2016

Dr. Babasaheb Ambedkar Marathwada University, Aurangabad (MS)

Deen Dayal Upadhyay KAUSHAL Kendra

Course Structure and Curriculum

Master of Vocation

(M.Voc)

In

Industrial Automation

Choice Based Credit System

(Effective from June 2016 onwards)

Structure and Curriculum for Master of Vocation (M. Voc)
in
Industrial Automation
(Choice Based Credit System)

This M.Voc (Industrial Automation) program is divided in four semesters having 102credits. The distribution or credits is as per following –

Sr. No.	Category of course(s)	Type of Course (Theory/ Practical/ Research Project)	Number of Course(s)	Total Credits	Semester-wise Credit Distribution
1	Compulsory Common Component (Constitution of India)	Theory	01	02	Sem I – 02
2	Core Component	Theory	07	14	Sem I - 08 Sem II - 06
3	Foundation Component (Elective)	Theory	01	02	Sem I – 02
4	Foundation Component (Research)	Theory	01	01	Sem I – 01
5	Foundation Component (Compulsory)	Theory	05	10	Sem I - 04 Sem II - 06
6	Generic Elective	Theory	05	10	Sem III – 08 Sem IV -02
7	Open Elective[#]	Theory	02	04	Sem III – 02 Sem IV - 02
8	Laboratory courses (Core)	Practical	07	10.5	Sem I - 06 Sem II - 4.5
9	Laboratory courses (Foundation)	Practical	05	7.5	Sem I - 03 Sem II - 4.5
10	Laboratory Courses (Generic Elective)	Practical	05	7.5	Sem III -06 Sem IV- 1.5
11	Research Component	Research/Industrial project			
	Part 1		Part 1	05	Sem II - 5.0
	Part 2		Part 2	09	Sem III- 9.0
	Part 3		Part 3	19.5	Sem IV - 19.5
			Total	**102 Credits**	

The above structure exercised component wise distribution as per following –

Constitution of India = 02 Credits

Core Component = 24. 5%

Foundation Component = 20.5%

Elective Component = 21.5 %

Research component = 33.5% (Excluding theory course entitled 'Research Methodology')

#Students can opt for open electives from courses offered by Automobile Division, Deen Dayal Upadhyay KASUSHAL Kendra

Preamble:

Dr. Babasaheb Ambedkar Marathwada University (BAMU) proposes to offer a two year Master programme invocation (M. Voc.).The curriculum design of this program is undertaken in the following framework (assumptions).

a) Although there has been remarkable progress in all sectors of education in last couple of decades, the less regulated area of the education sector-vocational training—seems to have lost its significance/importance. This has led to the widening gap between the supply and demand for skilled manpower across various industries and R&D organizations. This shortage of skills has translated directly into unemployment among an increasing number of graduates who pass-out every year and are forced to bare-trained in order to become market table.

This programme is designed to produce a skilled manpower in Industrial Automation to improve the opportModuleies for the unemployed youths in the country in both the private and public sectors.

b) According to a study conducted by the Associated Chambers of Commerce and Industry of India (ASSOCHAM), there should be a deficit of 40 million working professionals by the year 2020 and the employers would face the difficulty of filling positions because of the dearth of suitable talent and skilled person all in their industry. **This programme aims to provide some solution for this problem and this would facilitate to improve:**

(i) **Quality of training**
(ii) **High drop-out rates**
(iii) **Linkages with Universities and industry**
(iv) **Inadequacy of resources.**

c) **This programme is intended to offer practical training and skills needed to pursue an occupation straight away. It will provide options to the students to select the courses of their choice which are directly aligned to land a job in a chosen profession or a skilled trade.**

d) **This program is intended to offer students with life-long independent and reflective learning skills in their career.**

Program Educational Objectives:

The objectives of M.Voc (Industrial Automation) program are to produce graduates who -

1. Are equipped with time advanced knowledge of mechatronics and electronics to address multi disciplinary demand of automated manufacturing, and process in modern industries in capacity of productive Senior System Developers, Senior System Integrators and Plant Supervisors.
2. Have a acute knowledge base to practice industrial automation in the areas of robotics, manufacturing, and process control in industry and Government settings meeting the growth expectations of stakeholders.
3. Have an ability to pursue higher studies and succeed in academic and professional careers.
4. Have the ability to address professional demands individually and as a team member communicating effectively in technical environment using modern tools.
5. Recognize the need for and possess the ability to engage in lifelong learning.
6. Should be sensitive to consequences of their work both ethically and professionally for productive professional career.

Program Outcomes (PO):

Vocational Education is education that prepares the students for specific trades, crafts and career sat various levels and scopes. It trains the students from a trade/ craft, technician or professional position in R & D organizations.

The Program Outcomes are the skills and knowledge which the students have at each exit level/at the time of graduation. These Outcomes are generic and are common to all exit levels mentioned in the programme structure. Graduates of the M.Voc program are expected to -

PO1. **Domain knowledge:** Apply advanced knowledge of the specific skill based trade for the solution of target skill sector.

PO2. **Problem Analysis:** Identify industry domain related problems at varied complexity and analyze the same to formulate/ develop substantiated conclusion using first principles of domain sectors and technical literature.

PO3. **Design Development of solutions :** Design / develop solutions for specific critical problems in the target skill based trade to address changing challenges put forward by market demand/ stakeholder

PO4. **Conduct Investigation of complex problems:** Design and conduct technology enabled experiments, analyze the resulting data and interpret the same to provide valid conclusions

PO5. **Modern tools:** Use the techniques, skills and modern tools necessary skill based trade to practice with clear understanding of limitations.

PO6. **The citizenship and society:** Apply sound understanding of ethical and professional skill based trade practice in the context of global, economic, environmental and societal realities while encompassing relevant contemporary issues.

PO7. **Environment and sustainability:** Apply sound understanding of impact of skill based trade in a global, economic, environmental and societal context.

PO8. **Ethics:** Apply ability to develop practical solutions for skill trade problems within positive professional and ethical boundaries.

PO9. **Individual and team work:** Function effectively as a leader and as well as team member in diverse/ multidisciplinary environments.

PO10. **Communication:** Communicate effectively in oral and written format addressing specific professional/ social demands.

PO11. **Project management and finance**: Demonstrate knowledge and understanding of the first principles of skill trade and apply these to one's own work as a member and leader in a team, to complete project in any environment.

PO12. **Life-long learning:** Recognize the need for and have the ability to address to the changing technological demands of the target skill trade.

Program Specific Outcomes (PSO):

Graduates of the M.Voc (Industrial Automation) program are expected to -

1. Apply advance knowledge of electronics, electrical, mechatronics fundamentals and Industrial automation specialization for the solution of automated manufacturing and process related problems.

2. Identify complex industrial automation related problems at varied complexity and analyze the same to formulate/ develop substantiated conclusion using advance concepts of electronics, electrical and mechatronics and technical literature.

3. Design and conduct technology enabled experiments, analyze the resulting data and interpret the same to provide valid conclusions.

4. Use the techniques, skills and modern tools necessary for industrial automation practice with clear understanding of limitations.

Eligibility:

Those who have completed B.Voc (Industrial Automation)/ B. Sc with Physics and Electronics / B. E/ B. Tech (Electronics/Electronics and Telecommunication/ Instrumentation/ Electrical/ Mechanical/Mechatronics/Industrial Automation) from any recognized Board/Institution are eligible for registration / admission.

AND

Students having B. Sc degree with Physics and Electronics will have to complete at least 4 credits in terms of two theory courses namely – (i) Fundamentals of Hydraulics and Pneumatics (ii) Process Control and Instrumentation during First year of M.VOC apart from courses being taught in course of regular academic session.

Admission / Promotion Process:

In response to the advertisement for registration, interested students will have to register themselves. Admission should be done on the basis of performance of students at Common Entrance Test(CET). The CET should be conducted in the month of June every year.

There is Full Carry on for M.Voc i.e. irrespective of individual performance in first year; a student should be promoted to Second Year. However, for obtaining M. Voc. Degree, a student will have to complete all semesters successfully within 4 years/08 semesters.

Choice Based Credit System (CBCS):

The choice based credit system is going to be adopted by this Centre. This provides flexibility to make the system more responsive to the changing needs of our students, the professionals and society. It gives greater freedom to students to determine their own pace of study. The credit based system also facilitates the transfer of credits. Students will have to earn 102 credits for the award of two years Master of Vocation (M. Voc)

Credit-to-contact hour Mapping:

(a) One Credit would mean equivalent of 15 periods of 60 minutes each for theory lecture.

(b) For lab course/ workshops/internship/field work/project, the credit weightage for equivalent hours shall be 50% that for lectures /workshop

(c) For self- learning, based on e-content or otherwise, the credit weightage for equivalent hours of study should be 50% or less of that for lectures/workshops.

Attendance:

Students must have 75 % of attendance in each course for appearing examination, otherwise he / she should be strictly not allowed for appearing the semester examination of each course. Frequent absence from regular lecture/practical course may lead to disqualification from CIA process in respective subject.

Departmental Committee:

The Departmental Committee (DC) of the Centre will monitor smooth functioning of the program.

Results Grievances / Redressal Committee

Grievances / redressal committee should be constituted in the department to resolve all grievances relating to the evaluation. The committee shall consist of Head of the department, the concerned teacher of a particular course and senior faculty member of Department of Committee. The decision of Grievances / redressal committee will have to be approved by Department committee.

Evaluation Methods:

- The assessment will be based on 20: 80 ratio of continuous internal assessment (CIA) and semester end examination (SEE). Performance will be decided after combining performance in CIA and SEE. In case of failure in SEE in particular course(s), exam will be conducted in immediate subsequent semester. However, if a student fails in CIA

(considering independent CIA score), he/she may appear for the same CIA, at his/her own responsibility in the next academic year, when the same course is offered during regular academic session.

- In case a student fails in certain course(s) in a particular semester and the same course(s) are modified/ revised/ removed from the curriculum in due course, the student will have to appear as per the newly framed curriculum and/or pattern in subsequent semester, at his/her own responsibility.

Continuous Internal Assessment (CIA):

(A) For 4 credit courses-

- There will be 20 marks for Continuous Internal Assessment. Two internal tests (of 20 marks each) will be conducted, after completion of 40% and 80% of the curriculum respectively. Average performance of the two sets will be considered for final marks-memo preparation. The setting of question papers and the assessment will be done by concerned teacher.

(B) For 2 credit courses-

- There will be 10 marks for Continuous Internal Assessment. Two internal tests (of 10 marks each) will be conducted, after completion of 40% and 80% of the curriculum respectively. Average performance of the two sets will be considered for final marks-memo preparation. The setting of question papers and the assessment will be done by concerned teacher.

Semester End Examination (SEE):

- The semester end theory examination for each theory course of 4 credits will be of 80 marks, whereas, for 2 credit theory course, the same will be of 40 marks. Therefore, the total marks shall be 100 for 4 credit theory course (80 marks semester end exam + 20 marks CIA) and 50 for 2 credit theory course (40 marks semester end exam + 10 marks CIA).

- Semester end examination (SEE) time table will be declared by the departmental committee (as per the university annual calendar). The paper setting and assessment of theory courses, laboratory courses and project will done by external (50 %) and internal (50%) examiners. However, in case of non-availability of external examiner for either paper setting or assessment or both, department committee will be empowered to take appropriate decision.
- Pattern of semester end question paper will be as below:

(A) For 4 credit courses-

- The semester end examination of theory course will have two parts (20+60 = 80 Marks)

- Part A will be consisting of 10 questions having 2 marks each (multiple choice questions /

fill in the blanks/ answer in one sentence) as compulsory questions and it should cover entire course curriculum (20 Marks)

- Part B will contain 07 questions of 12 marks each (with more or less equal weightage on every module). Students will have to attempt 05 questions out of 07 (60 Marks).

- 20 to 30% weightage can be given to problems/ numerical (wherever applicable) wherein use of non-programmable scientific calculator may be allowed.

- Number of sub questions (with allotment of marks) in a question may be decided by the examiner.

(A) For 2 credit courses-

- The semester end examination of theory course will have two parts (10+30 = 40 Marks)

- Part A will be consisting of 10 questions having 1 marks each (multiple choice questions / fill in the blanks/ answer in one sentence) as compulsory questions and it should cover entire course curriculum (10 Marks)

- Part B will contain 05 questions of 10 marks each (with more or less equal weightage on every module). Students will have to attempt 03 questions out of 05 (30 Marks).

- 20 to 30% weightage can be given to problems/ numerical (wherever applicable) wherein use of non-programmable scientific calculator may be allowed.

- Number of sub questions (with allotment of marks) in a question may be decided by the examiner.

- Assessment of laboratory courses and project will be carried out at the end of semester. Student must perform at least eight experiments from each laboratory course. The semester end practical examination will be conducted at the end of each semester along with the theory examination.

- At the end of each semester, the Departmental Committee will assign grades to the students.
- The Director of the Centre shall send all results to the Controller of Examination for further processing.

- Every student will have privilege for revaluation of answer sheets or recounting of marks for each semester end examination. However, students will have to submit an application within 15 days from the date of declaration of results.

- Applications received for revaluation / recounting will be discussed in the Departmental committee and examiners will be appointed accordingly.

- The results of revaluation / recounting will be approved by Departmental committee and forwarded to Controller of Examination for further processing.

Earning Credits:

At the end of every semester, a letter grade should be awarded in each course for which a student had registered. A student's performance should be measured by the number of credits that he/she earned by the weighted Grade Point Average (GPA). The SGPA (Semester Grade Point Average) should be awarded after completion of respective semester and the CGPA (Cumulative Grade Point Average) should be awarded at the final exit.

Grading System:

- The grading reflects a student-own proficiency in the course. A ten point rating scale shall be used for the evaluation of the performance of the students to provide letter grade for each course and overall grade for the Master Programme. Grade points are based on the total number of marks obtained by him / her in all heads of the examination of the course. The grade points and their equivalent range of marks are shown in Table-I

Table – I : Ten point grade and grade description

Marks Obtained (%)	Grade Point	Letter Grade	Description
90-100	9.00- 10	O	Outstanding
80-89	8.00-8.90	A^{++}	Exceptional
70-79	7.00-7.90	A^{+}	Excellent
60-69	6.00-6.90	A	Very Good
55-59	5.50-5.90	B^{+}	Good
50-54	5.00-5.40	B	Fair
45-49	4.50-4.90	C^{++}	Average (Above)
41-44	4.1-4.49	C	Average
40	4.0	P	Pass
< 40	0.0	F	Fail (Unsatisfactory)
	0.0	AB	Absent

- Non-appearance in any examination / assessment shall be treated as the students have secured zero marks in that subject examination / assessment.
- Minimum P grade (4.00 grade points) shall be the limit to clear / pass the course / subject. A student with F grade should be considered as "failed" in the concerned course

and he / she has to clear the course by appearing in the next successive semester examinations. There should be no revaluation or recounting under this system.

