for simplifying Boolean expressions
- To outline the formal procedures for the analysis and design of combinational circuits and sequential circuits
- To introduce the concept of memories and programmable logic devices.
- To illustrate the concept of synchronous and asynchronous sequential circuits

UNIT I MINIMIZATION TECHNIQUES AND LOGIC GATES 9

Minimization Techniques: Boolean postulates and laws – De-Morgan's Theorem - Principle of Duality - Boolean expression - Minimization of Boolean expressions — Minterm – Maxterm - Sum of Products (SOP) – Product of Sums (POS) – Karnaugh map Minimization – Don't care conditions - Quine-McCluskey method of minimization.

Logic Gates: AND, OR, NOT, NAND, NOR, Exclusive-OR and Exclusive-NOR- Implementations of Logic Functions using gates, NAND-NOR implementations – Multi level gate implementations- Multi output gate implementations. TTL and CMOS Logic and their characteristics – Tristate gates.

UNIT II COMBINATIONAL CIRCUITS 9

Design procedure – Half adder – Full Adder – Half subtractor – Full subtractor - Parallel binary adder, parallel binary Subtractor – Fast Adder - Carry Look Ahead adder – Serial Adder/Subtractor - BCD adder – Binary Multiplier – Binary Divider - Multiplexer/ Demultiplexer – decoder - encoder – parity checker – parity generators - code converters - Magnitude Comparator.

UNIT III SEQUENTIAL CIRCUITS 9

Latches, Flip-flops - SR, JK, D, T, and Master-Slave – Characteristic table and equation –Application table – Edge triggering – Level Triggering – Realization of one flip flop using other flip flops – serial adder/subtractor- Asynchronous Ripple or serial counter – Asynchronous Up/Down counter - Synchronous counters – Synchronous Up/Down counters – Programmable counters – Design of Synchronous counters: state diagram-State table –State minimization –State assignment - Excitation table and maps-Circuit implementation - Modulo-n counter, Registers – shift registers - Universal shift registers – Shift register counters – Ring counter – Shift counters - Sequence generators.

UNIT IV MEMORY DEVICES

9

Classification of memories – ROM - ROM organization - PROM – EPROM – EEPROM – EAPROM, RAM – RAM organization – Write operation – Read operation – Memory cycle - Timing wave forms – Memory decoding – memory expansion – Static RAM Cell- Bipolar RAM cell – MOSFET RAM cell – Dynamic RAM cell –Programmable Logic Devices – Programmable Logic Array (PLA) - Programmable Array Logic (PAL) - Field Programmable Gate Arrays (FPGA) - Implementation of combinational logic circuits using ROM, PLA, PAL

UNIT V SYNCHRONOUS AND AYNCHRONOUS SEQUENTIAL CIRCUITS

9

Synchronous Sequential Circuits: General Model – Classification – Design – Use of Algorithmic State Machine – Analysis of Synchronous Sequential Circuits

Asynchronous Sequential Circuits: Design of fundamental mode and pulse mode circuits – Incompletely specified State Machines – Problems in Asynchronous Circuits – Design of Hazard Free Switching circuits. Design of Combinational and Sequential circuits using VERILOG

TUTORIAL = 15 Hrs.

TOTAL : 60 Hrs.

TEXT BOOKS

1. M. Morris Mano, Digital Design, 3rd Edition, Prentice Hall of India Pvt. Ltd., 2003 / Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2003.
2. S. Salivahanan and S. Arivazhagan, Digital Circuits and Design, 3rd Edition., Vikas Publishing House Pvt. Ltd, New Delhi, 2006

REFERENCES

1. John F.Wakerly, Digital Design, Fourth Edition, Pearson/PHI, 2006
2. John.M Yarbrough, Digital Logic Applications and Design, Thomson Learning, 2002.
3. Charles H.Roth. Fundamentals of Logic Design, Thomson Learning, 2003.
4. Donald P.Leach and Albert Paul Malvino, Digital Principles and Applications, 6th Edition, TMH, 2003.
5. William H. Gothmann, Digital Electronics, 2nd Edition, PHI, 1982.
6. Thomas L. Floyd, Digital Fundamentals, 8th Edition, Pearson Education Inc, New Delhi, 2003
7. Donald D.Givone, Digital Principles and Design, TMH, 2003.

AIM

To study and analyse characteristics of continuous, discrete signals and systems.

OBJECTIVES

- To study the properties and representation of discrete and continuous signals.
- To study the sampling process and analysis of discrete systems using z-transforms.
- To study the analysis and synthesis of discrete time systems.

1. CLASSIFICATION OF SIGNALS AND SYSTEMS 9

Continuous time signals (CT signals), discrete time signals (DT signals) - Step, Ramp, Pulse, Impulse, Exponential, Classification of CT and DT signals - periodic and periodic, random signals, CT systems and DT systems, Basic properties of systems - Linear Time invariant Systems and properties.

2. ANALYSIS OF CONTINUOUS TIME SIGNALS 9

Fourier series analysis, Spectrum of C.T. signals, Fourier Transform and Laplace Transform in Signal Analysis.

