Department of Electronics and Telecommunication Engineering

Third Semester Syllabus NEP 2020

Course Code	Name of Course	Course Category	Teaching Scheme				Credits	Evaluation Scheme					
								Theory			Practical		Total Marks
			L	T	P	Total Hours		TAE	CAE	ESE	INT	EXT	
SEMESTER-III													
23BTECL201 23BTECP201	Electronics Devices and Circuits	PCC 2	3	-	2	5	4	10	15	50	25	-	100
23BTECL202	Signals and Systems	PCC 3	3	1	-	4	4	10	15	50	-	-	75
23BTMBL201EC	Engineering Economics and Industrial Management	EEMC 1	2	-	-	2	2	10	15	50	-	-	75
23BTECL206	Multidisciplinary Minor	MDM 1	2	-	-	2	2	10	15	50	-	-	75
23BTXXXXX	Open Elective I	OE 1	4	-	-	4	4	10	15	50	-	-	75
23BTSHLXXX	Humanities Elective	VEC 1	2	-	-	2	2	10	15	50	-	-	75
23BTECP203	Electronics Product Design	CEP	-	-	4	4	2	-	-	-	50	-	50
TOTAL			**16**	**01**	**06**	**23**	**20**	**60**	**90**	**300**	**75**	**00**	**525**

Department of Electronics and Telecommunication Engineering

Course	Offered to Department	Name of Subject	Course Code
Multidisciplinary Minor (MDM1)	CSE	Fundamentals of Electronic Devices	23BTECL206CS
Multidisciplinary Minor (MDM1)	ETC	Computer Architecture	23BTCSL202EC
Humanities Elective	ETC	Applied life skills for Progressive Excellence	23BTSHL227
		Content Designing and Media Fundamentals	23BTSHL228
		Cyber Ethics and Moral Responsibility	23BTSHL229
Open Elective I	ETC	Advanced Communication Skills	23BTSHL225
		Introduction to Block Chain Technology	23BTCSL211
		Nonconventional Energy Sources	23BTEEL210
		Web Designing and Analytics	23BTDSL202
		Data Analysis for Business Intelligence	23BTAIL205
Open Elective I	Other than ETC	Sensors and its Applications	23BTECL210

Department of Electronics and Telecommunication Engineering

Course Title: **Electronic Devices & Circuits**										
Semester	III	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	PCC 2	3 Hrs.		2 Hrs.	4	10	15	50	25	---
Course Code	23BTECL201 23BTECP201									
Teaching Mode	Offline	5 Hrs.			Total	75			25	
Duration of ESE	3 Hrs.					100				

Course Objectives	To give understanding on how current flows through semiconductor devices and relating this phenomena to the characteristics and operation devices.
	To expose students to the function and application of the diodes, bipolar junction, field effect and CMOS transistors in electronic circuits.
	To use appropriate experimentation techniques to evaluate circuit performance.
Course Outcomes	Up on successful completion of this course, student will be able to:
	CO1: Relate operation of diodes and their role in design of various electronic applications.
	CO2: Develop the capability to analyze and design circuits using bipolar transistors.
	CO3: Design various types of Power Amplifiers and analyze their efficiency
	CO4: Design, Analyze and build the concepts of feedback and apply the concepts for improvement of performance of oscillator
	CO5: Interpret the operation of the Field Effect Transistor (FET), Metal Oxide Semiconductor Field Effect Transistor (MOSFET) and design FET & CMOS circuits.

Mapping of Course Outcomes with Program Outcomes:

Course Outcomes	Program Outcomes											
	PO 1	PO2	PO 3	PO4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	3	3	2	3	2	1	1	2	1	2	3
CO2	3	3	3	2	3	2	1	1	2	1	2	3
CO3	3	3	3	2	3	2	1	1	2	1	2	3
CO4	3	3	3	3	3	2	1	1	3	1	2	3
CO5	3	3	3	3	3	2	1	1	3	1	2	3

Department of Electronics and Telecommunication Engineering

Course Contents:

Unit	Contents	Hours
I	**Semiconductor Devices:** PN junction diode review, Design Half wave and full wave rectifiers, Zener Diode, Varactor Diode, Tunnel Diodes, BJT transistors- structure, Operations & characteristics, voltages and currents equations, CE, CB, CC configurations, Early Effect	9
II	**BJT Circuits** DC load line, Biasing circuits, Stability factor, thermal runaway, Compensation methods, h-parameters, Feedback Amplifiers,	9
III	**Power Amplifiers** Classification A, B, AB, C, Efficiency, Push Pull Configuration (A, B, AB) Complementary symmetry, Second Harmonic and Cross over Distortion,	9
IV	**Oscillators** Classification of Oscillators, Stability, Bark Hausen Criteria, Design of RC, LC and Crystal Oscillators.	9
V	**Field Effect Transistors & CMOS** Field Effect Transistor, MOSFET, NMOS, PMOS Principles of operation and characteristics, channel length modulation, CMOS inverters, NAND, NOR Circuits, VTC Characteristics	9

Text Books	1.	Electronics Devices and Circuits, S. Salivahanan, N Suresh Kumar, Tata McGraw-Hill 2008, Third Edition
	2.	Integrated Electronics Jacob Millman Tata McGraw-Hill, 2009, Second Edition
	3.	Electronics devices and Circuits and Theory Robert L. Boylestad, Louis Nashelsky, Pearson India, 2009, Tenth Edition
E--Books	1.	Electronics Devices and Circuits, S. Salivahanan
	2.	Solid State Electronic Devices, 6th Edition, Ben G.Streetman & Sanjiv Kumar Banerjee
Reference Books	1.	Electronic Devices & Circuits, Sanjiv Gupta
	2.	Microelectronics Circuits A. S. Sedra & K. C. Smith, Oxford University Press, 2013, Seventh Edition
	3.	Electronics Devices and Circuits, Nagrath I J Phi Learning Pvt Ltd, 2009, Third Edition.
Online TL Material	1.	Virtual Lab, Electronic Devices & Circuits, IIT Bombay http://vlabs.iitb.ac.in/vlab/electrical/index.html

Department of Electronics and Telecommunication Engineering

*Every practical will be performed on Bread Board

Sr. No.	Name of Experiments / Mini Projects
0	Study of different electronic components
1	Observe and draw V-I Characteristics of PN Diode & LED Diode.
2	Observe and draw the V-I characteristics and Regulation characteristics of a Zener diode.
3	Obtain ripple factor of Half Wave/Full wave Rectifier circuit with & without filter
4	Draw the input and output characteristics of transistor connected in CE/CB/CC any one Configuration
5	Design bipolar junction transistor as a switch
6	Design of Voltage Divider Bias for BJT.
7	Design Audio oscillator using BJT
8	Design Radio Oscillator using BJT
9	Design of Class B push pull power amplifier and observe cross over distortion
10	Draw the Drain and Transfer characteristics of a given FET in CS Configuration.
11	Draw the Drain and Transfer characteristics of a given MOSFET in CS Configuration.
Open Ended Experiments	
1	Design Zener regulator circuits for Processor Motherboard.
2	Design of Simple analog application circuits.
3	Minor Project

Department of Electronics and Telecommunication Engineering

Course Title: **Signals and Systems**										
Semester	III	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	PCC 3	3 Hrs.	1 Hr	-	4	10	15	50	-	---
Course Code	23BTECL202									
Teaching Mode	Offline	4 Hrs.			Total	75				
Duration of ESE	3 Hrs.					75				

Course Objectives	1. To introduce the fundamentals, characteristics, concept techniques of Signals & systems.
	2. Understanding signals and systems in terms of both the time and transform domains, taking advantage of the complementary insights and tools that these different perspectives provide.
	3. To characterize LTI systems in the Time domain and various Transform Domains
Course Outcomes	Upon successful completion of the course, students shall be able to
	CO1: To represent & classify signals, Systems & identify LTI systems.
	CO2: To understand LTI systems and its analysis.
	CO3: To analyze the Continuous Time systems by performing Convolution
	CO4: To understand Discrete time systems and LTI systems.
	CO5: To understand sampling of signals and quantization process