- Every student shall be awarded grade points out of maximum 10 points in each subject (based on 10 point scale). Based on the grade points obtained in each subject, Semester Grade Point Average (SGPA) and then Cumulative Grade Point Average (CGPA) shall be computed. Results should be announced at the end of each semester and CGPA should be given at final exit.

Computation of SGPA (Semester Grade Point Average) and CGPA (Cumulative Grade Point Average)

Grade in each subject / course should be calculated based on the summation of marks obtained in all five modules.

The computation of SGPA and CGPA should be as below

- Semester Grade Point Average (SGPA) is the weighted average points obtained by the students in a semester and should be computed as follows

$$SGPA = \frac{\text{Sum (Course Credits) X Number of Grade Points in concerned Course Gained by the Student}}{\text{Sum (Course Credits)}}$$

The SGPA should be mentioned on the grade card at the end of every semester.

- The Cumulative Grade Point Average (CGPA) should be used to describe the overall performance of a student in all semester of the course and should be computed as under.

$$CGPA = \frac{\text{Sum (All six Semester SGPA)}}{\text{Total Number of Semester}}$$

The SGPA and CGPA shall be rounded off to the second place of decimal.

Grade Card

Results should be declared by the Centre and the grade card (containing the grades obtained by the student along with SGPA) should be issued by the university after completion of every semester. The grade card should be consisting of following details.

- Title of the courses along with code opted by the student.
- Credits associated with the course.
- Grades and grade points secured by the student.
- Total credits earned by the student in a particular semester.
- Total credits earned by the students till that semester.
- SGPA of the student.

- CGPA of the student (at final exit).

Cumulative Grade Card

The grade card showing details grades secured by the student in each subject in all semesters along with overall CGPA should be issued by the University at final exit.

Course Structure

M. Voc (Industrial Automation)

Semester	Paper Code	Paper Title	Contact Hrs/Week	Credits
Semester I	**CC100**	Constitution of India	2	2
	IAC110	Electronic Systems	2	2
	IAC111	Power Electronics	2	2
	IAC112	Transducer Technology	2	2
	IAC113	Electric Drives	2	2
	IAF120	Embedded Systems Design	2	2
	IAF121	Programmable Logic Controllers	2	2
	CF101	Research Methodology	1	1
	EF1XX	Elective Foundation (Any One) ▪ Operations Management (EF130) ▪ Materials management (EF 131)	2	2
	IALC 140	Electronic Systems lab	3	1.5
	IALC 141	Power Electronics lab	3	1.5
	IALC 142	Instrumentation lab – I	3	1.5
	IALC 143	Electric Drives lab	3	1.5
	IALF 150	Embedded Systems Lab	3	1.5
	IALF 151	PLC lab	3	1.5
	Assignments/Tutorials will remain integral part of all courses			
		Total Credits for Semester – I		**26**

Semester	Paper Code	Paper Title	Contact Hrs/Week	Credits
Semester II	**IAC 210**	Communication Protocols for Instrumentation	2	2
	IAC 211	Mechatronics	2	2
	IAC 212	Advanced Transducers	2	2
	IAF 220	Robotics	2	2
	IAF 221	Process Control	2	2
	IAF 222	Industrial Automation	2	2
	IALC 230	Industrial Networking lab	3	1.5
	IALC 231	Mechatronics lab	3	1.5
	IALC 232	Instrumentation lab –II	3	1.5
	IALF 240	Robotics lab	3	1.5
	IALF 241	Process Control lab	3	1.5
	IALF 242	Industrial Automation lab	3	1.5
	IAR 250	Research/ Industrial Project – Phase I (Review of Literature/ Industrial Orientation, Formulation of Topic, Experimental Plan)	10	5
	Assignments/Tutorials will remain integral part of all courses			
		Total Credits for Semester – II		**26**

Semester	Paper Code	Paper Title	Contact Hrs/Week	Credits
Semester III	**IAGE 31X**	Generic Elective – I	2	2
	IAGE 31X	Generic Elective – II	2	2
	IAGE 31X	Generic Elective – III	2	2
	IAGE 31X	Generic Elective – IV	2	2
	IAOE 32X	Open Elective –I	2	2
	IALE 33X	Lab Course based on Generic Elective – I	3	1.5
	IALE 33X	Lab Course based on Generic Elective – II	3	1.5
	IALE 33X	Lab Course based on Generic Elective – III	3	1.5
	IALE 33X	Lab Course based on Generic Elective – IV	3	1.5
	IAR 340	Research/ Industrial Project – Phase II (Experimental Work)	18	9
	Assignments/Tutorials will remain integral part of all courses			
		Total Credits for Semester – III		**25**

Semester	Paper Code	Paper Title	Contact Hrs/Week	Credits
Semester IV	**IAGE 41X**	Generic Elective – V	2	2
	IAOE 42X	Open Elective – II	2	2
	IALE 43X	Lab Course based on Generic Elective – V	3	1.5
	IAR 440	Research/ Industrial Project – Phase III (Experimental Work Continued, Organization and Interpretation of Result, Dissertation, Presentation)	39	19.5
	Assignments/Tutorials will remain integral part of all courses			
		Total Credits for Semester – IV		**25**

Electives for Semester – III

(Any four theory paper along with corresponding lab course have to be chosen from generic electives)
(Any one theory paper have to be chosen from open electives)

	Paper Code	Paper Title		Paper Code	Paper Title
Generic	**IAGE 310**	Industrial Processes and Instrumentation	Generic(Lab)	**IALE 330**	Lab Course based on Industrial Process Control
	IAGE 311	SCADA System and Applications		**IALE 331**	Lab Course based on SCADA System and Applications
	IAGE 312	Applied Hydraulics and Pneumatics		**IALE 332**	Lab Course based on Applied Hydraulics and Pneumatics
	IAGE 313	Industrial Robotics		**IALE 333**	Lab Course based on Industrial Robotics

	IAGE 314	Advanced Sensor Technology		**IALE 334**	Lab Course based on Advanced Sensor Technology
	IAGE 315	Kinetics and Dynamics of Robotics		**IALE 335**	Lab Course based on Kinetics and Dynamics of Robotics
	IAGE 316	Mechatronics Systems Design		**IALE 336**	Lab Course based on Mechatronics Systems Design
	IAGE 317	Distributed Control System		**IALE 337**	Lab Course based on Distributed Control System
	IAGE 318	Advanced Electrical Drives		**IALE 338**	Lab Course based on Electrical Drives
	IAGE 319	Advanced Microcontrollers		**IALE 339**	Lab Course based on Advanced Microcontrollers
Open	**IAOE 321**	Automotive Engines			
	IAOE 322	Automobile Control Systems			

Electives for Semester – IV

(Any one theory paper along with corresponding lab course have to be chosen from generic electives)
(Any one theory paper have to be chosen from open electives)

	Paper Code	**Paper Title**		**Paper Code**	**Paper Title**
Generic	**IAGE 410**	Automated and Computer Integrated Manufacturing	**Generic(Lab)**	**IALE 430**	Lab Course based on Automated and Computer Integrated Manufacturing
	IAGE 411	CNC Technology		**IALE 431**	Lab Course based on CNC
	IAGE 412	Micro Mechatronic Systems		**IALE 432**	Technology Lab Course based on Micro Mechatronic Systems
Open	**IAOE 420**	Automated Manufacturing			
	IAOE 421	Industrial Robotics			
	IAOE 422	Mechatronics Fundamentals			

SEMESTER – I

IAC - 110

Electronic Systems

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Recognize OP-AMPs for building systems to develop application oriented platforms
2	Associate with controlled oscillations and monolithic frequency synthesizers
3	Experiment analog/digital timing and counting circuits
4	Classic treatments on Phase locked loops and frequency to voltage conversion
5	Interpret active filter operations
6	Identify necessary system requirements
7	Address and resolve complex application challenges

Course Contents:

Module– I: Special Operational Amplifiers and Non-linear Function Circuits (06 Hrs)

High voltage/high current amplifiers, chopper and chopper stabilized amplifiers, instrumentation amplifierand isolation amplifier.

Nonlinear function circuits: limiter, log/anti-log, multiplier/divider, peak detector, comparator, true RMS/DC converter, square wave oscillators.

Module– II: Oscillators, Timers, Counters (06 Hrs)

Sinusoidal and relaxation oscillators:phase shift oscillator, Ring oscillator, Wien-bridge oscillator, quadrature oscillator, crystal oscillator and clock circuits, voltage controlled oscillators – sine, square and triangle, frequency synthesizers.

Timing and counting circuits :digital counters, shift register, analog and digital timers, frequency counters, PLA and PLD applications.

Module– III: Phase Locked Loops and F/V conversion (06 Hrs)

Phase locked loop, Loop response, Applications of PLL.

Frequency-to-voltage converters: diode pump integrator, frequency and RPM transducers; Phase and phase/frequency comparators – analog and digital.

Module– IV: Active Filters **(06 Hrs)**

Active filter types, Filter approximations – Butterworth and chebyshev, filter realizations, frequency and impedance, scalings, filter transformations, sensitivity, switched capacitor circuit.

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. Sende, B.S. – Introduction to System design using Integrated Circuits, New Age International (P), NewDelhi.
2. Fitchen, F.C. – Integrated Circuits and Systems,Van Nostrand, New York.

IAC - 111

Power Electronics

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Memorize various Power Converter topologies and configurations.
2	Classify various Power devices and know their construction, working principle, how they are controlled by small power, advantages, disadvantages
3	Experiment with converter, inverter, cycloconverter
4	Construct and relate power devices with different loads
5	Assess and modify control related application of power electronics

Course Contents:

Module– I: DC – DC Converters (06 Hrs)

Principle of operation of buck, boost, buck-boost, cuk, fly back, forward, push-pull, half bridge, full bridge converters, multi output boost converters, diode rectifier based boost converters

Module– II: Inverters (06 Hrs)

Single and three phase inverters with R and RL loads, Voltage Control, Harmonic reduction, Square Wave generation, PWM inverters, modulation techniques, SPWM, Current Source Inverter

Module– III: Resonant Pulse Converters (06 Hrs)

Series and parallel resonant inverters – zero current and zero voltage switching, Frequency Response Two quadrant zero voltage switching, Resonant DC link inverters, soft switching

Module– IV: Cycloconverters and AC voltage Controllers (06 Hrs)

Single and Three phase cycloconverters with R and RL loads, Voltage control, harmonics and operation waveforms

Single and Three phase AC voltage controllers with R and RL loads, Voltage Control, harmonics, operation waveforms, PWM, Matrix converter

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. Mohan, Undeland, Robbins-Power Electronics: Converters, Application and Design, John Wiley & Sons, 1989
2. A.I. Pressman –Switching mode power supply design-MGH, 1992
3. M. H. Rashid- Power Electronics, PHI, 2004
4. Michel, D. –DC-DC Switching Regulator Analysis – MGH 1987
5. Bimal K. Bose- Modern Power Electronics and AC Drives- PHI, 1995
6. Erickson, Makgimovic – Fundamentals of Power Electronics – Springer, 1998
7. P. T. Krein – Elements of Power Electronics – OUP, 1989

IAC - 112

Transducer Technology

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Observe, monitor, analyze and sympathy towards the instruments form the basis of measurement.
2	Distinguish between transducers, sensors and transmitters
3	Define principle behind strain gauge and pressure sensors
4	Explain working of displacement, position, motion & temperature sensors
5	Work with different sensors

Course Contents:

Module– I: Introduction to Transducers (06 Hrs)

Characteristics and choice of Transducer, Classification of Transducer: Primary & secondary, Passive & Active, Transducers & Inverse Transducers; Advantages of Electrical Transducers, Summery of factors influencing the choice of Transducers, Types of signals: Pneumatic signal, Hydraulic signal, Electric signal, Difference between sensors, transmitter and transducer.

Module– II: Displacement, Position and Motion Sensor (06 Hrs)

Principles of variable resistance, variable inductance, variable reluctance, variable capacitance type sensors, Position and Motion sensor : Limit switches, proximity sensors, optical proximity sensor, ultrasonic proximity sensor
LVDT & RVDT: Construction, working principle, Advantages and Disadvantages
Hall Sensor: Working principle, Hall Effect gear tooth sensor
Accelerometer: Definition, General Construction, Working principle, types of accelerometer

Module– III: Temperature Sensors (06 Hrs)

Mechanical and resistance type temperature sensors, Thermistors: Construction of Thermistors, resistance temperature characteristics of thermistors, voltage current and current time characteristics of thermistors, salient features of thermistors
Thermocouple: Construction of thermocouple, Measurement of thermocouple output, Compensation circuit, reference junction compensation, Optical pyrometer

Module– IV: Strain Gauge and Pressure Sensor (06 Hrs)

Strain Gauge: Working principle, construction, piezo resistance co-efficient; Types of strain gauge: bonded, unbounded, semiconductor; Strain gauge measurement: Wheatstone bridge measurement
Pressure Sensor: Classification of pressure, Pressure measurement methods: inductive type, capacitance type, strain gauge type, reluctance type, piezoelectric pressure transducer

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. A K Ghosh: Introduction to Instrumentation and Control, Prentice Hall of India, New Delhi 2004.
2. A K Sawhney: A course on electrical and electronic measurements and instrumentation, Dhanpat Raj & Co, 2005
3. D Patranabis: Principle of Industrial Instrumentation, Tata McGraw-Hill, New Delhi 2004
4. John P.Bentley: Principles of measurement systems, 3rd edition, Addison Wesley Longman, 2000.
5. David A Bell: Electronic Instrumentation and measurement, Prentice Hall of India
6. M.M.S.Anand: Electronic instruments and instrumentation Technology, Prentice-Hall of India,2004.
7. Alan S.Morris: Principles of measurement and instrumentation, 2nd edition, Prentice-Hall of India,2004.
8. Ernest O. Doebelin: Measurement systems, 4th edition, Tata-McGraw Hill, 1990.
9. H.S.Kalsi-Electronic Instrumentation,3rd edition,2011

IAC - 113

Electric Drives

(02 credits – 50 marks)

Courser Outcomes:

On completion of the course, students should be able to-

1	State starting and braking of Drives
2	Observe Speed-torque characteristics of Drives
3	Demonstrate Chopper, Inverter, Cycloconverter and PWM based Control
4	Select drive for specific application
5	Categorize speed controlling of Motors

Course Contents:

Module– I: Introduction to Electrical Drives (06 Hrs)

Electrical Drives, Advantages Of Electrical Drives, Parts Of Electrical Drives, Choice Of Electrical Drives, Status Of DC And AC Drives, Types Of Loads, Quadrantal Diagram Of Speed-Torque Characteristics, Starting and Braking of Electric Drives

Module– II: Control of Electrical Drives (06 Hrs)

Control of electric Drives: Modes of operation. Closed-loop control of drives. Current-limit control. Closed-loop torque, and speed control. Speed and current sensing. Phase-locked-loop control.