3. LINEAR TIME INVARIANT –CONTINUOUS TIME SYSTEMS 9

Differential equation, Block diagram representation, Impulse response, Convolution integral, frequency response, Fourier and Laplace transforms in analysis, State variable equations and matrix representation of systems

4. ANALYSIS OF DISCRETE TIME SIGNALS 9

Sampling of CT signals and aliasing, DTFT and properties, Z-transform and properties of Z-transform.

5. LINEAR TIME INVARIANT - DISCRETE TIME SYSTEMS 9

Difference equations, Block diagram representation, Impulse response, Convolution sum, LTI systems analysis using DTFT and Z-transforms, State variable equations and matrix representation of systems.

Tutorial = 15

Total No of periods: 45 + 15 = 60

TEXT BOOK:

1. Allan V. Oppenheim, S. Wilsky and S.H. Nawab, Signals and Systems, Pearson Education, 2007.
2. Edward W. Kamen & Bonnie's Heck, "Fundamentals of Signals and Systems", Pearson Education, 2007.

REFERENCES:

1. H P Hsu, Rakesh Ranjan " Signals and Systems", Schaum's Outlines, Tata McGraw Hill, Indian Reprint, 2007
2. S. Salivahanan, A. Vallavaraj, C. Gnanapriya, Digital Signal Processing, McGraw Hill International/TMH, 2007.
3. Simon Haykins and Barry Van Veen, Signals and Systems John Wiley & sons, Inc, 2004.
4. Robert A. Gabel and Richard A. Roberts, Signals & Linear Systems, John Wiley, III edition, 1987.
5. Rodger E. Ziemer, William H. Tranter, D. Ronald Fannin. Signals & systems, Fourth Edition, Pearson Education, 2002.

AIM

The aim of this course is to familiarize the student with the analysis and design of basic transistor Amplifier circuits and power supplies.

OBJECTIVE

On completion of this course the student will understand

- The methods of biasing transistors
- Design of simple amplifier circuits
- Midband analysis of amplifier circuits using small - signal equivalent circuits to determine gain input impedance and output impedance
- Method of calculating cutoff frequencies and to determine bandwidth
- Design of power amplifiers
- Analysis and design of power supplies.

UNIT I TRANSISTOR BIAS STABILITY**9**

BJT – Need for biasing – Stability factor - Fixed bias circuit, Load line and quiescent point. Variation of quiescent point due to h_{FE} variation within manufacturers tolerance - Stability factors - Different types of biasing circuits - Method of stabilizing the Q point - Advantage of Self bias (voltage divider bias) over other types of biasing, Bias compensation – Diode, Thermistor and Sensistor compensations, Biasing the FET and MOSFET.

UNIT II MIDBAND ANALYSIS OF SMALL SIGNAL AMPLIFIERS**9**

CE, CB and CC amplifiers - Method of drawing small-signal equivalent circuit - Midband analysis of various types of single stage amplifiers to obtain gain, input impedance and output impedance - Miller's theorem - Comparison of CB, CE and CC amplifiers and their uses - Methods of increasing input impedance using Darlington connection and bootstrapping - CS, CG and CD (FET) amplifiers - Multistage amplifiers. Basic emitter coupled differential amplifier circuit - Bisection theorem. Differential gain – CMRR - Use of constant current circuit to improve CMRR - Derivation of transfer characteristic.

UNIT III FREQUENCY RESPONSE OF AMPLIFIERS**9**

General shape of frequency response of amplifiers - Definition of cutoff frequencies and bandwidth - Low frequency analysis of amplifiers to obtain lower cutoff frequency Hybrid – π equivalent circuit of BJTs - High frequency analysis of BJT amplifiers to obtain upper cutoff frequency – Gain Bandwidth Product - High frequency equivalent circuit of FETs - High frequency analysis of FET amplifiers - Gain-bandwidth product of FETs - General expression for frequency response of multistage amplifiers - Calculation of overall upper and lower cutoff frequencies of multistage amplifiers - Amplifier rise time and sag and their relation to cutoff frequencies.

UNIT IV LARGE SIGNAL AMPLIFIERS

9

Classification of amplifiers, Class A large signal amplifiers, second harmonic distortion, higher order harmonic distortion, transformer-coupled class A audio power amplifier – efficiency of Class A amplifiers. Class B amplifier – efficiency - push-pull amplifier - distortion in amplifiers - complementary-symmetry (Class B) push-pull amplifier, Class C, Class D amplifier – Class S amplifier – MOSFET power amplifier, Thermal stability and heat sink.

UNIT V RECTIFIERS AND POWER SUPPLIES

9

Classification of power supplies, Rectifiers - Half-wave, full-wave and bridge rectifiers with resistive load. Analysis for V_{dc} and ripple voltage with C, L, LC and CLC filters. Voltage multipliers, Voltage regulators - Zener diode regulator, principles of obtaining a regulated power supply, regulator with current limiting, Over voltage protection, Switched mode power supply (SMPS), Power control using SCR.

TUTORIAL = 15

TOTAL : 60

TEXT BOOKS

1. Millman J and Halkias .C., Integrated Electronics, TMH, 2007.
2. S. Salivahanan, N. Suresh Kumar and A. Vallavaraj, Electronic Devices and Circuits, 2nd Edition, TMH, 2007.