Mapping of Course Outcomes with Program Outcomes:

Course Outcomes	Program Outcomes														
	PO1	PO2	PO3	PO4	PO 5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO 3
CO1	3	3	3	2							**1**		**3**		
CO2	3	3	3	2							**1**		**3**		
CO3	3	3	3	2							**1**		**3**		
CO4	3	3	3	2							**1**		**3**		
CO5	3	3	3	2							**1**		**3**		

Department of Electronics and Telecommunication Engineering

Course Contents:

Unit	Contents	Hours
I	**Introduction to Signals and Systems:** Signals and systems as seen in everyday life, and in various branches of engineering and science electrical, mechanical, hydraulic, thermal, biomedical signals and systems as examples. Basic definitions, Classification of signals and systems. Signal operations and properties. Basic continuous time signals, discretization of continuous time signals, discrete time signals. Basic system properties, Some special signals of importance: the unit step, the unit impulse, the sinusoid, the complex exponential, Representation of digital signals.	10
II	**Continuous time and discrete time Linear shift invariant (LSI) systems:** Impulse response and step response, convolution, input-output behavior with aperiodic convergent inputs, cascade interconnections. Characterization of causality and stability of linear shift-invariant systems.	10
III	**Continuous Time Fourier Transform:** Representation of Aperiodic Signal, Fourier Transform for Periodic Signals, Properties of CTFT, Convolution and multiplication property of continuous FT, Systems characterized by Linear Constant Coefficient Differential equations. Convolution Property.	10
IV	**Discrete Time Fourier Transform (DTFT) and Discrete Fourier Transform (DFT):** Properties of DTFT and DFT, convolution property, multiplication property, Duality, Systems characterized by Linear Constant Coefficient Difference Equations	8
V	**Sampling:** Sampling theorem – Graphical and analytical proof for Band Limited Signals, impulse sampling, Natural and Flat top Sampling, Reconstruction of signal from its samples, effect of under sampling	8

Text Book Books	1.	Signals and Systems: Alan V Oppenheim, Alan S Willsky, S Hamid Nawab, Prentice Hall India 2009
	2.	Signals & Systems - Simon Haykin and Van Veen, Wiley, 2nd Edition.
	3.	Signals, Systems & Communications - B.P. Lathi, BS Publications, 2003.
EBooks	1.	https://drive.google.com/file/d/0B7SUGT- 4AMaJZGFvTi0tMHpmRjQ/view
Reference Books	1.	Signals & Systems - Simon Haykin and Van Veen,Wiley, 2nd Edition.
	2.	Signals, Systems and Transforms - C. L. Philips, J.M.Parr and Eve A.Riskin, Pearson education.3rd Edition, 2004.
	3	Fundamentals of Signals and Systems Michel J. Robert, MGH International Edition, 2008.
on line TL Material	1.	IIT's NPTEL lectures

Department of Electronics and Telecommunication Engineering

Course Title: Electronics Product Design										
Semester	III	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	CEP	--	--	4	2	-	-	-	50	-
Course Code	23BTECP203									
Teaching Mode	Offline	4Hrs			Total				50	
Duration of ESE	--					50				

Name of Subject: Electronics Product Design [23BTECP 203]		Semester: III (ETC)
COURSE OUTCOME		
CO1	Understanding about basic electronics components, measuring equipment and electronics products.	
CO2	Design of an electronics circuit using breadboard and simulate it using software.	
CO3	Understanding and development of PCB artwork, assembly of a circuit and testing process.	
CO4	Design of product package with Ergonomic and Aesthetics Considerations.	
CO5	Identify innovative ideas for a problems based on Community/Societal needs for Electronics Product development.	