Module– III: DC Drive (06 Hrs)

DC Drive: Single phase half wave and full wave converter Drive, Three phase half wave and full wave converter Drive , Chopper fed DC Drive: Motoring Control, Two –quadrant Chopper Drives

Module– IV: AC Drive (06 Hrs)

AC Drive : Inverter fed drive, single phase and three phase cycloconverters Operations in different modes and configurations, Stator voltage control, stator frequency control, Stator Current control, PWM based control

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books :

1. Bimal.K. Bose, “Power Electronics and Variable frequency drives”, Standard Publishers Distributors, New Delhi, 2000
2. Murphy J.M.D, Turnbull, F.G, “Thyristor control of AC motor, Pergamon press, Oxford, 1988.
3. M. H. Rashid, "Power Electronics -Circuits, Devices and Applications", P.H.I Private Ltd. New Delhi, Second Edition, 1994
4. N. Mohan et.al. "Power Electronics-Converters, Applications and Design", John Wiley & Sons (Asia) Private Ltd., Singapore, 1996
5. Bimal K Bose, “ Modern Power Electronics and AC Drives” PHI
6. R. Krishnan, “Electric motor drives: modeling, analysis and control, Pearson
7. Dubey G.K. “Power Semiconductor controlled drives”, Prentice Hall inc, A division of Simon and Schester England cliffs, New Jersey 1989.
8. Sheperal, Wand Hully, L.N. “Power Electronic and Motor control” Cambridge University Press Cambridge 1987
9. Dewan,S. Slemon B., Straughen,A. G.R., “Power Semiconductor drives”, John Wiley and Sons, NewYork 1984.

   10.Dr. P.S. Bhimbra,”Power Electronics”, Khanna Publishers,2012

IAF – 120

Embedded Systems Design

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	State the concepts of interfacing 8051 microcontroller to real world elements
2	Recognize protocols for interfacing 8051 microcontroller to real world elements
3	Demonstrate interfacing concepts and protocols for 8051 microcontroller.
4	Develop programs for interfacing real world elements to 8051 microcontroller
5	Implement 8051 microcontroller for process automation applications

Course Contents:

Module- I: Introduction (05 Hrs)

Introduction, Microcontroller and embedded processors, Overview of 8051 family, 8051 Architecture, PSW registers, register bank and stacks, addressing modes, introduction to the use of assemblers and simulators.

Module- II: Arithmetic, Logic Instructions and Assembly language program (08 Hrs)

Jump, loop and call instructions, Addressing modes, arithmetic instructions, logical instructions, Assembly language programs, introduction to timers and counters.

Module- III: Real World Interfacing - I (06 Hrs)

Interfacing of - LCD, Keyboard, ADC (Parallel and Serial), DAC; Analog and Digital Sensor; Case Studies

Module- IV: Real world interfacing– II (06 Hrs)

Interfacing of - External Memory, RTC, Stepper Motor, DC motor, Speed control of motors; Case studies

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. Muhammad Ali Mazidi, J. G. Mazidi and Rolin D. McKinlay – The 8051 Microcontroller and Embedded Systems - Pearson, 2nd edition 2013
2. 8051 Architecture, Programming and Interfacing- K.J. Ayala; Penram International
3. John B. Peat Man- Design with Microcontroller, Pearson Edition Asia, 1998
4. Burns, Alan and Wellings, Andy, Real Time Systemand Programming Languages, 2nd edition 2013, Harlow: Addison- Wesley
5. Frank Wahid - Embedded Systems
6. Raj Kamal -Embedded Systems

IAF - 121

Programmable Logic Controllers

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Recognize typical components of a Programmable Logic Controller.
2	Explain the basic concepts of a Programmable Logic Controller
3	Develop basic programming skills for process automation with PLC's
4	Employ Allen Bradley PLCs for industrial applications
5	Design and program basic PLC circuits for entry-level PLC applications
6	Compose and develop a small, automated Industrial production line.

Course Contents:

Module– I: PLC fundamentals (06 Hrs)

Overview of PLC systems,input/output modules, power supplies, isolators, rack assembly, PLC programming Modules, Input and Output devices for PLC based systems; Relay ladder logic Circuits, Conceptualization of ladder diagram.

Module– II: PLC Functions – I (06 Hrs)

General PLC programming procedures; Addressing, Relationship of Data File addresses to I/O modules; Language of ladder diagram, programming on-off inputs/ outputs; Auxiliary commands and functions: PLC Basic Functions: Register basics, timer functions, counter functions.

Module- III: PLC Functions - II (06 Hrs)

Arithmetic functions, number comparison functions, Skip and MCR functions, data manipulation functions; PLC Advanced intermediate functions: Utilizing digital bits, sequencer functions, matrix functions.

Module– IV: PLC Advanced Functions and Applications (06 Hrs)

PLC advanced functions: Alternate programming languages, analog PLC operation, networking of PLC, PLC -PID functions; PLC installation, troubleshooting and maintenance, design of interlocks and alarms using PLC. Creating ladder diagrams from real time system descriptions.

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. J. W. Webb, R. A. Reis – Programmable Logic Controllers: Principles and Applications- PHI, New Delhi, 2013
2. W. Bolton – Programmable Logic Controllers – Elsevier, UK, 2006
3. J. R. Hackworth, F. D. Hackworth Jr- Programmable Logic Controllers: Programming Methods and Applications – Pearson, New Delhi, 2004
4. F. Petruzella – Programmable Logic Controllers – MGH, UK, 2014
5. G. D. Anderson – PLC programming using RSLogix 500: Ladder Logic Diagonistics and Trobleshooting (Vol 1-3)

CF 101

Research Methodology

(01 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define research and describe the research process and research methods
2	Estimate qualitative research and methods used to execute and validate qualitative research
3	Relate basic aspects of the research process in order to plan and execute a research project
4	Select a suitable analytical method for a specific research approach
5	Demonstrate a good understanding of how to write a research report
6	Critically assess published quantitative research with regard to the statistical methods and approaches adopted .

Course Contents:

Module- I : Research Fundamentals (04 Hrs)

Introduction: Definition, objectives of the research, characteristics of the research, what makes people to do research, importance of research

Module- II : Identification of Research Problem (04 Hrs)

Defining the research problem: Identification of research problems, selection of research problem, facts one should know regarding selection of research problem, the process of research problem definition, some facts involved in defining research problem

Module- III : Formulation of Research Problem (04 Hrs)

Formulation of the problems: steps involved in defining a problem, formulation of the problems, Formulation of hypothesis: Concept of hypothesis, hypothesis testing, Developing the research plan: implementation, interpreting and reporting the findings, Importance of hypothesis of in decision making.

Module- IV : Research Report and Proposal Writing (04 hrs)

Introduction, research proposal writing: costing, the research proposal, rationale for the study, research objectives, research methodology, target respondents, research Centres, sample size and sample composition, sampling procedures, research project execution, research Modules; An insight into research report and proposal, research project synopsis, research report writing : types of research reports, guidelines for writing reports; Steps in writing report, report presentation, typing the report, documentation and bibliography, formatting guidelines for writing a good research report / research paper.

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

References:

1. Research Methodology by Dr. S. L. Gupta, Hitesh Gupta; International Book House Pvt Ltd (**2013),** ISBN-10: 8191064278, ISBN-13: 978-8191064278
2. Basic Research Methods-Gerard Guthrie SAGE Publications, India, Pvt Ltd, New Delhi (**2010),** ISBN-10: 8132104579, ISBN-13: 978-8132104575
3. Research Methodology-methods and techniques By C. R. Kothari, New Age International Publishers **(2011)** ISBN 978-81-224-1522-3
4. Principles of Research Methodology- Phyllis G. Supino, Jeffrey S. Borer; Springer, Verlag New York **(2012),** ISBN-ebook: 1461433592, ISBN (Hardcover): 978-1461433590
5. Research Design Qualitative, Quantitative. and Mixed Methods Approaches- John W. Creswell; SAGE Publications Ltd, UK **(2011),** ISBN-9780857023452
6. Research Methodology -A Step-by-Step Guide for Beginners- Ranjit Kumar; Sage Publications Ltd **(2010)**, ISBN- 1849203016.
7. Scientific Writing and Communication- Angelika Hofmann; Oxford University Press, US **(2010),** ISBN-13-: 978-0 199947560, ISBN-10: 01 99947562
8. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded- Joshua Schimel, Oxford University Press, **(2011)**, ISBN: 9780199760237
9. Handbook of Scientific Proposal Writing- A.Yavuz Oruc; CRC Press, Taylor & Francis group **(2011)**, ISBN: 9781439869185

EF 130
Operations Management

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define 'operations' and 'operations management'
2	Identify the roles and responsibilities of operations managers in different organizational context.
3	Apply the 'transformation model' to identify the inputs, transformation processes and outputs of an organization
4	Identify operational and administrative processes
5	Describe the boundaries of an operations system, and recognize its interfaces with other Functional areas within the organization and with its external environment

Course Contents:

Module– I:Introduction to Operations Management (06 Hrs)

Introduction to Operation Management, Operations Strategy, Role of Operations Strategy, Importance of Operation strategy, Classification of production system – Job shop, Batch, Mass, Continuous production, Competitive Advantage, Time Based Competition.

Module- II: Product Development Cycle (06 Hrs)

Product Decision and Analysis, Product Development, Process Selection, Process Design, Process Analysis, Process-Product Matrix, Evolution of Production Systems, Batch Sizing-Models-Optimization

Module- III: Layout and Management of Operation (06 Hrs)

Facility Location, Facility Layout, Capacity Planning, Capacity Decisions, Waiting Lines, Demand Management-models, Resource Planning-models, Total Quality Management, Supply Chain Management and Just-in-Time/Lean Operations

Module- IV: Planning and Management **(06 Hrs)**

Aggregate Planning, Basics of MRP / ERP**,** Basics of Scheduling**,** Basics of Project Management, Basics of Work Study, Job Design and Work Measurement**,** Basics of ISO 14000 / 9000, Basics of Value Engineering & Analysis

Module- V:

Presentation's, case studies, Assignments, Tutorials based on Module I to IV

Ref. Books:

1. Production & Operations Management -S. N. Chary
2. Operations Management – S.Anil Kumar, N.Suresh- New age International Publishers
2. Operations Management – Andrew Greasley - SAGE Publications
3. Modern Production Management -By E. S. BUFFA
4. Production and Operations Management -By Norman Gaither
5. Theory and problem in Production and operations Management -By S. N. Chary
6. Production and operation Management - By Chunawalla Patel
7. Production & operation Management – Kanishka Bedi – Oxford
8. Production & operation Management – R.C. Manocha
9. Production & operation Management – Muhlemann

EF-131

Materials Management

(02 credits – 50 marks)

Course Outcome:

On completion of the course, students should be able to-

1	Define Materials and its Management
2	Identify Integrated Approach to Materials Management
3	Understand in International procurement-Imports

Course Contents:

Module– I: Materials Management- an overview (06Hrs)

Introduction, Importance of Materials Management, Objectives of Materials Management, Costs involved in the Management of Materials, Integrated approach to Materials Management, organizing Materials Management, Organization based on Commodities, Organization based on Location, Organization based on function, Inter-departmental relationships, Centralized versus Decentralized materials management.

Module- II: Materials Planning (06Hrs)

Introduction and factors influencing materials planning, Techniques of materials planning, Bill-of-Materials, Materials Requirement Planning (MRP), Past Consumption Analysis Technique, Moving Average method, Exponential Smoothing.

Module- III: Purchasing (06Hrs)

Purchasing principles, policies, procedures and practices, Objectives, scope, responsibility and limitations, Sources of supply and Supplier selection, Vendor development-evaluation and rating, Price forecasting, Price-cost analysis, Negotiations, Reciprocity, Legal aspects of purchasing, Purchase orders/ contracts, Method of buying- under certainty, under risk, and under uncertainty

Module- IV: International procurement-Imports (06 Hrs)

International commercial terms, Import procedures and documentation, Categories of importers, Identification of foreign sources, Payment terms including Letter of credit, Types of L/Cs, Custom tariff, Custom clearance, Bill of Lading and other documents.

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV

Ref.Books:

1. Materials and Logistics Management By Prof. L.C. Jhamb (Everest Publishing House, Pune).
2. Purchasing and Materials Management By P.Gopalkrishnan (Tata McGraw Hill, New Delhi).
3. Materials Management –An integrated approach By P.Gopalkrishnan and M. Sundaresan (Prentice-Hall India, New Delhi).
4. Materials Management-Procedures, Text and Cases By A.K. Datta (Prentice-Hall India, NewDelhi).
5. Introduction to Materials Management By JR Tony Arnold and Stephan Chapman (Pearson Education, New Delhi) 2004 Fifth Edition.
6. Purchasing and Materials Management By N.K.Nair (Vikas Publishing House, New Delhi)

IALC - 140

Electronic Systems Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should able to –

1	Demonstrate working of different types of amplifiers, timers, counters, oscillators and filters.
2	Illustrate operation of industry standard programmable timer.
3	Apply different amplifiers/ timers/ counters/ oscillators/ filters for real time applications

List of Experiments: (Any 5 experiments are to be performed)

1. Study of Instrumentation amplifier
2. Study of log/antilog amplifier
3. Study of window comparator
4. Study of Phase shift/ Wien bridge oscillator
5. Study of typical monolithic frequency synthesizer
6. Study of voltage controlled oscillator
7. Study of fundamental digital counters
8. Study of industry standard event counter
9. Study of industry standard programmable timer (analog and digital)
10. Study of filters (any one pertinent to theory course)

IALC - 141

Power Electronics Lab

(1.5 credits – 50 marks)

Course Outcomes

On completion of the course, students should able to –

1	Demonstrate working of different types of converter/ inverter and cyclo converter.
2	Illustrate operation of zero voltage switching.
3	Apply different converter/ inverter and cyclo converter for real time applications

List of Experiments: (Any 5 experiments are to be performed)

1. Study of Buck Converter
2. Study of Boost Converter
3. Study of Flyback Converter
4. Study of Forward Converter
5. Study ofsingle phase inverter with R load
6. Study ofsingle phase inverter with RL load
7. Study of PWM converter
8. Study of series inverter
9. Study of parallel inverter
10. Study of zero voltage switching
11. Study of single phase cycloconverter with R load
12. Study of single phase cycloconverter with RL load
13. Study of single phase AC voltage control scheme (any one pertinent to theory course)

IALC - 142

Instrumentation Lab

(1.5 credits – 50 marks)

Course Outcomes

On completion of the course, students should able to –

1	Demonstrate working of different transducers.
2	Illustrate working of optical rotary/ angle encoder for speed / position measurement.
3	Apply different transducers for real time applications.

List of Experiments: (Any 5 experiments are to be performed)

1. Study of Resistive Transducer
2. Study of Inductive Transducer
3. Study of Differential Output Transducer (LVDT)
4. Study of optical rotary encoder for speed measurement
5. Study of optical angle encoder for position measurement
6. Study of Capacitive Transducer
7. Study of RTD
8. Study of Photo Electric Transducer
9. Study of Pressure Cell
10. Study of Piezo Electric Transducer
11. Study of Optical fiber Transducer

IALC - 143

Electric Drives lab

(1.5 credits – 50 marks)

Course Outcomes

On completion of the course, students should able to –

1	Demonstrate working of different comparators.
2	Illustrate working of single/ three phase cycloconverter AC Drive.
3	Apply different single/ three phase PWM/ cycloconverter AC drive for real time applications.