REFERENCES

1. Robert L. Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory, 9th Edition, Pearson Education / PHI, 2007.
2. David A. Bell, Electronic Devices & Circuits, 4th Edition, PHI, 2007
3. Floyd, Electronic Devices, Sixth Edition, Pearson Education, 2002.
4. I.J. Nagrath, Electronic Devices and Circuits, PHI, 2007.
5. Anwar A. Khan and Kanchan K. Dey, A First Course on Electronics, PHI, 2006.
6. B.P. Singh and Rekha Singh, Electronic Devices and Integrated Circuits, Pearson Education, 2006.
7. Rashid M, Microelectronics Circuits, Thomson Learning, 2007.

1. Design and implementation of Adder and Subtractor using logic gates.
2. Design and implementation of code converters using logic gates
 - (i) BCD to excess-3 code and vice versa
 - (ii) Binary to gray and vice-versa
3. Design and implementation of 4 bit binary Adder/ subtractor and BCD adder using IC 7483
4. Design and implementation of 2 bit Magnitude Comparator using logic gates 8 Bit Magnitude Comparator using IC 7485
5. Design and implementation of 16 bit odd/even parity checker generator using IC74180.
6. Design and implementation of Multiplexer and De-multiplexer using logic gates and study of IC74150 and IC 74154
7. Design and implementation of encoder and decoder using logic gates and study of IC7445 and IC74147
8. Construction and verification of 4 bit ripple counter and Mod-10 / Mod-12 Ripple counters
9. Design and implementation of 3-bit synchronous up/down counter
10. Implementation of SISO, SIPO, PISO and PIPO shift registers using Flip- flops
11. Design of experiments 1, 6, 8 and 10 using Verilog Hardware Description Language

LIST OF EQUIPMENTS AND COMPONENTS FOR A BATCH OF 30 STUDENTS (2 per Batch)

S.No	Name of the equipments / Components	Quzntity Required	Remarks
1	Digital IC Tester	2 Nos	
2	Power Supply	10	5V DC
3	Multimeter	10	Digital
4	Computer with HDL software Installed	2	
Consumables (Minimum of 25 Nos. each)			
1	IC7400	25	
2	IC7404	25	
3	IC74682	25	
4	IC7402	25	
5	IC7408	25	
6	IC7411	25	
7	IC7432	25	
8	IC7483	25	
9	IC7485	25	

10	IC7486	25	
11	IC74150	25	
12	IC74151	25	
13	IC74147	25	
14	IC7445	25	
15	IC7474	25	
16	IC7476	25	
17	IC7491	25	
18	IC7494	25	
19	IC7447	25	
20	IC74180	25	
21	IC555	25	
22	Seven Segment Display	25	
23	LEDs	25	
24	Bread Board	25	
25	Wires		

(Common to ECE & Bio Medical Engineering)

- Expt No.1 Fixed Bias amplifier circuit using BJT
1. Waveforms at input and output without bias.
 2. Determination of bias resistance to locate Q-point at center of load line.
 3. Measurement of gain.
 4. Plot the frequency response & Determination of Gain Bandwidth Product
- Expt No.2 Design and construct BJT Common Emitter Amplifier using voltage divider
- bias (self-bias) with and without bypassed emitter resistor.
1. Measurement of gain.
 2. Plot the frequency response & Determination of Gain Bandwidth Product
- Expt No.3 Design and construct BJT Common Collector Amplifier using voltage divider
- bias (self-bias).
1. Measurement of gain.
 2. Plot the frequency response & Determination of Gain Bandwidth Product
- Expt No.4 Darlington Amplifier using BJT.
1. Measurement of gain and input resistance.
 2. Comparison with calculated values.
 3. Plot the frequency response & Determination of Gain Bandwidth Product
- Expt No.5 Source follower with Bootstrapped gate resistance
1. Measurement of gain, input resistance and output resistance with and without Bootstrapping.
 2. Comparison with calculated values.
- Expt No.6 Differential amplifier using BJT
1. Measurement of CMRR.
- Expt No.7 Class A Power Amplifier
1. Observation of output waveform.
 2. Measurement of maximum power output.
 3. Determination of efficiency.
 4. Comparison with calculated values.
- Expt No.8 Class B Complementary symmetry power amplifier
1. Observation of the output waveform with crossover Distortion.
 2. Modification of the circuit to avoid crossover distortion.
 3. Measurement of maximum power output.
 4. Determination of efficiency.
 5. Comparison with calculated values.

- Expt No.9 Power Supply circuit - Half wave rectifier with simple capacitor filter.
1. Measurement of DC voltage under load and ripple factor, Comparison with calculated values.
 2. Plot the Load regulation characteristics using Zener diode.

- Expt No.10 Power Supply circuit - Full wave rectifier with simple capacitor filter
1. Measurement of DC voltage under load and ripple factor, Comparison with calculated values.
 2. Measurement of load regulation characteristics. Comparison with calculated values.