Electronics Product Development Course under Community Engagement Project category (CEP) is mainly focused on the following domain:

Sr. No.	Domain	Details
1	**Basic**	Fundamental knowledge about basic electronics components, measuring equipment and electronics products.
2	**Design**	Design and study the performance of an electronics circuit on the breadboard with components and also perform simulation on PC/Laptop to verify and analyze it's various operations.
3	**Assembly & Troubleshooting**	Design and develop a Printed Circuit Board by art work process and assemble all the components using soldering operations and test the circuit for the intended result. For any issue, recheck the circuit, retest it.
4	**Advanced**	Design and develop packaging enclosure for an assembled electronics circuit with ergonomic and aesthetic considerations using CAD software and 3D printer, if possible.

5	**Community Engagement Project (mini project)**	Identify innovative ideas for a problems based on Community/Societal needs for Electronics Product development. With the focus on self-learning, innovation, addressing community/societal problems and entrepreneurship quality development within the students through the Electronics Product /Mini Projects.

Guidelines for Community/Societal based Electronics Product/ Mini Project:

- A group of students or even a single student could be assigned/motivated for a particular habitation or village or municipal ward, as far as possible, in the near vicinity of their place of stay, so as to enable them to commute from their residence and return back by evening.
- The Community Service Project is a twofold one –
- First, the student/s could conduct a survey of the habitation, if necessary, in terms of their own domain or subject area. Or it can even be a general survey, incorporating all the different areas. A common survey format could be designed, it could be another primary source of data.
- Secondly, the student/s could take up a community/social activity, concerning their domain or subject area. The different areas, could be like –
  - Water facilities and drinking water availability.
  - Health and hygiene.
  - Stress levels and coping mechanisms.
  - Health intervention programmes.
  - Horticulture.
  - Herbal plants.
  - Botanical survey.
  - Zoological survey.
  - Marine products.
  - Aqua culture.
  - Inland fisheries.

- Students shall submit an implementation plan in the form of poster/chart, which will cover weekly activity of mini projects.
- A log book to be prepared by each group, wherein the group can record weekly work progress,

guide/supervisor can verify and record notes/comments.

- The mentors of a group of students should take the responsibility of motivating, facilitating, and guiding the students. They have to interact with local leadership and people and appraise the objectives and benefits of this kind of projects.
- Students in a group shall understand the problem effectively, propose multiple solutions and select the best possible solution in consultation with the guide/ supervisor. Students shall convert the best solution into a working model using various components and demonstrate. The solution to be validated with proper justification and report to be compiled in standard format.
- With the focus on self-learning, innovation, addressing community/societal problems and entrepreneurship quality development within the students through the Electronics Product /Mini Projects.
- Systematic, Factual, methodical and honest reporting shall be will be highly credited.

Assessment Criteria of Community/Societal based Electronics Product/ Mini Project:

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification from various community/societal domain.
2. Clarity of Problem definition based on their need.
3. Feasibility of proposed problem solutions and selection of best solution
4. Innovativeness in solutions and cost effectiveness.
5. Community/Societal impact.
6. Full functioning of working model as per stated requirements.
7. Effective use of standard engineering norms and skill sets.
8. Contribution of an individual's as member or leader in a group.
9. Clarity in written and oral communication.

Department of Electronics and Telecommunication Engineering

Mapping of CO – PO- PSO

Correlation levels as -

1: Slight (Low)**;** **2:** Moderate (Medium); 3: High

CO/PO/ PSO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO1	3	-	-	-	2	-	-	-	-	-	-	3	-	2	-
CO2	3	3	2	2	3	-	-	-	3	2	-	3	-	2	2
CO3	3	3	2	2	3	-	-	-	3	2	-	3	-	2	2
CO4	3	3	2	2	3	-	-	-	3	2	-	3	-	2	2
CO5	3	3	3	2	2	1	1	1	3	2	2	3	2	2	-
Avg. CO	3	3	1.8	2	2.6	1	1	1	3	2	2	3	2	2	2

Text Books	1.	Harper, “Handbook of Electronic Packaging”, McGraw Hill, New York 1979.
	2.	Walter C Bosschard, “PCB design & Technology”, McGraw Hill, New Delhi.
Reference Books	1.	Avram Bar - Cohen & Allan Craus, “Thermal Analysis and Control of Electronic, Equipment”, McGraw Hill, Hemisphere Pub. Co., New York 1983.
	2.	Kraig Mitzner, “Complete PCB Design Using OrCAD Capture and PCB Editor”,Academic Press; 2nd edition , 20 June 2019.
Online Repositor		Teachers are recommended to use a free online simulation platform “Tinkercad” for the simulation of Arduino based circuits : https://www.tinkercad.com