List of Experiments: (Any 5 experiments are to be performed)

1. To study single phase converter using RAMP Comparator
2. To study three phase converter using RAMP Comparator
3. To study operation of single phase cycloconverter AC Drive
4. To study operation of three phase cycloconverter AC Drive
5. To study single phase PWM based AC Drive
6. To study three phase PWM based AC Drive
7. To study thyristors based DC motor drive
8. Study of Industry grade VFD for motor control (ABB/Danfoss/Siemens)

IALF - 150

Embedded Systems Lab

(1.5 credits – 50 marks)

Course Outcomes

On completion of the course, students should able to –

1	Develop algorithms to perform real time operations using microcontroller
3	Apply embedded systemknowledge for real world device interfacing.

List of Experiments:

Every student should build at least 02 individual projects by implementing interface of 8051 with devices pertinent to theory course. Each project should invariably include at least two devices that should demonstrate clear operational correlation.

IALF - 151

PLC Lab

(1.5 credits – 50 marks)

Course Outcomes

On completion of the course, students should able to –

1	Develop miniprojects employing PLCs
3	Apply knowledge PLCs for real world device interfacing and applications.

List of Experiments:(Any 5 experiments are to be performed)

Allen Bradley platform to be employed

1. Develop ladder programming to implement (i)basic logic gates and (ii) sequencing operations employing timers (lamp output)

2. Develop ladder programming to implement counter operation (proximity sensor to be used as event indicator) for triggering an enunciator after a certain batch of count is over
3. Develop ladder programming to operate a conveyor based liquid vending station
4. To study operation of
5. Develop ladder programming to operate a density based traffic light arrangement
6. Develop ladder programming to operate an X-Y plotter
7. Develop ladder programming to address different sequence of operation in a real time batch process unit (should contain at least two liquid tanks as main storage, one mixing tank, stirrer, heater, liquid dispenser, conveyor based handling, liquid level indicators etc.).
8. Develop program for at least two real time industrial processes with ITS – PLC virtual platform

SEMESTER – II

IAC – 210

Communication Protocols for Instrumentation

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Identify the issues and challenges in the architecture of computer network
2	Explain the concept of communication model, OSI reference model, Recent Industry Networks.
3	Classify the Network selection applicable for specific industrial needs.
4	Differentiate the Network Architecture and describe the concepts of Industrial protocols.
5	Classify and Compare various Wireless Networking protocols

Course Contents:

Module-I: Introduction and Communication Protocols (06 Hrs)

An Introduction to Networks in process automation: Information flow requirements, Hierarchical communication model, Data Communication basics, OSI reference model, Industry Network, Introduction to Communication Protocols: Communication basics, Network Classification, Device Networks, Control Networks.

Module-II: Network Architectures (06 Hrs)

Proprietary and open networks: Network Architectures, Building blocks, Industry open protocols (RS-232C, RS- 422, and RS-485), Ethernet, Advantages and Limitations of Open networks, IEEE 1394

Module-III: Field Bus (06 Hrs)

Field bus: Field bus Trends, Hardware selection, Field bus design, Installation, Documentation, Field bus advantages and limitations. HART: Introduction, Design, Installation, calibration, commissioning.

Module-IV:Planning and Commissioning (06 Hrs)

Foundation Field bus & Profibus: Introduction, Design, Calibration, Commissioning, Application in Hazardous and Non-Hazardous area. Introduction to wireless Protocols: WPAN, Wi-Fi, Bluetooth, ZigBee, Z-wave.

Module-V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. B.G. Liptak - Process Software and Digital Networks - CRC Press ISA-, 2002.
2. R. Bowden - HART Communications Protocol-Fisher-Rosemount, 2003.
3. A.S. Tanenbaum -Computer Networks - Pearson Education, 1996/PHI.
4. K. Kant – Computer based Process Control – New Age International, 1998

IAC - 211

Mechatronics

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define and Classify mechatronics system.
2	Classify and Compare different types of Transducers.
3	Define various performance terminologies in Sensors.
4	Explain different types of actuators used in mechatronics
5	Analyze various types of sensors and selection procedure for various applications.
6	Design the real time application of Mechatronics based System.

Course Contents:

Module– I: Introduction (06 Hrs)

Introduction to Mechatronics; Mechatronics Systems, Need for Mechatronics, Emerging area of Mechatronics, Classification of Mechatronics, Measurement Systems, Control Systems.

Module– II: Sensors and Transducers (06 Hrs)

Performance Terminology in sensor technology; Potentiometers, LVDT, Capacitance sensors, Strain gauges, Eddy current sensor, Hall Effect sensor, Temperature sensors, Light sensors, Selection of sensors, Signal processing.

Module– III: Actuators (06 hrs)

Actuators: Mechanical, Electrical, Fluid Power, Piezoelectric, Magnetostrictive, Shape memory alloy, applications, selection of actuators.

Module– IV: Design and Mechatronics Case Studies (06 Hrs)

Stages in mechatronics system design, Traditional and Mechatronics design concepts, Case studies of Mechatronics systems - Pick and place Robot, Conveyor based material handling system, PC based CNC drilling machine, Mechatronics Control in Automated Manufacturing

Module-V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. Bolton.W – Mechatronics - Pearson education, second edition, fifth Indian Reprint, 2003
2. Smaili.A and Mrad.F - Mechatronics integrated technologies for intelligent machines - Oxford university press, 2008.
3. Devadas Shetty and Richard A.Kolk, - Mechatronics systems design - PWS Publishing Company, 2007.
4. Godfrey C. Onwubolu - Mechatronics Principles and Applications - Elsevier, 2006.
5. Nitaigour Premchand Mahalik -Mechatronics Principles, Concepts and Applications - Tata
6. McGraw-Hill Publishing Company Limited, 2003.
7. Michael B.Histand and Davis G. Alciatore - Introduction to Mechatronics and Measurement
8. Systems - McGraw Hill International edition, 1999.
9. Bradley D.A, Dawson.D, Buru N.C and Loader A.J – Mechatronics - Nelson Thornes Ltd, Eswar press, Indian print, 2004.

IAC - 212

Advanced Transducers

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Discuss calibration protocol for test various types of sensors
2	Explain different types of errors in Sensor Systems.
3	Classify different types of Flow sensors based on flow measurements.
4	Identify techniques to measure viscosity and density
6	Discuss on different types of sensors in robotics

Course Contents:

Module– I: Testing, Calibration and Error (06 Hrs)

Testing and calibration: Traceability. Measurement reliability. Calibration experiment and evaluation of results. Primary calibration. Secondary calibration. Direct calibration. Indirect calibration. Routine calibration. Calibration of a voltmeter, ammeter and an oscilloscope.Measurement Errors. Human Error. Systematic Error. Limiting and Random Errors.

Module– II: Flow Sensors (06 Hrs)

Flow measurement: Introduction, definitions and Modules, classification of flow meters, Pitot tubes, orifice meters, venturi tubes, flow tubes, flow nozzles, positive displacement liquid meters and provers, positive displaceTesting and calibration ment gas flowmeters, variable area meters Positive displacement type: Piston; oval gear, nutating disk and rotary vane types,Velocity meters: turbine, vortex shedding, electromagnetic and sonic design; head type flow meter, electromagnetic flow meter, rotameter, anemometer, ultrasonic flow meter

Module– III: Viscosity Sensors (06 Hrs)

Measurement of viscosity: definition, Modules, Newtonian and Non-Newtonian behavior, Measurement of viscosity using laboratory viscometer, industrial viscometers,viscometer selection and application.

Measurement of density – definitions, Modules, liquid density measurement, gas densitometers – application and selection.

Module– II: Smart Sensors and Sensors in Robotics (06 Hrs)

Smart Sensors: Methods of internal compensation, information coding, integrated sensor principles, present trends Sensors in Robotics: Potentiometers, synchros and resolvers, optical encoder, tactile and proximity sensors, non-contact ranging sensors, ultrasonic transducers, opto-electronic sensors, geomagnetic sensors, gyroscopes; Different type of load cells and its application, Torque measurement.

Module- V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. A K Ghosh: Introduction to Instrumentation and Control, Prentice Hall of India, New Delhi 2004.
2. A K Sawhney: A course on electrical and electronic measurements and instrumentation, Dhanpat Raj & Co, 2005
3. D Patranabis: Principle of Industrial Instrumentation, Tata McGraw-Hill, New Delhi 2004
4. John P.Bentley: Principles of measurement systems, 3rd edition, Addison Wesley Longman, 2000.
5. David A Bell: Electronic Instrumentation and measurement, Prentice Hall of India
6. M.M.S.Anand: Electronic instruments and instrumentation Technology, Prentice-Hall of India,2004.
7. Alan S.Morris: Principles of measurement and instrumentation, 2nd edition, Prentice-Hall of India,2004.
8. Ernest O. Doebelin: Measurement systems, 4th edition, Tata-McGraw Hill, 1990.
9. H.S.Kalsi-Electronic Instrumentation,3rd edition,2011

IAF - 220

Robotics

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Classify Robots in different categories.
2	Explain robot kinematics and dynamics.
3	Analyze forward and reverse kinematics
4	Summarize path planning by a Robot.
5	Describe robot manipulator.
6	Program Robot for various applications

Course Contents:

Module– I: Introduction (06 Hrs)

Specifications of Robots, Classifications of robots, Laws of Robotics, Flexible automation versus Robotic technology, Applications of Robots

Module– II: Robot Kinematics And Dynamics (06 Hrs)

Positions, Orientations and frames, Mappings: Changing descriptions from frame to frame, Operators: Translations, Rotations and Transformations, Transformation Arithmetic, D-H Representation, Forward and inverse Kinematics, Robot Arm dynamics

Module- III: Manipulators (06 Hrs)

Construction of Manipulators, Manipulator Dynamic and Force Control, Electronic and Pneumatic manipulators, Classification of End effectors (Tools as end effectors), Drive system for grippers(Mechanical, adhesive, vacuum, magnetic, grippers), Hooks & scoops, Gripper force analysis and gripper design, Active and passive grippers.

Module- IV: Path Planning &Programming (06 Hrs)

Trajectory planning and avoidance of obstacles, path planning, skew motion, joint integrated motion, straight line motion, Robot Programming

Module-V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. S. R. Deb and S. Deb, ‘Robotics Technology and Flexible Automation’, Tata McGraw Hill Education Pvt. Ltd, 2010.
2. John J.Craig , “Introduction to Robotics”, Pearson, 2009.
3. Mikell P. Groover et. al., "Industrial Robots - Technology, Programming and Applications", McGraw Hill, New York, 2008.
4. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering – An Integrated Approach", Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
5. Fu K S, Gonzalez R C, Lee C.S.G, "Robotics : Control, Sensing, Vision and Intelligence", McGraw Hill, 1987

IAF - 221

Process Control

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define Process Modeling Fundamentals.
2	Describe various modeling techniques of process control
3	Explain the Characteristics of Controller.
4	Summarize Control System configurations.
5	Describe Control systems with multiple loops.
6	Analyze Different Process loop and tuning techniques.

Course Contents:

Module– I: Modelling of processes (08 Hrs)

Need for Process Control, Mathematical model of first order liquid and thermal processes, Processes with dead time, Processes with inverse response, Interacting and non-interacting systems, Continuous and batch processes, Servo and regulator operation

Module– II:Controller Characteristics (05 Hrs)

Basic control action, Characteristics of ON-OFF, Proportional, Integral and Derivative Control Modes, Composite Control Modes, Electronic controllers to realize various control actions

Module– III: Control Systems with Multiple Loops (07 Hrs)

Control system configurations; Cascade control, Feed forward control, Ratio Control, Selective Control system; Split Range Control, Adaptive and Inferential Control,

Module– IV: Process Loop tuning (06 Hrs)

Evaluation criteria in control systems Quality, IAE, ISE, ITAE and ¼ decay ratio,; Process loop tuning- Open loop transient Response method, Ziegler – Nichols method, Cohencoon method, Damped oscillations method

Module-V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. D. P. Eckman – Automatic Process Control – Wiley Eastern Ltd., New Delhi, 1993
2. G. Stephanopoulis – Chemical Process Control- PHI, New Delhi, 1990
3. B. G. Liptak – Process Control – Chilton Book Company, 1994
4. C. D. Johnson – Process Control Instrumentation Technology – 7^{th} edition, Pearson Education, New Delhi, 2002
5. J. G. Balchen, K. J. Mumme – Process Control Structures and Application – Van Nostrand Reinhold Co., New York, 1988

IAF - 222

Industrial Automation

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Explain the requirements of modern day industries.
2	Classify the different types of automated techniques used.
3	Describe high volume manufacturing automation.
4	Explain various flexible manufacturing concepts.
5	Summarize Assembly Automation.
6	Analyze Performance evaluation and economics of assembly systems.

Course Contents:

Module– I: Introduction (06 Hrs)

Automated production system, Mechanization and automation, Types of automation, Automation strategies, Economics of automation, Review of actuation devices used in automated systems

Module– II: High Volume Manufacturing Automation (06 Hrs)

Classification and type of automatic transfer machines; Automation in part handling and feeding, Analysis of automated flow lines, design of single model, multimodel and mixed model production lines.

Module– III: Flexible Manufacturing Concepts (04 Hrs)

Introduction to Group Technology, Grouping methods, Cell Design, Flexible manufacturing system.

Module– IV: Flexible Manufacturing Automation (08 Hrs)

Assembly Automation: Assembly systems, Automatic transfer, feeding and orienting devices, Flexible assembly systems, AS/RS, Performance evaluation and economics of assembly systems.

Module-V:

Presentations, case studies, Assignments, Tutorials based on Module I to IV.