LIST OF EQUIPMENTS AND COMPONENTS FOR A BATCH OF 30 STUDENTS (3 per Batch)

S.No	Name of the equipments / Components	Quantity Required	Remarks
1	Variable DC Power Supply	8	(0-30V)
2	CRO	10	30MHz
4	Multimeter	6	Digital
6	Function Generator	8	1 MHz
7	DC Ammeter	10	
8	DC Voltmeter	10	
Consumables (Minimum of 25 Nos. each)			
9	BC107, BC147, BC 108, BC 148, BC547, BC 548, SL 100, SK100 or Equivalent transistors.		
10	Resistors 1/4 Watt Assorted		
11	Capacitors		
12	Inductors		
13	Diodes, Zener Diodes		
14	Bread Boards		
15	Transformers	4	

1. Basic Programs for C++ Concepts
2. Array implementation of List Abstract Data Type (ADT)
3. Linked list implementation of List ADT
4. Cursor implementation of List ADT
5. Stack ADT - Array and linked list implementations

The next two exercises are to be done by implementing the following source files

- (a) Program source files for Stack Application 1
- (b) Array implementation of Stack ADT
- (c) Linked list implementation of Stack ADT
- (d) Program source files for Stack Application 2

An appropriate header file for the Stack ADT should be #included in (a) and (d)

6. Implement any Stack Application using array implementation of Stack ADT (by implementing files (a) and (b) given above) and then using linked list implementation of Stack ADT (by using files (a) and implementing file (c))
7. Queue ADT – Array and linked list implementations
8. Search Tree ADT - Binary Search Tree
9. Heap Sort
10. Quick Sort

**LIST OF EQUIPMENTS AND COMPONENTS FOR A BATCH OF 30 STUDENTS (1
per Batch)**

S.No	Name of the equipments / Components	Quzntity Required	Remarks
1	P IV Computer Variable DC Power Supply	30 Nos	
2	C and C++ Compiler	30 Users	
Consumables (Minimum of 25 Nos. each)			
	Nil		

AIM

This course aims at providing the necessary basic concepts in random processes. Knowledge of fundamentals and applications of random phenomena will greatly help in the understanding of topics such as signals & systems, pattern recognition, voice and image processing and filtering theory.

OBJECTIVES

At the end of the course, the students would

- Have a fundamental knowledge of the basic probability concepts.
- Have a well-founded knowledge of standard distributions which can describe real life phenomena.
- Acquire skills in handling situations involving more than one random variable and functions of random variables.
- Understand and characterize phenomena which evolve with respect to time in probabilistic manner.
- Be able to analyze the response of random inputs to linear time invariant systems.

UNIT I RANDOM VARIABLES**9 + 3**

Discrete and continuous random variables – Moments - Moment generating functions and their properties. Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and normal distributions – Function of Random Variable.

UNIT II TWO DIMENSIONAL RANDOM VARIABLES**9 + 3**

Joint distributions - Marginal and conditional distributions – Covariance - Correlation and Regression - Transformation of random variables - Central limit theorem (for iid random variables)

UNIT III CLASSIFICATION OF RANDOM PROCESSES**9 + 3**

Definition and examples - first order, second order, strictly stationary, wide-sense stationary and ergodic processes - Markov process - Binomial, Poisson and Normal processes - Sine wave process – Random telegraph process.

UNIT IV CORRELATION AND SPECTRAL DENSITIES**9 + 3**

Auto correlation - Cross correlation - Properties – Power spectral density – Cross spectral density - Properties – Wiener-Khintchine relation – Relationship between cross power spectrum and cross correlation function

UNIT V LINEAR SYSTEMS WITH RANDOM INPUTS**9 + 3**

Linear time invariant system - System transfer function – Linear systems with random inputs – Auto correlation and cross correlation functions of input and output – white noise.

LECTURES : 45 TUTORIAL : 15 TOTAL : 60 PERIODS

TEXT BOOKS

1. Oliver C. Ibe, "Fundamentals of Applied probability and Random processes", Elsevier, First Indian Reprint (2007) (For units 1 and 2)
2. Peebles Jr. P.Z., "Probability Random Variables and Random Signal Principles", Tata McGraw-Hill Publishers, Fourth Edition, New Delhi, 2002. (For units 3, 4 and 5).

REFERENCES

1. Miller,S.L and Childers, S.L, "Probability and Random Processes with applications to Signal Processing and Communications", Elsevier Inc., First Indian Reprint 2007.
2. H. Stark and J.W. Woods, "Probability and Random Processes with Applications to Signal Processing", Pearson Education (Asia), 3rd Edition, 2002.
3. Hwei Hsu, "Schaum's Outline of Theory and Problems of Probability, Random Variables and Random Processes", Tata McGraw-Hill edition, New Delhi, 2004.
4. Leon-Garcia,A, "Probability and Random Processes for Electrical Engineering", Pearson Education Asia, Second Edition, 2007.
5. Yates and D.J. Goodman, "Probability and Stochastic Processes", John Wiley and Sons, Second edition, 2005.

UJT sawtooth waveform generator, Pulse transformers – equivalent circuit – response - applications, Blocking Oscillator – Free running blocking oscillator - Astable Blocking Oscillators with base timing – Push-pull Astable blocking oscillator with emitter timing, Frequency control using core saturation, Triggered blocking oscillator – Monostable blocking oscillator with base timing – Monostable blocking oscillator with emitter timing, Time base circuits - Voltage-Time base circuit, Current-Time base circuit - Linearization through adjustment of driving waveform.

TUTORIAL= 15**TOTAL = 60****TEXT BOOKS**

1. Sedra / Smith, Micro Electronic Circuits Oxford University Press, 2004.
2. S. Salivahanan, N. Suresh Kumar and A. Vallavaraj, Electronic Devices and Circuits, 2nd Edition, TMH, 2007.