Department of Electronics and Telecommunication Engineering

Course Title: Computer Architecture MD-I										
Semester	III	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	ODD	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	Core	2 Hrs.	- -	--	2	10	15	50	--	--
Course Code	23BTCSL208									
Teaching Mode	Offline	2 Hrs			Total	75			-	
Duration of ESE	2 Hrs.					75				

Course Objectives	To understand the design principles of digital computing systems
	To provide essential understanding of different subsystems of modern computer system and design aspects these subsystems3
	To provide overview on performance enhancement methods in instruction execution
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: To describe the basic components and design of a computer system
	CO2: To examine the issues involved in the instruction execution and various stages of instruction life stage
	CO3: To apply the concept of various memories and interfacing technologies
	CO4: To analyze the different parallel processing technique
	CO5: To design different high performance computing architecture

Mapping of Course Outcomes with Program Outcomes and Program Specific Outcomes:

Course Outcomes	Program Outcomes and Program Specific Outcomes													
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO0	PO1	PO2	PSO1	PSO2
CO1	1	--	--	--	--	--	--	--	--	--	--	--	3	--
CO2	--	2	--	--	--	--	--	--	--	--	--	--	2	--
CO3	--	3	--	--	--	--	--	--	--	--	--	--	2	--
CO4	--	--	3	--	--	--	--	--	--	--	--	--	3	--
CO5	--	--	3	--	--	--	--	--	--	--	--	--	--	3

Department of Electronics and Telecommunication Engineering

Course Contents:

Unit	Contents	Hours
I	**Introduction:** Overview and history of computer architecture, CPU, memory, input-output subsystems, control unit. Instruction set architecture of a CPU:–registers, instruction execution cycle, RTL interpretation of instructions, addressing modes, Instruction set architecture CISC, RISC. **Case study: –**instruction sets of common CPUs, performance matrices for calculation of processingin Computer	5
II	**Computer Arithmetic:** Fixed point Addition, Subtraction, Multiplication and Division. FloatingPoint Arithmetic, High-performance arithmetic, Booth's algorithm: Division and Multiplication, Data representation methods. **IEEE standard:** single and double precision format and examples, ALU	5
III	**Memory Architecture:** Memory hierarchy, Memory Chip Organization, Cache memory, Virtualmemory, Parallel Bus Architectures, Internal Communication Methodologies, Serial Bus Architectures, Mass storage, Input and Output Devices, Segmentation, TLB, DMA	5
IV	**An Overview of Pipelining:** Basic concepts of Pipelining, Pipelined Datapath, and Control. **Data Hazards:** Forwarding versus Stalling, Control Hazards, Exceptions, Arithmetic and Instruction Pipeline, throughput and speedup, pipeline hazards.	5
V	**Processor Architecture:** hardwired and micro-programmed design approaches, Case study - design of a simple hypothetical CPU. Multicore processors architecture, Introduction toGraphics Processing Units, Clusters and Warehouse scale computers, Advanced topics & its application.	5

Text Books	1.	Computer Organization and Architecture by Carl Hamacher 4th Edition
	2.	Advance computer Architecture by Kai Hwang under Tata McGraw Hill Publications
	3.	Introduction to Parallel Processing: Algorithms & Architectures, Behrooz Parhami in Springer Shop
EBooks	1.	Computer Architecture and Organization by William Stalling http://home.ustc.edu.cn/~leedsong/reference_books_tools/Computer%20Org anization%20and%20Architecture%2010th%20-%20William%20Stallings.pdf
Reference Books	1.	Introduction to Parallel Processing by P. Ravi Prakash, M. Sasikumar, Dinesh Shikhare By PHI Publications
	2.	Fundamentals of Parallel Processing by Jordan Harry, Alaghband Gita, PHI Publication
	3	Parallel Computers – Architecture and Programming by V. Rajaraman And C. Siva Ram Murthy.
	4.	Introduction to Parallel Programming by Steven Brawer
On-line TL Material	1.	NPTL https://nptel.ac.in/courses/106/105/106105163/