Ref. Books:

1. M. P. Groover- Automation, Production System & Computer Integrated Manufacturing -PHI, New Delhi, 2001
2. Malov and Ivanov - Principles of Automation & Automated Production Process - Mir Publications, Moscow
3. Oates and Georgy - Automation in Production Engineering - Newness Publications
4. Buzacott& Shanty Kumar - Stochastic Models of Manufacturing Systems – PHI, New Delhi
5. W. Bolton – Mechatronics – Pearson Education, 1999
6. J. Boothroyd, P. Dewhurst, W. A. Knight – Product Design for Manufacture and assembly –CRC press, 2011

IALC - 230

Industrial Networking Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Identify necessary protocol for a particular application
2	Interface real time devices to microprocessors/ computers using standard protocols
3	Design a simple fieldbus/profibus network

List of Experiments: (Any 4 protocols are to be studied)

1. Study of 7 Layer OSI reference model
2. Study of Industry open protocol – RS 232
3. Study of IEEE 1394 protocol
4. Study of Bluetooth Technology
5. Study of Zigbee Technology
6. Study of Ethernet protocol
7. Study of Fieldbus Protocol
8. Study of profibus protocol

IALC - 231

Mechatronics Lab

(1.5 credits – 50 marks)

Learning Outcomes:

On completion of the course, students should be able to –

1	Illustrate different supplementary operations of sensors and actuators in combination
2	Design simple mechatronics systems pertinent to real life operations

List of Experiments: (Any 5 experiments are to be performed)

1. Study of LVDT as displacement Sensor
2. Study of Strain Gauge as analog/digital balance
3. Study of Hall effect sensor as an event counter
4. Study of Stepper Motor
5. Study of BLDC
6. Study of Spring Mass system
7. Study of Hydraulic/Pneumatic Cylinders
8. Study of Hydraulic/Pneumatic Motors
9. Study of PC based CNC Drill Machine
10. Study of Automatic door closing and opening arrangement (PLC/PC/microcontroller based)
11. Study of user defined 2/3 floor elevator module (PLC/PC/microcontroller based)

IALC - 232

Instrumentation Lab-II

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Illustrate concept of calibration of sensors
2	Apply industry grade sensors for various measurements

List of Experiments: (Any 5 experiments are to be performed)

1. Study of Calibration of Bourdon Gauge using dead weight tester
2. Determination of discharge coefficient using Orifice Meter
3. Study of Calibration of Rota-meter
4. Study and calibration of Differential pressure transmitter
5. Study of water level measurement by Capacitive method/ Bubble purge method/ Contact method
6. Instrumentation tutor for Flow meter calibration.
7. Measurement of viscosity.
8. Measurement of temperature by using Thermocouple.
9. Study of water and air flow meter
10. Study of optical encoder
11. Study of Ultrasonic transducer.
12. Study of Differential flow measurement

IALF - 240

Robotics Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Identify components of a robot
2	Describe different links and joints used in robots
3	Perform basic programming for simple operations with different robotic platforms

List of Experiments: (Any 5 experiments are to be performed)

1. Study of components of robots with drive system and end effectors
2. Study of different types of robots based on configuration and application
3. Study of different type of links and joints used in robots
4. Programming exercises with moving Robotic arm platform for sorting/ batching/ stacking applications
5. Robot Programming exercises for line following and obstacle avoiding applications
6. Robot programming exercises for Pick and place operation on same plane
7. Robot programming exercises for Pick and place operation on orthogonal plane

IALF - 241

Process Control Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Illustrate closed loop operations
2	Tune a PID controller installed in real time systems
3	Illustrate cascade control system

List Of Experiments: (Any 5 experiments are to be performed)

1. Study of interacting and non-interacting system.
2. Response of different order processes with and without transportation lag

3. Response of P+I+D Controller
4. Study of Closed loop response of flow control loop
5. Study of Closed loop response of level control loop
6. Study of Closed loop response of temperature control loop
7. Study of Closed loop response of pressure control loop
8. Tuning of PID Controller
9. Response of Cascade Control System

IALF - 242

Industrial Automation Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Illustrate concept of Automation in manufacturing through a modular FMS platform
2	Identify components of a modular FMS platform
3	Operate independent elements of the modular FMS platform
4	Develop PLC (Allen Bradley) based programs for performing automated steps in a modular FMS platforms

List Of Experiments: (Any 3 experiments are to be performed with expt. 7 as compulsory)

1. Study of Conveyor based material handling
2. Study of pick and place operation
3. Study of gravity based feed station
4. Study of linear transfer mechanism
5. Study of Rotary Indexing Platform
6. Study of AS/RS System
7. Study of a Modular FMS System

IAR – 250

Research/Industrial Project (Phase-I)

(5 credits – 100 marks)

(Review of Literature/ Industrial Orientation, Formulation of Topic, Experimental Plan)

Students are expected to go through review of literature on a particular technical aspect and/or pay industrial visit to identify a point of further study and research/investigation. The student (or group of students), thereafter, would propose a subject on basis of literature review and/or industrial orientations and will have to present a short seminar on his/her proposal to the board of examiners constituted by faculties of the department. If approved, he/she should be allowed to work on that particular project. Within a week after this approval, the student(s) will have to finalize their topic/subject of project and duly officiate it.

During phase – I of Research/Industrial Project, it is expected that the student(s) will –

(i) build up a concrete fundamental of the concept on which they are going to work,

(ii) carry out thorough literature survey to find out scope of work in the particular field,

(iii) thereby, finalizing the topic of further study/investigation

(iv) and finally, draft a systematic experimental plan to achieve projected goal

(v) deliver regular presentations

(vi) systematically document the above activities in bound volume and submit one copy to the department, one copy to concerned faculty and retain one copy with him/herself

SEMESTER – III

IAGE – 310

Industrial Processes and Instrumentation

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to -

1	Interpret type of controller that can be used for specific problems in chemical industry
2	Design of controllers for interacting multivariable systems
3	Work with controller tunning
4	Ability to design feed forward anf cascade control system
5	Predict multivariable system

Course Contents:

Module-I : Process characteristics (07 Hrs)

Incentives for process control, Process Variables types and selection criteria,, Process degree of freedom, Characteristics of physical System, Elements of Process Dynamics, Types of processes- Dead time, Single /multicapacity, self-Regulating /non self regulating, Interacting /noninteracting, Linear/non linear, and Selection of control action for them. Study of Liquid Processes, Gas Processes, Flow Processes, Thermal Processes in respect to above concepts

Module-II : Performance of Feedback Control system (06 Hrs)

Basic principles, Elements of the feedback Loop, Block Diagram, Control Performance Measures for Common Input Changes, Selection of Variables for Control Approach to Process Control. Controller tuning based on stability Control Performance via closed loop frequency Response, Control system factors influencing control Performance

Module-III : MultiLoop & Nonlinear Systems (07 Hrs)

Cascade control, Feed forward control, feedback-feedforward control, Ratio control, Selective Control , Split range control- Basic principles, Design Criteria , Performance, Controller Algorithm and Tuning, Examples and any special features of the individual loop and industrial applications. Nonlinear Elements in Loop: Limiters, Dead Zones, Backlash, Dead Band Velocity Limiting, Negative Resistance,

Module-IV : Automation Multivariable Control (07 Hrs)

Concept of Multivariable Control: Interactions and its effects, Modelling and transfer functions, Influence of Interaction o the possibility of feedback control, important effects on Multivariable system behavior Relative Gain Array, effect of Interaction on stability and Multiloop Control system. Multiloop control Performance through: Loop Paring, tuning, Enhancement through Decoupling, Single Loop Enhancements.

Module-V : Tutorials, assignments and presentation based on Module I to IV

References:

1. S Donald Eckman – Automatic Process Control, Wiley Eastern Limited
2. Thomas E Marlin - Process Control- Designing processes and Control Systems for Dynamic Performance, McGraw-Hill International Editions
3. Process control Systems-F.G.Shinskey,TMH
4. Computer Based Industrial Control –Krishna Kant, PHI
5. Process Instrumentation and control Handbook –Considine
6. Fuzzy Logic with Engineering Applications, T.J.Ross

IAGE-311: SCADA System and Applications

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the course, students should be able to –

1	State the basic features of SCADA, HMI
2	Develop architecture of SCADA and explain the importance of SCADA in critical infrastructure.
3	Analyze the theory and applications of SCADA
4	Develop projects with SCADA and HMI
5	Implementation of SCADA application.

Course Contents:

MODULE – I : SCADA System (08 Hrs)

Introduction, definitions and history of Supervisory Control and Data Acquisition, typical SCADA system Architecture, Communication requirements, Desirable Properties of SCADA system, features, advantages, disadvantages and applications of SCADA. SCADA Architectures (First generation - Monolithic, Second generation - Distributed, Third generation – Networked Architecture),

SCADA systems in operation and control of interconnected power system, Power System Automation (Automatic substation control and power distribution), Petroleum Refining Process, Water Purification System, Chemical Plant

MODULE – II : SCADA Protocols (07 Hrs)

Open systems interconnection (OSI) Model, TCP/IP protocol, DNP3 protocol, IEC61850 layered architecture, Control and Information Protocol (CIP), Device Net, Control Net, Ether Net/IP, Flexible Function Block process (FFB), Process Field bus (Profibus). Interfacing of SCADA with PLC

Module – IV: Project Development and HMI (08 Hrs)

Project Development: Creating Project , Screens project Configuration, Device Settings, Communication Configuration and Defining Tags

Graphic Control: Planning Graphic Design, Screen Preparation and Navigation Control, Graphic Elements and Libraries and Linking Objects with Tags

Other HMI Features: Tag Logging, On Line and Historical Trending, Alarm System – Designing and Handling and Recipes- Designing and Handling, User Administration and Transferring Project to HMI

MODULE – III : Various Case Studies on SCADA Applications (07 Hrs)

Case Study on Controlling Electrical Power System Network, Manufacturing Industries and Waste Water Treatment and Distribution Plants

Module V: Tutorials, assignments and presentation based on Module I to IV

References:

1. Ronald L. Krutz, "Securing SCADA System", Wiley Publications.
2. Stuart A Boyer, "SCADA supervisory control and data acquisition", ISA, 4th Revised edition 4. Gordan Clark, Deem Reynders, "Practical Modern SCADA Protocols", ELSEVIER
3. Scada: Supervisory Control And Data Acquisition 4th Edition by Author Stuart A. Boyer ISBN-13: 978-1936007097 ISBN-10: 1936007096
4. A Guide to Utility Automation: Amr, Scada, and: it Systems for Electric PowerPaperback – Import, 15 Jan 1999 by Author Michael Wiebe
5. Power System SCADA and Smart Grids 1st Edition by Mini S. Thomas (Author), John Douglas McDonald (Author) ISBN-13: 978-1482226744 ISBN-10: 148222674X
6. Behrouz A. Forouzan 2005, Data Communications Networking, McGraw-Hill Education [ISBN: 9780071254427]
7. David Bailey 2003, PRACTICAL SCADA FOR INDUSTRY, NEWNES [ISBN: 13: 978-0-7506-5805-8]

IAGE - 312

Applied Hydraulics and Pneumatics

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Recall the basic concepts of in hydraulic systems and fluidics and hydropneumatics
2	Describe function of hydraulic system, servo systems, torque motors, Bistable flip flop, turbulence amplifier, Pneumatic controls,
3	Illustrate area of applications of a Hydraulic transmission, fluidics and pneumatic circuit
4	Analyze the designing aspects of hydraulic system and pneumatic system
5	Discriminate hydropneumatics, hydraulic and hydropneumatc system, Types of transmission
6	Design and construct rehydraulic circuit with servo valve, hydraulic circuit with proportional valve, pneumatic sequencing circuit, pneumatic circuit with quick exhaust valve, pneumatic circuit with time delay valve, pneumatic speed control circuit, Hydraulic regenerative circuit

Course Contents:

Module-I : Hydraulic Servo Techniques and Hydrokinetics (07 HRS)

Overview of function of hydraulic system, Mechanical feedback and application of tracer valve, Feedbeck in the system, Electro-hydraulic servo systems, Torque Motors, Types of Servo valves, Special valve features, Terminologies in servo technology. Types of transmission, pump-motor combination, Applications of Hydraulic transmission

Module-II : Design of Hydraulic Systems (06 HRS)

Hydraulic circuits, Manual and automatic hydraulic systems, Regenerative ckt., use of check valves, selection of pump, Circuit Diagram standards, basic circuits functional diagram, application of functional diagram, electrical control of hydraulic systems

Module-III : Fluidics and Hydropneumatics (07 HRS)

Introduction to fluidics, Bistable flip flop, turbulence amplifier, low pressure, pneumatics sensors, application of fluidics/ low pressure pneumatics as sensors proportional devices, Hydropneumatics systems, hydraulic check Modules, hydropneumatic cylinder , parallel check Module, integral air-oil, cylinder, types of feed, intensities, comparision of hydropneumatics, hydraulic and hydropneumatc system.

Module-IV : Automation and Principle of Pneumatic circuit design (07 HRS)

Pneumatic controls, Functional diagram in pneumatic circuit design, Movement diagram, Cascade system in pneumatic circuit design, Logics in pneumatic circuit design, Logics and Boolean algebra. Demorgam's theorem of inversion. Examples of control equation , use of K-V map for pneumatic circuit design, K-V diagram, Control problem

Module-V : Tutorials, assignments and presentation based on Module I to IV

References:

1. S. R. Majumdar – Oil Hydraulic Systems: Principles and Maintenance, Tata McGraw Hill Education Pvt. Ltd., ISBN – 0-07-463-748-7
2. W. Bolton – Pneumatic and Hydraulic Systems, Butterworth Heinemann, ISBN – 0-07-506-383-62
3. A. Parr – Hydraulics and Pneumatics: A Technician‘s and Engineer‘s Guide, Butterworth Heinemann, ISBN – 0-08-096-674-8
4. S R Majumdar; 2006 (Sixteenth Reprint); Pneumatic Systems (Principal and maintenance); Tata McGraw - Hill Publishing Company Limited; ISBN 0-07-460231-
5. P. Joji; 2008; Pneumatic Controls; Willey India Pvt. Ltd., ISBN 978-81-265-1542-4
6. Antony Barber; 1997 (Eighth Ed.); Pneumatic Handbook; Elsevier Science Ltd.; ISBN 978-81-265
7. Andrew Parr; 2011 (Third Ed.); Hydraulics and Pneumatics-A Technician's and Engineer's Guide; Elsevier Ltd. (Butterwoth-Heinemann); ISBN-13: 978-0-08-0966748

IAGE - 313

Industrial Robotics

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Recall the fundamental aspects of automation and robotics
2	Discuss brief history of robotics, robotics market and future prospectus
3	Use the robots in various manufacturing processes
4	Explain the safety training and maintenance and quality improvement aspects; social issues and future of robotics
5	Reframe the robot programming
6	Develop simple programs to define pre-coordinated trajectory of robots, for pick and place operation with a six axis industrial robot, for stacking operation with a six axis industrial robot

Course Contents:

Module- I: Fundamentals of Robotics (04 Hrs)

Introduction, Automation and Robotics, A brief History of Robotics, Robotics Market and the Future Prospectus

Module- II: Robot Programming (07 Hrs)

Methods of Robot Programming, Lead through Programming Methods, Robot Program as path in space, Motion Interpolation, WAIT Signal and Delay Commands, Capabilities and Limitations of Lead through Methods; Robot Languages: Textual Robotic Languages, Generations of Robotic Programming Languages, Robot Language Structure, Motion Commands, Program Control and Subroutines, Monitor Mode Commands

Module- III: Robot Applications in Manufacturing (07 Hrs)

Material Transfer and Machine Loading/Unloading, Processing Operation: spot welding, arc welding, spray coating, other processing operation using Robotics, Assembly and Inspection: Assembly and Robotic Assembly Operation, Inspection Automation

Module- IV: Implementation Principles and Issues of Robotics (06 Hrs)

Implementation of Robotics; Safety Training and Maintainence and Quality Improvement; Social Issues and Future of Robotics

Module- V: Tutorials, assignments and presentation based on Module I to IV

Reference:

1. Industrial Robotics-Technology Programming and Applications by Mikell P Groover, Mitchell Weiss, Nagel and Odrey ISBN-13:978-0-07-026509-7 ISBN- 10: 0-07-026509-7
2. Richard D. Klafter, Thomas .A, Chri Elewski, Michael Negin, Robotics Engineering an Integrated Approach, Phi Learning., 2009.
3. 3. P.A. Janaki Raman, Robotics and Image Processing An Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.
4. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1987.
5. Bernard Hodges, Industrial Robotics, Second Edition, Jaico Publishing house, 1993.
6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, MIT Press. 2003.
7. John J. Craig, Introduction to Robotics Mechanics and Control, Third Edition, Pearson, 2008.
8. Bijay K. Ghosh, Ning Xi, T.J. Tarn, Control in Robotics and Automation Sensor – Based integration, Academic Press, 1999
9. Deb. S. R. “Robotics technology and flexible automation”, Tata McGraw Hill publishing company limited, 1994

IAGE – 314

Advanced Sensor Technology

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to -

1	Describe basic characteristics of measurement system
2	Discuss elements of motion and dimensional measurements
3	Explain working of basic force and torque measurement
4	Explain working of advanced temperature transducers

Course Contents:

Module-I : Characteristics Of Measurement Systems (07 Hrs)

Static characteristics - Dynamic characteristics - Mathematical model of transducer - Zero, I and II order transducers. Response to impulse, step, ramp and sinusoidal inputs. Simulation using MATLAB.