REFERENCES

1. Millman J. and Taub H., Pulse Digital and Switching Waveforms, TMH, 2000.
2. Schilling and Belove, Electronic Circuits, 3rd Edition, TMH, 2002.
3. Robert L. Boylestad and Louis Nasheresky, Electronic Devices and Circuit Theory, 9th Edition, Pearson Education / PHI, 2002.
4. David A. Bell, Solid State Pulse Circuits, Prentice Hall of India, 1992.
5. Millman and Halkias. C., Integrated Electronics, TMH, 1991.

AIM

To study the various analog communication fundamentals viz., Amplitude modulation and demodulation, angle modulation and demodulation. Noise performance of various receivers and information theory with source coding theorem are also dealt.

OBJECTIVE

- To provide various Amplitude modulation and demodulation systems.
- To provide various Angle modulation and demodulation systems.
- To provide some depth analysis in noise performance of various receiver.
- To study some basic information theory with some channel coding theorem.

1. AMPLITUDE MODULATION SYSTEMS 10

Review of Spectral Characteristics of Periodic and Non-periodic signals; Generation and Demodulation of AM, DSBSC, SSB and VSB Signals; Comparison of Amplitude Modulation Systems; Frequency Translation; FDM; Non – Linear Distortion.

2. ANGLE MODULATION SYSTEMS 8

Phase and Frequency Modulation; Single tone, Narrow Band and Wideband FM; Transmission Bandwidth; Generation and Demodulation of FM Signal.

3. NOISE THEORY 8

Review of Probability, Random Variables and Random Process; Gaussian Process; Noise – Shot noise, Thermal noise and white noise; Narrow band noise, Noise temperature; Noise Figure.

4. PERFORMANCE OF CW MODULATION SYSTEMS 10

Superheterodyne Radio receiver and its characteristic; SNR; Noise in DSBSC systems using coherent detection; Noise in AM system using envelope detection and its FM system; FM threshold effect; Pre-emphasis and De-emphasis in FM; Comparison of performances.

5. INFORMATION THEORY 9

Discrete Messages and Information Content, Concept of Amount of Information, Average information, Entropy, Information rate, Source coding to increase average information per bit, Shannon-Fano coding, Huffman coding, Lempel-Ziv (LZ) coding, Shannon's Theorem, Channel Capacity, Bandwidth- S/N trade-off, Mutual information and channel capacity, rate distortion theory, Lossy Source coding.

TEXT BOOKS

1. Dennis Roddy & John Coolen - Electronic Communication (IV Ed.), Prentice Hall of India.
2. Herbert Taub & Donald L Schilling – Principles of Communication Systems (3rd Edition) – Tata McGraw Hill, 2008.

REFERENCE:

1. Simon Haykin, Communication Systems, John Wiley & sons, NY, 4th Edition, 2001.
2. Bruce Carlson - Communication Systems. (III Ed.), Mc Graw Hill.
3. B.P.Lathi, Modern Digital and Analog Communication Systems, Third Edition, Oxford Press, 2007.
4. R.P Singh and S.D.Sapre, "Communication Systems – Analog and Digital", Tata McGraw Hill, 2nd Edition, 2007.
5. John G. Proakis, Masoud Salehi, Fundamentals of Communication Systems, Pearson Education, 2006.

AIM

To familiarize the student to the concepts, calculations and pertaining to electric, magnetic and electromagnetic fields so that an in depth understanding of antennas, electronic devices, Waveguides is possible.

OBJECTIVES

- To analyze fields a potentials due to static changes
- To evaluate static magnetic fields
- To understand how materials affect electric and magnetic fields
- To understand the relation between the fields under time varying situations
- To understand principles of propagation of uniform plane waves.

UNIT I STATIC ELECTRIC FIELDS

9

Introduction to Co-ordinate System – Rectangular – Cylindrical and Spherical Co-ordinate System – Introduction to line, Surface and Volume Integrals – Definition of Curl, Divergence and Gradient – Meaning of Stokes theorem and Divergence theorem
Coulomb's Law in Vector Form – Definition of Electric Field Intensity – Principle of Superposition – Electric Field due to discrete charges – Electric field due to continuous charge distribution - Electric Field due to charges distributed uniformly on an infinite and finite line – Electric Field on the axis of a uniformly charged circular disc – Electric Field due to an infinite uniformly charged sheet.
Electric Scalar Potential – Relationship between potential and electric field - Potential due to infinite uniformly charged line – Potential due to electrical dipole - Electric Flux Density – Gauss Law – Proof of Gauss Law – Applications.

UNIT II STATIC MAGNETIC FIELD

9

The Biot-Savart Law in vector form – Magnetic Field intensity due to a finite and infinite wire carrying a current I – Magnetic field intensity on the axis of a circular and rectangular loop carrying a current I – Ampere's circuital law and simple applications.
Magnetic flux density – The Lorentz force equation for a moving charge and applications – Force on a wire carrying a current I placed in a magnetic field – Torque on a loop carrying a current I – Magnetic moment – Magnetic Vector Potential.