Department of Electronics and Telecommunication Engineering

Course Title: **Fundamentals of Electronic Devices** (Multi-Disciplinary Minor) (Other than ETC Students)										
Semester	III	Teaching Scheme				Evaluation Scheme				
						Theory			Practical	
Term	Odd	Th	Tu	Pr	Credits	TAE	CAE	ESE	INT	EXT
Course Category	MDM 1	2 Hrs.	-	-	2	10	15	50	-	---
Course Code	23BTECL206XX									
Teaching Mode	Offline	2 Hrs.			Total	75				
Duration of ESE	3 Hrs.					75				

Course Objectives	To give understanding on how current flows through semiconductor devices and relating this phenomena to the characteristics and operation devices.
	To expose students to the function and application of the diodes, bipolar junction, field effect transistors in electronic circuits.
	To use appropriate experimentation techniques to evaluate circuit Performance.
Course Outcomes	Upon successful completion of this course, student will be able to:
	CO1: Relate operation of diodes and their role in design of various electronic applications.
	CO2: Develop the capability to analyze and design circuits using bipolar transistors.
	CO3: Design and build the concepts of feedback and apply the concepts for improvement of performance of oscillator
	CO4: Interpret the operation of the Field Effect Transistor (FET), Metal Oxide Semiconductor Field Effect Transistor (MOSFET) circuits.
	CO5: Demonstrate familiarity with basic electronic components and use them to design simple electronic sensors and Transducers.

Mapping of Course Outcomes with Program Outcomes:

Course Outcomes	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 11	PO 12
CO1	3	3	3	2	3							2
CO2	3	3	3	2	3							2
CO3	3	3	3	2	3							2
CO4	3	3	3	3	3							2
CO5	3	3	3	3	3							2

Department of Electronics and Telecommunication Engineering

Course Contents:

Unit	Contents	Hours
I	**Semiconductor Devices:** PN junction diode review, Half and full wave rectifiers, Zener Diode, Varactor Diode, Tunnel Diodes.	6
II	**BJT Circuits:** BJT transistors- structure, Operations & characteristics, voltages and currents equations, CE, CB, CC configurations, Early Effect, Introduction to Feedback Amplifiers.	6
III	**Oscillators:** Classification of Oscillators, Design of RC, LC and Crystal Oscillators.	6
IV	**FETs :** Drain and Transfer characteristics, N-channel FET,P-Channel FET , MOSFETs,(Depletion Type ,Enhancement Type) and its Applications. (FET used as a Switch, MOSFET as an Amplifier).	6
V	**Sensors :** Temperature Sensors, Light Sensors, Piezo electrical Transducers, Humidity Sensors	6

Text Books	1.	Electronics Devices and Circuits, S. Salivahanan, N Suresh Kumar, Tata McGraw-Hill 2008, Third Edition
	2.	Integrated Electronics, Jacob Millman, Tata McGraw-Hill, 2009, Second Edition
	3.	Electronics devices and Circuits and Theory, Robert L. Boylestad, Louis Nashelsky, Pearson India, 2009, Tenth Edition
E--Books	1.	Electronics Devices and Circuits, S. Salivahanan
	2.	Solid State Electronic Devices, Ben G.Streetman & Sanjiv Kumar Banerjee, 6th Edition
Reference Books	1.	Electronic Devices & Circuits, Sanjiv Gupta
	2.	Electronics Devices and Circuits, Nagrath I J, PHI Learning Pvt. Ltd, 2009, Third Edition.
	3	Patranabis D, “Sensors and Transducers”, 2nd Edition, PHI, New Delhi, 2010.
Online TL Material	1.	Virtual Lab, Electronic Devices & Circuits, IIT Bombay http://vlabs.iitb.ac.in/vlab/electrical/index.html