Module-II : Motion and Dimensional measurement (06 Hrs)

Fundamental standards, relative displacements- translational and rotational, Calibration, Resistive potentiometers, differential transformers, variable inductance & variable reluctance pickups, capacitance pickup, Digital displacement transducers, Mechanical fly ball angular velocity sensor, Mechanical revolution counters and timers, tachometer encoder methods, stroboscopic method, translational velocity transducer, eddy current Drag-cup tachometer, velocity sensors.

Module-III : Force, Torque, Shaft power (07 Hrs)

Standards & calibration; basic methods of force measurement; characteristics of elastic force transducer-Bonded strain gauge, differential transformer, Piezo electric transducer, variable reluctance/FM-oscillator, digital systems. Loading effects; Torque measurement on rotating shafts, shaft power measurement (dynamometers).

Module-IV : Temperature measurement (07 Hrs)

Standards & calibration; thermal expansion methodsbimetallic thermometers, liquid-in-glass thermometers, pressure thermometers; RTD, thermister and thermocouple (comparative study); digital thermometers. Radiation Methods – radiation fundamentals, radiation detectors: thermal

and photon, monochromatic brightness radiation thermometers, two color radiation thermometers, black body tipped fiber optic radiation thermometer, Fluor optic temperature measurement, infrared imaging systems.

Module-V : Tutorials, assignments and presentation based on Module I to IV

References:

1. S E.A. Doebelin, „Measurement Systems – Applications and Design", Tata Mc Graw Hill, New York, 2012
2. John P. Bentley, „Principles of Measurement Systems", 4th Edition,Pearson Education, 2005.
3. S. Ranganathan, „Transducer Engineering", Allied Publishers Pvt. Ltd.,2003.
4. D.V.S. Murthy, „Transducers and Instrumentation", Prentice Hall of India, 2011.
5. D.Patranabis, „Sensors and Transducers", Prentice Hall of India, 2004

IAGE - 315

Kinetics and Dynamics of Robotics

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Recall the fundamental aspects of automation and robotics
2	Discuss various co-ordinate systems
3	Use the robots in various manufacturing processes
4	Explain the kinematic and Dynamic model
5	Model the Robot
6	Develop programs for pick and place operation with a six axis industrial robot, for stacking operation with a six axis industrial robot and for other industrial applications

Course Contents:

Module- I: Coordinate Frames, Mapping and Transformation of Robots (04 Hrs)

Introduction, Anantomy of Robot in brief, Co-ordinate frames: mapping ; transformation of vectors: rotation, translation and combined; Fundamentals of Rotational Matrices: principal axis rotation, fixed angle, Euler angle.

Module- II: Symbolic Modelling of Robots- Direct Kinematic Models (07 Hrs)

Mechanical Structure and Notations, Description of links and joints, Kinematic modeling of the Manipulator, Denavit-Hartenberg Notation, Kinematic relationship between adjacent joints, manipulator transformation matrix.

Module- III: Inverse Kinematics (05 Hrs)

Manipulator Workspace, Solvability of Inverse Kinematic Model, Solution Techniques, Closed Form Solution

Module- IV: Dynamic modeling of Robotics (06 Hrs)

Lagrangian Mechanics, Two degree of freedom manipulator-Dynamic Model, Lagrange-Euler Formulation, Newton-Euler Formulation, Comparision of Lagrange-Euler and Newton-Euler Formulation, Inverse Dynamics

Module- V: Tutorials, assignments and presentation based on Module I to IV

References:

1. Robotics: Control Sensing. Vis. By K S Fu,Ralph Gonzalez,C S G Lee Tata McGraw-Hill Education, 2008, ISBN-978-0-07-026510-3, ISBN: 0-07-026510-0
2. Industrial Robotics-Technology Programming and Applications by Mikell P Groover, Mitchell Weiss, Nagel and Odrey ISBN-13:978-0-07-026509-7 ISBN- 10: 0-07-026509-7
3. Richard D. Klafter, Thomas .A, Chri Elewski, Michael Negin, Robotics Engineering an Integrated Approach, Phi Learning., 2009.
4. 3. P.A. Janaki Raman, Robotics and Image Processing An Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.
5. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1987.
6. Bernard Hodges, Industrial Robotics, Second Edition, Jaico Publishing house, 1993.
7. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, MIT Press. 2003.
8. John J. Craig, Introduction to Robotics Mechanics and Control, Third Edition, Pearson, 2008.
9. Bijay K. Ghosh, Ning Xi, T.J. Tarn, Control in Robotics and Automation Sensor – Based integration, Academic Press, 1999
10. Deb. S. R. “Robotics technology and flexible automation”, Tata McGraw Hill publishing company limited, 1994

IAGE 316: Mechatronics System Design

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the course, students should able to –

1	Explain various mechanical elements of mechatronics
2	Discuss elements of mechatronics process design
3	Explain advance control mechanisms in mechatronics

Course Contents:

Module - I: Introduction **(05 Hrs)**

Introduction to mechatronics systems. Basic building blocks of mechatronic systems. Mechatronics key elements, Mechatronics in industry automation, Scope of Mechatronics. Advantages of Mechatronics

Module - II: Machines in Mechatronics **(07 Hrs)**

Physical translation and rotational systems, Fluid systems, guideways, Mechanism used in mechatronics (High resolution scanning mechanisms, Indexing mechanisms), Assembly techniques, Hydraulic and pneumatic actuators, microactuators. Piezoelectric actuators

Module - III: Mechatronics Design Process **(07 Hrs)**

Generalized Mechatronics Design Process: Recognition of the Need, Conceptual Design and Functional Specification, First principle Modular Mathematical Modeling, Sensor and Actuator Selection, Drivers for Actuators, Detailed Modular Mathematical Modeling, Control System Design, Design Optimization, Prototyping Hardware-in-the-loop Simulation, Deployment/Life Cycle, Deployment of Embedded Software, Life Cycle Optimization.

Module -IV: Advance Approaches in Mechatronics **(05 Hrs)**

Advance Approaches in Mechatronics: Servo control, Process Control, Supervisory Control, Shop Floor Control, Plant Control.

Module – V: Tutorials, assignments and presentation based on Module I to IV

References

1. Mechatronics, Kenji Uchino and Jayne R. Giniewicz, publication: Marcel Dekker, Inc.
2. Applied Mechatronics- A. Smaili and F. Mrad, OXFORD university press.
3. Mechatronics System Design , Shetty and Kolk CENGAGE Learning, India Edition
4. Introduction to Mechatronics and Measurement Systems , Alciatore and Histand Tata McGraw-Hill
5. Mechatronics, Necsulescu, Pearson education.
6. Mechatronics - Electromechanics and Control Mechanics , Mill Springer-Verlag
7. Mechatronics - Electronic Control Systems in Mechanical Engineering , Bolton Pearson
8. Mechatronics - Electronics in products and processes , Bradley, et al.
Chapman and Hall
9. Mechatronics - Mechanical System Interfacing , Auslander and Kempf, Prentice Hall
10. Introduction to Mechatronics, Appu Kuttan K.K., OXFORD Higher Education

IAGE - 317

Distributed Control System

(Process Automation)

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Recall basics of automation , PLC, DSC and SCADA
2	Classify and compare types of plant and control, PLC and SCADA
3	Illustrate Control system architecture, Architecture and working of PLC, DCS architecture and specifications
4	Analyze the various systems of SCADA
5	Summarize advanced PLC instructions, integration of PLC and computer, integration of DCs and computer
6	Program DCS for control of remote process

Course Contents:

Module- 1: Automation Fundamentals (07 Hrs)

Automation and its importance, automation applications, expectations of automation, Types of plant and control – categories in industry, open loop and close loop control functions, continuous processes, discrete processes, and mixed processes. Automation hierarchy – large control system hierarchy, data quantity & quality and hierarchical control. Control system architecture – evolution and current trends, comparison of different architectures.

Module -II: Programmable Logic Controller (07 Hrs)

Hardware Evolution of PLC, Definition, functions of PLC, Advantages, Architecture, working of PLC, Scan time, Types & Specifications. DI-DO-AI-AO examples and ratings, I/O modules, local and remote I/O expansion, special purpose modules, wiring diagrams of different I/O modules, communication modules, Memory & addressingmemory organization (system memory and application memory), I/O addressing, hardware to software interface. Software-Development of Relay Logic Ladder Diagram, introduction to PLC Programming, programming devices, IEC standard PLC programming languages, LD programming- basic LD instructions, PLC Timers and Counters: Types and examples, data transfer & program control instructions, advanced PLC instructions, PID Control using PLC.

Module -III: Distributed Control System (07 Hrs)

Introduction to DCS – Evolution of DCS, DCS flow sheet symbols, architecture of DCS – controller, Input and output modules, communication module, data highway, local I/O bus, workstations, specifications of DCS. Introduction to Hierarchical Control and memory: Task listing, Higher & Lower Computer level tasks. Supervisory computer tasks and DCS configuration –Supervisory Computer functions, Control techniques, Supervisory Control Algorithm, DCS & Supervisory Computer displays, advanced control Strategies, Computer interface with DCS. DCS – system integration with PLCs and computer: Man machine interface-sequencing, supervisory control, and integration with PLC, personal computers and direct I/O, serial linkages, network linkages, links between networks.

Module- IV: SCADA (07 Hrs)

SCADA introduction, brief history of SCADA, elements of SCADA. Features of SCADA, MTU- functions of MTU, RTU- Functions of RTU, Protocol Detail SCADA as a real time system, Communications in SCADAtypes & methods used, components, Protocol structure and Mediums used for communications, SCADA Development for any one typical application

(Additional module : Safety Instrumented System (SIS) Need for safety instrumentation- risk and risk reduction methods, hazards analysis. Process control systems and SIS. Safety Integrity Levels (SIL) and availability. Introduction to the international functional safety standard IEC61508.)

Module-V: Tutorials, assignments and presentation based on Module I to IV

Reference:

1. Samuel M. Herb, “Understanding Distributed Processor Systems for Control”, ISA Publication.
2. Thomas Hughes, “Programmable Logic Controller”, ISA Publication.
3. Stuart A. Boyer, “SCADA supervisory control and data acquisition”, ISA Publication.
4. Poppovik Bhatkar, “Distributed Computer Control for Industrial Automation”, Dekkar Publication.
5. S.K.Singh, “Computer Aided Process Control”, Prentice Hall of India.
6. Krishna Kant, “Computer Based Process Control”, Prentice Hall of India
7. N.E. Battikha, “The Management of Control System: Justification and Technical Auditing”, ISA.
8. Gary Dunning, “Introduction to Programmable Logic controller”, Thomas Learning, edition, 2001.

IAGE-318: Advanced Electrical Drives

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the course, students should able to –

1	Understand the various drive mechanisms and methods for energy conservation.
2	Apply power electronic converters to control the speed of DC motors and induction motors.
3	Evaluate the motor and power converter for a specific application.
4	Develop closed loop control strategies of drives.

Course Contents:

Module -I: Electrical Drives- An Introduction (5 Hrs)

Introduction to electric drives: Electrical Drives, Advantages of Electric drives, Parts of Electrical Drives, Electric Motors, Power Modulators, Sources, Control Module, Choice of Electric Drives and Losses.

Module –II: Dynamics of electrical drives (7 Hrs)

Dynamics of electrical drives: Fundamental torque equation, components of load torque, load characteristics, modified torque equation, speed-torque convention & multi-quadrant operation. Equivalent values of drive parameters, load with rotational motion, loads with translational motion, measurement of moment of inertia, components of load torques, Nature and classification of load torque. Calculation of time and energy loss in transient operation, steady state stability, loads equalization.

Module -III: Control of electrical drives (6 Hrs)

Control of electrical drives: Modes of operation, speed control and drive classifications, closed loop control of drives. DC Motor Drives: Starting, Braking, Speed control of DC motors using single phase fully controlled and half controlled rectifiers. Three phases fully controlled and half controlled converter fed DC motor drives. Chopper controlled DC drives.

Module – IV: Induction Motor Drives (7 Hrs)

Induction Motor Drives: Speed control using pole changing, stator voltage control, AC voltage controllers. Variable frequency and variable voltage control from inverter. Different types of braking, dynamic, regenerative and plugging.

Energy Conservation in Electric Drives: Losses in Electric drive systems, measurement of Energy conservation in Electric drives. Use of efficient converters, energy efficient operation of drives, Improvement of p.f., improvement of quality of supply, maintenance of motors

Module – V: Tutorials, assignments and presentation based on Module I to IV

References:

1. Vedam Subramanyam: Electric Drives Concepts & Applications –Tata McGraw Hill Edn. Pvt.Ltd, Second edition 2011

2. Gopal K Dubey; 2001; Fundamentals of Electrical Drives (SECOND EDITION); Narosa Publishing House; New Delhi (India)

3. Nisit K.De and Prashanta K.Sen: Electric Drives, PHI., 2001

4. V. Subrahmanyam: Thyristor Control of Electric Drives, Tata McGraw Hill Edn. Pvt.Ltd, 2010.
5. Werner Leonhard: Control of Electric Drives, Springer international edition 2001
6. Nisit K.De and Swapan K.Dutta: Electric Machines and Electric Drives, PHI learning Pvt. Ltd 2011.

IAGE – 319
Advanced Microcontrollers

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1	State configuration of ARM Microcontroller, Registers, addressing modes, interfacing methods, ISR, Timing generations and measurements
2	Classify Data types , Thumb instructions used in programming,
3	Illustrate ARM architecture and architectural support for system development & operating system
4	Explain implementation of ARM
5	Summarize instructions used for high level language
6	design an embedded hardware using ARM series of Microcontroller

Course Contents:

Module – I: The ARM architecture (**05 Hrs)**

Introduction to ARM microcontrollers. The Acorn RISC Machine, The architectural inheritance, The ARM programmer's model, ARM development tools, Basics of Assembly Language Programming.