UNIT III ELECTRIC AND MAGNETIC FIELDS IN MATERIALS

9

Poisson's and Laplace's equation – Electric Polarization-Nature of dielectric materials-Definition of Capacitance – Capacitance of various geometries using Laplace's equation – Electrostatic energy and energy density – Boundary conditions for electric fields – Electric current – Current density – point form of ohm's law – continuity equation for current.
Definition of Inductance – Inductance of loops and solenoids – Definition of mutual inductance – simple examples. Energy density in magnetic fields – Nature of magnetic materials – magnetization and permeability - magnetic boundary conditions.

AIM:

To teach the basic concepts in the design of electronic circuits using linear integrated circuits and their applications in the processing of analog signals.

OBJECTIVES

- To introduce the basic building blocks of linear integrated circuits.
- To teach the linear and non-linear applications of operational amplifiers.
- To introduce the theory and applications of analog multipliers and PLL.
- To teach the theory of ADC and DAC
- To introduce the concepts of waveform generation and introduce some special function ICs.

UNIT - I IC FABRICATION AND CIRCUIT CONFIGURATION FOR LINEAR ICS 9

Advantages of Ics over discrete components – Manufacturing process of monolithic Ics – Construction of monolithic bipolar transistor – Monolithic diodes – Integrated Resistors – Monolithic Capacitors – Inductors. Current mirror and current sources, Current sources as active loads, Voltage sources, Voltage References, BJT Differential amplifier with active loads, General operational amplifier stages -and internal circuit diagrams of IC 741, DC and AC performance characteristics, slew rate, Open and closed loop configurations.

UNIT - II APPLICATIONS OF OPERATIONAL AMPLIFIERS 9

Sign Changer, Scale Changer, Phase Shift Circuits, Voltage Follower, V-to-I and I-to-V converters, adder, subtractor, Instrumentation amplifier, Integrator, Differentiator, Logarithmic amplifier, Antilogarithmic amplifier, Comparators, Schmitt trigger, Precision rectifier, peak detector, clipper and clamper, Low-pass, high-pass and band-pass Butterworth filters.

UNIT - III ANALOG MULTIPLIER AND PLL 9

Analog Multiplier using Emitter Coupled Transistor Pair - Gilbert Multiplier cell - Variable transconductance technique, analog multiplier ICs and their applications, Operation of the basic PLL, Closed loop analysis, Voltage controlled oscillator, Monolithic PLL IC 565, application of PLL for AM detection, FM detection, FSK modulation and demodulation and Frequency synthesizing.

UNIT - IV ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTERS 8

Analog and Digital Data Conversions, D/A converter – specifications - weighted resistor type, R-2R Ladder type, Voltage Mode and Current-Mode $R-2R$ Ladder types - switches for D/A converters, high speed sample-and-hold circuits, A/D Converters – specifications - Flash type - Successive Approximation type - Single Slope type - Dual Slope type - A/D Converter using Voltage-to-Time Conversion - Over-sampling A/D Converters.

UNIT - V WAVEFORM GENERATORS AND SPECIAL FUNCTION ICs 9

Sine-wave generators, Multivibrators and Triangular wave generator, Saw-tooth wave generator, ICL8038 function generator, Timer IC 555, IC Voltage regulators - Three terminal fixed and adjustable voltage regulators - IC 723 general purpose regulator - Monolithic switching regulator, Switched capacitor filter IC MF10, Frequency to Voltage and Voltage to Frequency converters, Audio Power amplifier, Video Amplifier, Isolation Amplifier, Opto-couplers and fibre optic IC.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. Sergio Franco, Design with operational amplifiers and analog integrated circuits, 3rd Edition, Tata McGraw-Hill, 2007.
2. D.Roy Choudhry, Shail Jain, Linear Integrated Circuits, New Age International Pvt. Ltd., 2000.

REFERENCES:

1. B.S.Sonde, System design using Integrated Circuits , New Age Pub, 2nd Edition, 2001
2. Gray and Meyer, Analysis and Design of Analog Integrated Circuits, Wiley International, 2005.
3. Ramakant A.Gayakwad, OP-AMP and Linear ICs, Prentice Hall / Pearson Education, 4th Edition, 2001.
4. J.Michael Jacob, Applications and Design with Analog Integrated Circuits, Prentice Hall of India, 1996.
5. William D.Stanley, Operational Amplifiers with Linear Integrated Circuits, Pearson Education, 2004.
6. K Lal Kishore, Operational Amplifier and Linear Integrated Circuits, Pearson Education, 2006.
7. S.Salivahanan & V.S. Kanchana Bhaskaran, Linear Integrated Circuits, TMH, 2008.