Module – II: ARM organization and Implementation (**08 Hrs)**

3-stage pipeline ARM organization, 5-stage pipeline ARM organization, ARM instruction execution, ARM implementation, The ARM coprocessor interface.ARM instruction set-Branch, branch with link(B,BL),branch, branch with link and exchange(BX,BLX),software interrupt(SWI),data processing instructions, multiply instructions, multiple register transfer instructions, Co-processor instructions. Memory Hierarchy- Memory size and speed, On-chip memory, Caches, Cache design, Memory management.

Module – III: Architectural Support for High level Language (**08 Hrs)**

Data types, floating point data types, ARM Floating point Architecture, Expressions, Conditional statements, Loops, Functions and Procedure, Use of memory, run time environment, Thumb Instruction set - The Thumb bit in the CPSR, The Thumb programmer's model, Thumb branch instructions ,Thumb software interrupt instruction, Thumb data processing instructions, Thumb

single register data transfer instructions ,Thumb multiple register data transfer instructions, Thumb breakpoint instruction, Thumb implementation, Thumb application.

Module – IV: Architectural Support for System Development & Operating System (**07 Hrs)**

The ARM memory interface, The Advanced Microcontroller Bus Architecture (AMBA), The ARM reference peripheral specification Hardware system prototyping tools, The ARMulator,The JTAG boundary scan test architecture, The ARM debug architecture, ARM processor Cores-ARM7TDMI,ARM8, An introduction to operating systems, The ARM system control coprocessor,CP15 protection Moduleregisters, ARM protection Module,CP15 MMU registers, ARM-MMU architecture, Synchronization, Context switching, Input/output.

Module-V: Tutorials, assignments and presentation based on Module I to IV

References:

1. ARM System on chip Architecture- Prof. Steve Furber, 2nd Edition,Addison Wesley,2000,ISBN-0-201-67519-6.
2. RM Microcontrollers, Part 1: 35 Projects For Beginners, Bert Van Dam, Elektor International Media, ISBN-10: 0905705947, ISBN-13: 9780905705941.
3. Embedded Systems: Introduction to Arm(r) Cortex(tm)-M Microcontrollers: 1; Jonathan Valvano
4. Steave Furber, “ARM system – on – chip architecture”, Addison Wesley, 2000
5. Daniel Tabak, “Advanced Microprocessors”, McGraw Hill. Inc., 1995

Open Electives
IAOE 321
Automotive Engines

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1.	Define the key terms like Supercharging, Turbocharging
2	Differentiate the fuel dynamics for SI and CI engines
3	Acquainted with the latest technologies.

Course Content:

Module-I: Introduction to Engines (05 Hrs)

Introduction, Carnot cycle, Classification, I.C. Engines, Otto cycle, Diesel cycle, Flywheel, performance parameters, Brake Power, Indicated Power, Zeroth law of thermodynamics, First law of thermodynamics, Second law of thermodynamics, Fuel-Air cycles, numerical on performance parameters.

Module- II: Petrol Engines (07 Hrs)

Engine Construction and Operation: Constructional details of 4-stroke petrol engine. Working principle, actual indicator diagram, Firing order and its significance, Two Stroke Engines: Terminologies and definitions, Theoretical scavenging methods. Effect of operating variables: Compression Ratio, Fuel- Air Ratio, Ignition system, Combustion in petrol engine, morse test, motoring test, willans line method

Module- III: Diesel Engines (07 Hrs)

Engine construction and operation. Two stroke and four stroke diesel engines. Fuel-air and actual cycle analysis. Diesel fuel, Ignition quality, fuel injection systems, supercharging, turbo charging, Diesel Engine Testing and Performance: Automotive and stationary diesel engine testing, Performance characteristics. Variables affecting engine performance. Methods to improve engine performance. Heat balance.

Module- IV Advanced Engines (05 Hrs)

Need of advancement in engine, Common Rail Direct Injection Engine, Multi point fuel injection engine, Gasoline Direct Injection engine, Lean burn engines, Homogeneous charge compression ignition engine, variable compression ratio engine, Wankel Engine.

Module –V: Tutorials, case studies and presentation based on Module I to IV

References:

1. Internal Combustion Engines, Ganesan.V, Tata McGraw Hill Publishing Co., New York, 4 th Edition (2012), ISBN-0-07-049457-6.
2. High Speed Combustion Engines, Heldt.P.M, Oxford Publishing Co., New York, (1990).
3. Automotive Engines, William H. Crouse (Author), Donald Anglin (Author), Donald L. Anglin, McGraw-Hill Education (ISE Editions); (1994), ISBN-10: 0071138846, ISBN-13: 978-0071138840.
4. Automotive Engines, Ellinger.H.E, Prentice Hall Publishers (1992).
5. Diesel Engine Operation and Maintenance, Maleev.V.M, McGraw Hill (1974)
6. Dicksee.C.B, Diesel Engines, Blackie & Son Ltd., London (1964)

IAOE 322
Automobile Control Systems

(02 credits – 50 marks)

Course Outcomes:

On completion of the Course, students should be able to

1.	Define the key terms in Automotive Control System
2.	State various criteria's in components selection
3	Explain steering system, braking system and suspension system
4	Acquaint with the latest technologies

Course Content:

Module –I: Components Selection **(04 Hrs)**

Tyre selection, air resistance, rolling resistance, requirement of engine power, transmission system layout

Module –II: Steering systems **(07 Hrs)**

Front axle types, constructional details, front wheel geometry, Condition for True rolling, skidding, steering linkages for conventional & independent suspensions, turning radius, wheel wobble and shimmy, power and power assisted steering

Module –III: Braking system **(06 Hrs)**

Types of brakes, brake-actuating mechanisms, factors affecting brake performance, power & power assisted brakes, Brake system design, Recent developments in transmission & braking system

Module –IV: Suspension systems **(07 Hrs)**

Rigid and independent Suspension, Types of Independent suspension system-McPherson strut, wishbone type, Semi-elliptical Leaf spring, coil spring , torsion bar arrangement, Construction and working of Air Suspension System, Construction and working of- Shock absorbers - Telescopic and Gas filled, Anti roll bar or stabilizer bar.

Module –V: Tutorials, assignments and presentation based on Module I to IV

References:

1. The Automotive Chassis – Engineering Principle – Jornsen Reimpell, Helmut Stoll, Jurgen Betzler, (2001), 2nd Edition ISBN-9780080527734
2. Automotive Chassis – Design & Calculation – P. Lukin, G. Gasparyarts, V. Rodionov, MIR Publishing, Moskow (2005)
3. Automotive Chassis – P. M. Heldt, Chilton Co. NK, 2012, ISBN-13:9781258374150, ISBN-13: 9781258386382
4. Mechanics for Road Vehicles – W. Steed, Illiffe Books Ltd., London (1960), ASIN: B0000CKKGV
5. Automotive Mechanics, Crouse, Anglin, Tata McGraw - Hill Career Education ISBN 10: 0028009436 ISBN 13: 9780028009438
6. Machine Design, P.Kannaiah, Scitech, (2010) ISBN 10: 8183711510 / ISBN 13: 9788183711517
7. Auto design, R. B Gupta, Satya Prakashan, ISBN: 8176840106 ISBN-13: 9788176840101

IALE - 330

Industrial Process Control Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should able to –

1	Explain the various loops of industrial process control.
2	Develop complex loop system.
3	Design and Implementation of Advance process controller.

List of Experiments: (Any five experiments should be performed)

1. Finding dynamic elements for any process. (TD, TS)
2. Analysis of Flow loop.
3. Analysis of Level loop.
4. Analysis of Temperature loop.
5. Analysis of Pressure loop.
6. Study of Cascade control loop.
7. Study of Ratio control/ Selective control. (any one)
8. Study of SLPC for process control.
9. Design and Implementation of Advance process controller. (ANN/Fuzzy/MPC) (May be implemented using any suitable software)
10. Study of non linear control elements.

IALE-331

SCADA System and Applications Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should able to –

1	Observe Parameter reading of PLC in SCADA.
2	Different controls using SCADA system.
3	Design complex control system using SCADA.

List of Experiments: (Any five experiments should be performed)

1. Parameter reading of PLC in SCADA
2. Alarm annunciation using SCADA
3. Pressure control by using SCADA
4. Tank Level control using SCADA System
5. Temperature monitoring using SCADA System
6. Speed control of machine by SCADA System
7. Pressure control by using SCADA
8. Controlling Electrical Power System using SCADA

IALE 332

Applied Hydraulics and Pneumatics Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should able to –

1	Construct Hydraulic and Pneumatic circuit for different valves.
2	Design Pneumatic circuit for control operations
3	Design sequential Hydraulic / Pneumatic circuit.

List of Experiments: (Any 5 experiments are to be performed)

1. Design of a rehydraulic circuit with servo valve
2. Design and construction of a hydraulic circuit with proportional valve
3. Design and construction of a pneumatic sequencing circuit
4. Design and construction of a pneumatic circuit with quick exhaust valve
5. Design and construction of a pneumatic circuit with time delay valve
6. Design and construction of a pneumatic speed control circuit
7. Design and construction of Hydraulic regenerative circuit
8. Design and construction of Hydraulic Punch and Drill circuit

IALE 333

Industrial Robotics Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should able to –

1	Develop simple programs to define pre-coordinated trajectory of robots.
2	Program a parallel kinematic robot for a palletizing application.
3	Calibrate External TCP and Moving Base / Frame Coordinate.

List of Experiments: (Any 5 experiments are to be performed)

1. Develop simple programs to define pre-coordinated trajectory of robots
2. Develop program for pick and place operation with a six axis industrial robot
3. Develop program for stacking operation with a six axis industrial robot
4. Develop program for picking an object from predefined position of ASRS and placing it in a pneumatic vice with a five axis industrial robot.
5. Develop program for emulating a welding operation with a six axis industrial robot.
6. Offline Programming: The modeled robot is programmed offline, also using the industrial robot simulation system
7. Programming a parallel kinematic robot for a palletizing application.
8. External TCP and Moving Base / Frame Coordinate Calibration
9. Program using external TCP and Moving Base / Frame
10. Loop Programming of Industrial Robot
11. Interrupt Programming of Industrial Robot

IALE - 334

Advanced Sensor Technology Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should able to –

1	Apply sensors pertinent to Course IAGE 314 for real time applications

Students are supposed build one project deploying more than one sensors (that have been taught in IAGE 314). A batch of three students should submit one project.

IALE - 335

Kinematics and Dynamics of Robot Lab

(1.5 credits – 50 marks)

Course Outcomes:

On completion of the course, students should able to –

1	Demonstrate different Industrial grade Robot
2	Describe various Co-ordinate system of Robot
3	Design robot for various applications.

List of Experiments: (Any five experiments should be performed)

1. Study of Robot (Industrial grade eg. KUKA/ FANUC etc)
2. Mastering of Robot
3. Study of various Co-ordinate system of Robot
4. Adjusting position of Robot
5. Programming of robot for Linear Motion
6. Programming of robot for Circular Motion
7. Programming of Robot for various applications
8. Mini Project (based on various applications of Robot)

IAGE 336 :

Mechatronics System Design Lab

(1.5 Credits)

Course Outcomes:

On completion of the course, students should able to –

1	Identify suitable sensor and actuator for a control system
2	Develop simple mechatronic systems

List Of Experiments: (Any 5 experiments are to be performed)

1. System identification for actuators
2. Stability analysis of predicted transfer function, and PID tuning and implementation on experimental setup.
3. Experimental identification of mechanisms such as flexural based systems etc.
4. Experiment on image based navigation and control of robot.
5. Experiment on control of non-linear systems.
6. Experiment on control of inverted pendulum
7. Experiment on system identification and control of scanning mechanism

IALE 337

Distributed Control System Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should able to –

1	Develop of Human Machine Interface using any SCADA package
2	Control of Pressure and flow using DCS.
3	Create interlock logic in DCS.

List of Experiments:

1. Control of a multi process batch reactor (configurable) using PLC
2. Development of Human Machine Interface using any SCADA package.
3. Level and flow control using PLC.
4. Pressure and flow control using DCS.
5. Creating an analog – open loop & Digital loop using DCS
6. Configuring DCS- System for given application.
7. Creating interlock logic in DCS.

IALE 338

Electrical Drives Lab

Course Outcomes:

On completion of the course, students should able to –

1	Apply concepts of chopper control for motoring and generating control
2	Control of AC and DC motor using suitable drive
3	Develop application of Electric Drive

List of Experiments:

1. Study chopper control of D.C. Motor for motoring and generating control.
2. Study of D.C. Motor drive using PLL.
3. Study and simulate AC voltage controller based speed control of AC motor.
4. Study and simulate Inverter based speed control of Induction/Synchronous motor.
5. Study and simulate Cycloconverter based speed control of synchronous motor.
6. Study and simulate AC voltage controller based speed control of AC motor.
7. Study of solar and battery powered drives.
8. Study of traction drives.

SEMESTER – IV

Generic Elective

Industrial Automation

IAGE – 410

Automated and Computer Integrated Manufacturing

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Identify elements of an automated manufacturing cell in modern production Module
2	Explain Fundamentals of NC Technology
3	Apply knowledge of CAM, CAD/CAM, CIM for automated manufacturing
4	Analyze various quality control systems
5	Evaluate Positioning System, NC part programming, Automated assembly systems
6	Work in a flexible manufacturing workstation

Course Contents:

Module-I: Overview of Manufacturing (06 Hrs)

Introduction, Manufacturing operations, metrics, and economics; Automated manufacturing

Module- II: CNC and CAD /CAM (08 Hrs)

Fundamental of NC Technology, Computers and numerical control, Applications of NC, Analysis of Positioning System, NC part programming

Product design and CAM, CAD/CAM, CIM

Module -III: Automated Manufacturing Systems (08 Hrs)

Overview, Single station Manufacturing Cells, Automated Production line, Automated assembly systems

Module-IV: Quality Control Systems (06 Hrs)

Inspection Principles and Practices, Automated Inspection, Analysis of Inspection Systems, Inspection Metrology, Conventional Measuring and gaging Techniques, Coordinate measuring machines, Surface measurement, Machine Vision, Optical/non optical techniques

Module-V : Tutorials, assignments and presentation based on Module I to IV

References:

Automation, Production Systems, and Computer-Integrated Manufacturing
By Mikell P. Groover; Pearson Education India

Mechatronics; HMT; Tata Mc Graw Hill

Computer-Aided Manufacturing by Tien-Chien Chang and Richard A. Wysk; Prentice Hall

IAGE- 411: CNC Technology

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the course, students should be able to –

1	Define the basic of CNC machine.
2	Apply Features of CNC Machines and Retrofitting
3	Design CNC part programming.
4	Describe types of measuring systems in CNC machines.