AIM

To familiarize the students with concepts related to the operation analysis and stabilization of control systems

OBJECTIVES

- To understand the open loop and closed loop (feedback) systems
- To understand time domain and frequency domain analysis of control systems required for stability analysis.
- To understand the compensation technique that can be used to stabilize control systems

- 1. CONTROL SYSTEM MODELING** **9**
Basic Elements of Control System – Open loop and Closed loop systems - Differential equation - Transfer function, Modeling of Electric systems, Translational and rotational mechanical systems - Block diagram reduction Techniques - Signal flow graph
 - 2. TIME RESPONSE ANALYSIS** **9**
Time response analysis - First Order Systems - Impulse and Step Response analysis of second order systems - Steady state errors – P, PI, PD and PID Compensation, Analysis using MATLAB
 - 3. FREQUENCY RESPONSE ANALYSIS** **9**
Frequency Response - Bode Plot, Polar Plot, Nyquist Plot - Frequency Domain specifications from the plots - Constant M and N Circles - Nichol's Chart - Use of Nichol's Chart in Control System Analysis. Series, Parallel, series-parallel Compensators - Lead, Lag, and Lead Lag Compensators, Analysis using MATLAB.
 - 4. STABILITY ANALYSIS** **9**
Stability, Routh-Hurwitz Criterion, Root Locus Technique, Construction of Root Locus, Stability, Dominant Poles, Application of Root Locus Diagram - Nyquist Stability Criterion - Relative Stability, Analysis using MATLAB
 - 5. STATE VARIABLE ANALYSIS & DIGITAL CONTROL SYSTEMS** **9**
State space representation of Continuous Time systems – State equations – Transfer function from State Variable Representation – Solutions of the state equations - Concepts of Controllability and Observability – State space representation for Discrete time systems. Sampled Data control systems – Sampling Theorem – Sample & Hold – Open loop & Closed loop sampled data systems.
- TOTAL : 45 PERIODS**

TEXTBOOK:

1. J.Nagrath and M.Gopal, "Control System Engineering", New Age International Publishers, 5th Edition, 2007.
2. M.Gopal, "Control System – Principles and Design", Tata McGraw Hill, 2nd Edition, 2002.

REFERENCES:

1. Benjamin.C.Kuo, "Automatic control systems", Prentice Hall of India, 7th Edition, 1995.
2. M.Gopal, Digital Control and State Variable Methods, 2nd Edition, TMH, 2007.
3. Schaum's Outline Series, 'Feedback and Control Systems' Tata McGraw-Hill, 2007.
4. John J.D'azzo & Constantine H.Houpis, 'Linear control system analysis and design', Tata McGraw-Hill, Inc., 1995.
5. Richard C. Dorf & Robert H. Bishop, " Modern Control Systems", Addison – Wesley, 1999.

Design of following circuits

1. Series and Shunt feedback amplifiers:
Frequency response, Input and output impedance calculation
2. RC Phase shift oscillator, Wien Bridge Oscillator
3. Hartley Oscillator, Colpitts Oscillator
4. Tuned Class C Amplifier
5. Integrators, Differentiators, Clippers and Clampers
6. Astable, Monostable and Bistable multivibrators

SIMULATION USING PSPICE:

1. Differential amplifier
2. Active filters : Butterworth 2nd order LPF, HPF (Magnitude & Phase Response)
3. Astable, Monostable and Bistable multivibrator - Transistor bias
4. D/A and A/D converters (Successive approximation)
5. Analog multiplier
6. CMOS Inverter, NAND and NOR

LIST OF EQUIPMENTS AND COMPONENTS FOR A BATCH OF 30 STUDENTS (3 per Batch)

S.No	Name of the equipments / Components	Quantity Required	Remarks
1	Variable DC Power Supply	8	(0-30V)
2	Fixed Power Supply	4	+ / - 12V
3	CRO	6	30MHz
4	Multimeter	6	Digital
5	Multimeter	2	Analog
6	Function Generator	6	1 MHz
7	Digital LCR Meter	1	
8	PC with SPICE Simulation Software	6	
Consumables (Minimum of 25 Nos. each)			
9	BC107, BF195, 2N2222, BC147		
10	Resistors 1/4 Watt Assorted		
11	Capacitors		
12	Inductors		
13	Diodes, Zener Diodes		
14	Bread Boards		

Design and testing of

1. Inverting, Non inverting and Differential amplifiers.
2. Integrator and Differentiator.
3. Instrumentation amplifier
4. Active lowpass, Highpass and bandpass filters.
5. Astable & Monostable multivibrators and Schmitt Trigger using op-amp.
6. Phase shift and Wien bridge oscillators using op-amp.
7. Astable and monostable multivibrators using NE555 Timer.
8. PLL characteristics and its use as Frequency Multiplier.
9. DC power supply using LM317 and LM723.
10. Study of SMPS.
11. Simulation of Experiments 3, 4, 5, 6 and 7 using PSpice netlists.

Note: Op-Amps uA741, LM 301, LM311, LM 324 & AD 633 may be used

LIST OF EQUIPMENTS AND COMPONENTS FOR A BATCH OF 30 STUDENTS (3 per Batch)

S.No	Name of the equipments / Components	Quantity Required	Remarks
1	Dual ,(0-30V) variable Power Supply	10	-
2	CRO	9	30MHz
3	Digital Multimeter	10	Digital
4	Function Generator	8	1 MHz
5	IC Tester (Analog)	2	
6	Bread board	10	
7	Computer (PSPICE installed)	1	
Consumables (Minimum of 25 Nos. each)			
1	IC 741	25	
2	IC NE555	25	
3	LED	25	
4	LM317	25	
5	LM723	25	
6	ICSG3524 / SG3525	25	
7	Transistor – 2N3391	25	
8	Diodes,	25	IN4001,BY126
9	Zener diodes	25	
10	Potentiometer		
11	Step-down transformer	1	230V/12-0-12V
12	Capacitor		
13	Resistors 1/4 Watt Assorted	25	
14	Single Strand Wire		

AIM

1. To expose the students to the basic operation of electrical machines and help them to develop experimental skills.
2. To study the concepts, performance characteristics, time and frequency response of linear systems.
3. To study the effects of controllers.