Course Contents:

Module -I: Fundamentals of CNC Machines (05 Hrs)

Introduction to Computer Numerical Control: CNC Systems – An Overview of Fundamental aspects of machine control, Different types of CNC machines – Advantages and disadvantages of CNC machines.

Module –II: Constructional Features of CNC Machines and Retrofitting (07 Hrs)

Features of CNC Machines: Structure, Drive Mechanism, gearbox, Main drive, feed drive, Spindle Motors, Axes motors. Timing belts and pulleys, Spindle bearing – Arrangement and installation. Slide ways. Re - circulating ball screws – Backlash measurement and compensation, linear motion guide ways. Tool magazines, ATC, APC, Chip conveyors. Retrofitting of Conventional Machine Tools: Modification to be carried out on conventional machines for retrofitting.

Module -III: Control System, Feed Back Devices and Tooling (06 Hrs)

Description of a simple CNC control system. Interpolation systems. Features available in a CNC system – introduction to some widely used CNC control systems. Types of measuring systems in CNC machines – Incremental and absolute rotary encoders, linear scale – resolver – Linear inductosyn – Magnetic Sensors for Spindle Orientation. Qualified and pre-set tooling – Principles of location – Principles of clamping – Work holding devices

Module – IV: CNC Part Programming (05 Hrs)

Part Program Terminology-G and M Codes – Types of interpolation Methods of CNC part programming – Manual part programming – Computer Assisted part programming – APT language – CNC part programming using CAD/CAM-Introduction to Computer Automated Part Programming.

Factors influencing selection of CNC Machines – Cost of operation of CNC Machines – Practical aspects of introducing CNC machines in industries – Maintenance features of CNC Machines – Preventive Maintenance, Other maintenance requirements.

Module – V: Tutorials, Assignments, Demonstrations and Presentation Based On Module I to IV.

References:

1. Radhakrishnan P., Computer Numerical Control Machines, New Central Book Agency 1992.
2. Berry Leatham – Jones, Computer Numerical Control, Pitman, London, 1987.
3. Steave Krar And Arthur Gill, Cnc Technology And Programming, Mcgraw–Hill Publishing Company, 1990. 46
4. Hans B.Kief And T.Frederick Waters, Computer Numerical Control Macmillan/Mcgraw-Hill, 1992.
5. G.E.Thyer, Computer Numerical Control Of Machine Tools. Second Edition, B/H Newnes, 1993.
6. Groover, M.P., Automation, Production Systems And Computer Integrated Manufacturing, Prentice Hall, 1998.
7. Mike Mattson, "Cnc Programming Thomson Learning, 2003. Me3306
8. Yoreur Koren, "Computer Control Of Manufacturing Systems", Pitman, London, 1987

IAGE - 412

Micro Mechatronic System

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define Micromechatronics system.
2	Classify Piezoelectric Actuators.
3	Define various performance terminologies in Sensors.
4	Explain different types of actuators used in Micro-mechatronics.
5	Analyze Control Techniques For Piezoelectric Actuators.
6	Develop prototype of Micro-Mechatronic System.

Course Contents:

Module–I: Current trends for Actuators and Micromechatronics (06 Hrs)

The Need for New Actuators, Conventional Methods for Micropositioning, An Overview of Solid-State Actuators, Critical Design Concepts and the Structure of the Text.

Module– II: A Theoretical Description Of Field-Induced Strains (06 Hrs)

Ferroelectricity, Microscopic Origins of Electric Field Induced Strains, Tensor/Matrix Description of Piezoelectricity, Theoretical Description of Ferroelectric and Antiferroelectric Phenomena Phenomenology of Magnetostriction, Ferroelectric Domain Reorientation, Grain Size and Electric Field-Induced Strain in Ferroelectrics.

Module– III: Actuators Materials (06 Hrs)

Practical Actuator Materials, Figures of Merit for Piezoelectric Transducers, The Temperature Dependence of the Electrostrictive Strain, Response Speed, Mechanical Properties of Actuators.

Module– IV: Drive / Control Techniques For Piezoelectric Actuators (06 Hrs)

Classification of Piezoelectric Actuators, Feedback Control, Pulse Drive, Resonance Drive, Sensors and Specialized Components for Micromechatronic Systems

Module-V: Presentations, case studies, Assignments, Tutorials based on Module I to IV.

References:

1. Kenji Uchino, Jayne Giniewicz, MicroMechatronics- CRC Press, April 25, 2003, ISBN 9780824741099
2. Bolton.W – Mechatronics - Pearson education, second edition, fifth Indian Reprint, 2003, SBN, 8131762572, 9788131762578
3. Smaili.A and Mrad.F - Mechatronics integrated technologies for intelligent machines - Oxford university press, 2008. ISBN-10: 0198060165 ISBN-13: 978-0198060161
4. Devadas Shetty and Richard A.Kolk, - Mechatronics systems design - PWS Publishing Company, 2007. ISBN-13: 978-1439061985 ISBN-10: 143906198X
5. Godfrey C. Onwubolu - Mechatronics Principles and Applications - Elsevier, 2006. ISBN-13: 978-0750663793 ISBN-10: 0750663790
6. Nitaigour Premchand Mahalik -Mechatronics Principles, Concepts and Applications - Tata
7. McGraw-Hill Publishing Company Limited, 2003. ISBN 10: 0070634459 / ISBN 13: 9780070634459
8. Michael B.Histand and Davis G. Alciatore - Introduction to Mechatronics and Measurement
   Systems - McGraw Hill International edition, 1999.
9. Bradley D.A, Dawson.D, Buru N.C and Loader A.J – Mechatronics - Nelson Thornes Ltd, Eswar press, Indian print, 2004. ISBN-13: 978-0748757428 ISBN-10: 0748757422

IALE 430

Automated and Computer Integrated Manufacturing Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should be able to-

1	Perform simple automated manufacturing task of a flexible manufacturing cell
2	Analyze automated workpiece loading/unloading in CNC machining stations by articulated robot

List of Experiments (Any 5 experiments are to be performed)

1. Study of a FMS Cell
2. Study of FMS model for any industry
3. Study and demonstration on 5 axis robot in a CIM Cell
4. Programming of a 5 axis robot for AS/RS and linear transfer
5. Programming of a 5 axis robot for CNC lathe/ milling loading/unloading operation combined with any turning process.
6. Programming of a 5 axis robot for CNC lathe/ milling loading/unloading operation combined with any milling process.

IALE 431

CNC Machines Lab

(1.5 credits)

Course Outcome:

On completion of the course, students should be able to-

1	Develop basic competency to perform CNC machining operations
2	Illustrate concepts of synchronized CNC operation in a CNC based FMS cell

List of Experiments (Any 3 experiments from sub head 3 are to be performed)

1. Study of a CNC based FMS Cell
2. Study of various instructions for programming of CNC
3. Pragramming of CNC for various applications
   1) Cutting
   2) Milling
   3) Boring
   4) Spinning
   5) Gluing
   6) Routing
   7) Drilling
4. Miniproject based on combination or single CNC Application

IALE - 432

Micro Mechatronic System Lab

(1.5 credits)

Course Outcomes:

On completion of the course, students should be able to-

1	Develop basic simulation concepts for design of micromechatronic/micro-electromechanical elements

List of Experiments (Any 5 experiments are to be performed)

1. To Perform Multiphysics Analysis of a Thermal Actuator
2. Tutorial – 1 Introduction to MEMS & Microsystems.
3. Tutorial – 2 Mechanics of MEMS.
4. Tutorial – 3 Dynamics of MEMS.
5. Tutorial – 4 Fabrications processes for MEMS.
6. Design and Analysis of MEMS Pressure Sensor-I
7. Design and Analysis of MEMS Pressure Sensor-II
8. Design and Analysis of MEMS Pressure Sensor-III

Open Elective

IAGE - 420

Automated Manufacturing

(02 credits – 50 marks)

Course Outcomes:

On completion of the course, students should be able to-

1	Define Manufacuring
2	Classify schemes of manufacturing systems.
3	Define various principles and strategies of Automation.
4	Explain Production lines and Assembly ststions.
5	Analyze parts delivery systems at workstations.

Course Contents:

Module–I: Introduction to Manufacturing (06 Hrs)

Production Systems, Automation in Production System, Manual Labor in Production systems, Automation Principles and Strategies

Module– II: Components of Manufacturing System (06 Hrs)

Components of manufacturing system: production machines, material handling system, computer control system, human resources; classification scheme for manufacturing systems; types of operations performed, number of workstations, system layout, part or product variety, classification scheme

Module– III: Automated Production Lines (06 hrs)

Fundamentals of Automated Production Lines: system configurations, workpart transfer mechanisms, storage buffers, control of production lines; Applications of production lines; Analysis of transfer lines.

Module– IV: Automated Assembly Stations (06 hrs)

Fundamentals of Automated Assembly Systems: system configurations, parts delivery at workstations, applications; Quantitative analysis of Assembly stations: parts delivery systems at workstations, multistation assembly machines, single station assembly machines, partial automation

Module-V: Presentations, case studies, Assignments, Tutorials based on Module I to IV.

References:

1. Mikell P Groover- Automation Production Systems and Computer Integrated Manufacturing
   Pearson Publication ISBN: 78-93-325-4981-4
2. Bolton.W – Mechatronics - Pearson education, second edition, fifth Indian Reprint, 2003, SBN, 8131762572, 9788131762578
3. Smaili.A and Mrad.F - Mechatronics integrated technologies for intelligent machines - Oxford university press, 2008. ISBN-10: 0198060165 ISBN-13: 978-0198060161
4. Devadas Shetty and Richard A.Kolk, - Mechatronics systems design - PWS Publishing Company, 2007. ISBN-13: 978-1439061985 ISBN-10: 143906198X
5. Godfrey C. Onwubolu - Mechatronics Principles and Applications - Elsevier, 2006. ISBN-13: 978-0750663793 ISBN-10: 0750663790
6. Nitaigour Premchand Mahalik -Mechatronics Principles, Concepts and Applications - Tata
7. McGraw-Hill Publishing Company Limited, 2003. ISBN 10: 0070634459 / ISBN 13: 9780070634459
8. Michael B.Histand and Davis G. Alciatore - Introduction to Mechatronics and Measurement
   Systems - McGraw Hill International edition, 1999.
9. Bradley D.A, Dawson.D, Buru N.C and Loader A.J – Mechatronics - Nelson Thornes Ltd, Eswar press, Indian print, 2004. ISBN-13: 978-0748757428 ISBN-10: 0748757422

IAOE 421

Industrial Robotics

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the Course, students should be able to

1	Familiar with the applications of robotic systems as they are currently used in industry and research
2	Define the needs acquire necessary information
3	Select appropriate robots for various industrial applications
4	Apply the knowledge gained for the design and development of simple robotic aspects

Course Contents:

Module- I: Review of Robotics (06 Hrs)

Automation and Robotics, Robotics Market and Future Prospects, Review of Robot Anatomy and Robot Motion analysis,

Module -II: Application Engineering for Manufacturing (07 Hrs)

Robot Cell Design: Robot Cell Layouts, Multiple Robots and Machine interface, Workcell Control;

Economic Analysis for Robotics: Methods for economic analysis, Differences in Production rates, Robot project analysis form.

Module- III: Robot application in Manufacturing (07 Hrs)

Material Transfer and Machine loading/unloading: material transfer applications, machine loading and unloading ;

Processing Operations: Spot Welding, Spray coating, other processing operations using Robots;

Assembly and Inspection.

Module- IV: **Implementation Principles and Issues** (07 Hrs)

An approach for Implementing Robotics: Plant Survey, Selection of Robot, Planning and Engineering the installation;

Safety, Training, Maintenance and Quality; Social Issues and Future of Robotics.

Module V: Tutorials, assignments and presentation based on Module I to IV

References:

1. Robotics and Control by Mittal &NagrathTata McGraw-Hill Education, 2003: ISBN 10: 0070482934 / ISBN 13: 9780070482937

2. Industrial Robotics By Michel P Groover**1St Edition Edition**; ISBN-13: 978-0070249899 / ISBN- 10: 007024989X

3. Robotic Engineering By Dr. Surender Kumar, Dr.S K. Mukherjee (TMH)

4. , "Robotic Engineering - An Integrated Approach" by Richard D. Klafter, Thomas A. Chmielewski and Michael Negin, Prentice Hall India, 2002

5. S.R. Deb, Robotics Technology and flexible automation, Tata McGraw-Hill Education., 2009

6. Robotics control, sensing, vision and intelligence, Fu. K. S., Gonzalez. R. C. & Lee C.S.G., "", McGraw Hill Book co, 1987

7. Robots and Manufacturing Automation, Ray Asfahl. C., John Wiley & Sons Inc.,1985

8.. Introduction to Robotics mechanics and control, by Craig. J. J., Addison- Wesley, 1999

IAOE 422

Mechatronics Fundamentals

(2 Credits: 50 Marks)

Course Outcomes:

On completion of the course, students should able to –

1	Explain the various Analog & Digital circuit elements.
2	Develop the program using PIC Microcontroller.
3	Differentiate the different sensor technology.
4	Describe design aspects for the mechatronics system.

Course Contents:

Module - I: Analog circuits and Digital circuits. (05 Hrs)

Analog Circuit Elements. Mechanical Switches. Circuit Analysis. Equivalent Circuits. Impedance. AC Signals. Power in Circuits. Operational Amplifiers. Grounding. Solenoids and Relays,Combinational Logic Circuits. Sequential Logic Circuits. Circuit Families. Digital Devices. H-Bridge Drives.

Module - II: Data acquisition and Microcontroller/pc interfacing (07 Hrs)

PIC Microcontroller. Programming the PIC Microcontroller,PIC MCU Devices and Features. Interrupts

Sampling Theory. Parallel Port. Data Acquisition Board Programming. USART Serial Port. Serial Peripheral Interface. Inter-Integrated Circuit Interface. USB Communication. Network Connection.

Module - III: Sensors & Actuators (06 Hrs)

Sensors Performance Terminology. Displacement Measurement. Proximity Measurement. Speed Measurement. . Force and Torque Measurement. Temperature Measurement. Signal Conditioning. Sensor Output.

DC Motors. AC Motors. Stepper Motors. Other Motor Types. Actuator Selection.

Module -IV: Mechatronics Projects (05 Hrs)

Stepper-Motor Driven Rotary Table. A Paper Dispensing System That Uses a Roller Driven by a Position Controlled DC Motor. A Temperature-Controlled Heating System That Uses a Heating Coil, a Copper Plat, and a Temperature Sensor.

Module – V: Tutorials, Assignments, Demonstrations and Presentation Based On Module I to IV

References:

1. "Fundamentals of Mechatronics," Musa Jouaneh, Cengage Learning, 2011.
2. "Mechatronics: a Foundation Course", Clarence de Silva, CRC Press, 2010.
3. "Mechatronics Systems Fundamentals", Rolf Isermann, Springer, 2005.
4. W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, 6thEdition, Pearson Education, 2015
5. Murthy, D.V.S., Transducers and Instrumentation, Prentice Hall of India (2008).