1. Open circuit and load characteristics of separately excited and self excited D.C. generator.
2. Load test on D.C. shunt motor.
3. Swinburne’s test and speed control of D.C. shunt motor.
4. Load test on single phase transformer and open circuit and short circuit test on single phase transformer
5. Regulation of three phase alternator by EMF and MMF methods.
6. Load test on three phase induction motor.
7. No load and blocked rotor tests on three phase induction motor (Determination of equivalent circuit parameters)
8. Study of D.C. motor and induction motor starters.
9. Digital simulation of linear systems.
10. Stability Analysis of Linear system using Mat lab.
11. Study the effect of P, PI, PID controllers using Mat lab.
12. Design of Lead and Lag compensator.
13. Transfer Function of separately excited D.C.Generator.
14. Transfer Function of armature and Field Controller D.C.Motor.

P = 45 Total = 45

1. **Open circuit and load characteristics of separately excited and self excited D.C. generator.**

SI. No.	Apparatus	Range	Quantity
1	Motor Generator set	-	1
2	Rheostat	200Ω, 5A 175Ω, 1.5A	1 2
3	Voltmeter DC	300V 30V	1 1
4	Ammeter DC	30A 2A	1 2
5	DPST switch		2
6	Three point starter		1
7	Tachometer		1

2. Load test on D.C. shunt motor.

Sl. No.	Apparatus	Range	Quantity
1	DC Motor	-	1
2	Rheostat	175Ω, 1.5A	1
3	Voltmeter DC	300V	1
4	Ammeter DC	30A	1
5	DPST switch		1
6	Three point starter		1
7	Tachometer		1

3. Swinburne's test and speed control of D.C. shunt motor

Sl. No.	Apparatus	Range	Quantity
1	DC Motor	-	1
2	Rheostat	100Ω, 5A 175Ω, 1.5A	1 1
3	Voltmeter DC	300V	1
4	Ammeter DC	5A 2A	1 1
5	DPST switch		1
6	Tachometer		1

4. Load test on single-phase transformer and open circuit and short circuit test on single-phase transformer.

Sl. No.	Apparatus	Range	Quantity
1	Single phase Transformer	-	1
2	Wattmeter	300V, 5A,UPF 300V, 5A,LPF	1 1
3	Voltmeter AC	300V	2
4	Ammeter AC	5A 30A	1 1
5	Single phase auto-transformer		1
6	Resistive load		1

5. Regulation of three-phase alternator by EMF and MMF method.

Sl. No.	Apparatus	Range	Quantity
1	Motor Alternator set	-	1
2	Rheostat	200 Ω , 5A 175 Ω , 1.5A	1 1
3	Voltmeter DC Voltmeter AC	300V 600V	1 1
4	Ammeter DC Ammeter AC	2A 30A	1 1
5	DPST switch TPST switch		1 1
6	Tachometer		1

6. Load test on three phase Induction motor.

Sl. No.	Apparatus	Range	Quantity
1	Three Phase Induction Motor	-	1
2	Wattmeter	600V, 10A,UPF	2
3	Voltmeter AC	600V	1
4	Ammeter AC	10A	1
5	Brake drum arrangement		
6	Star delta starter		1
7	Tachometer		1

7. No load and blocked rotor test on three-phase induction motor (Determination of equivalent circuit parameters)

Sl. No.	Apparatus	Range	Quantity
1	Three Phase Induction Motor	-	1
2	Wattmeter	600V, 10A,UPF 600V, 5A,LPF	2 2
3	Voltmeter AC	600V 150V	1 1
4	Ammeter AC	10A 5A	1 1
5	Brake drum arrangement		
6	Three phase auto-transformer		1

8. Study of D.C. motor and Induction motor starters.

Sl. No.	Apparatus	Quantity
1	Three point starter	1
2	Four point starter	1
3	Star-delta starter	1
4	DOL starter	1
5	Three phase auto-transformer	1

9. Digital simulation of linear systems.

Simulink software for minimum 3 users license

10. Stability analysis of linear system using Mat lab.

Matlab software for minimum 3 users license

11. Study of effect of P, PI, PID controllers using Mat lab.

Matlab software for minimum 3 users license

12. Design of lead and lag compensator.

Sl. No.	Apparatus
1	Resistor
2	Capacitor
3	Function generator
4	Bread Board

13. Transfer function of separately excited D.C. generator.

Sl. No.	Apparatus	Range	Quantity
1	Motor Generator set	-	1
2	Rheostat	200 Ω , 5A 175 Ω , 1.5A	1 2
3	Voltmeter DC	300V 30V	1 1
4	Ammeter DC	30A 2A	1 2
5	DPST switch		2
6	Three point starter		1
7	Tachometer		1

14. Transfer function of armature and field controller D.C. motor.

Sl. No.	Apparatus	Range	Quantity
1	DC Motor	-	1
2	Rheostat	175 Ω , 1.5A	1
3	Voltmeter DC	300V	1
4	Ammeter DC	30A	1
5	DPST switch		1
6	Three point starter		1
7	Tachometer		1

