BACHELOR OF TECHNOLOGY (B.TECH.)
IN
INSTRUMENTATION AND CONTROL ENGINEERING
(2024 - 2028)

Flexible CURRICULUM and SYLLABUS
for the students admitted in
the academic year 2024 – 2025 onwards

DEPARTMENT OF
INSTRUMENTATION AND CONTROL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015.
TAMIL NADU, INDIA

Bachelor of Technology (B.Tech.)

in

INSTRUMENTATION AND CONTROL ENGINEERING

Flexible CURRICULUM and SYLLABUS

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DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015, TAMIL NADU, INDIA

VISION OF THE INSTITUTE

To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

To be a world class centre of excellence in Instrumentation and Control Engineering

MISSION OF THE DEPARTMENT

- To inspire the students to realize their aspiration and potential through quality education inInstrumentation and Control Engineering.
- To enhance knowledge, create passion for learning, foster innovation and nurture talents towardsserving the society and the country.
- To encourage faculty and students to keep in pace with the latest technological developments and topursue research in those areas.
- To enable the students to engage themselves in entrepreneurship and product development for thebenefit of the global community.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The major objectives of the 4-year B.Tech. Instrumentation and Control Engineering (ICE) programme offered by the department of Instrumentation and Control Engineering are:

PEO1	To prepare students for core industries/ manufacturing sectors / Information Technology Enabled Services (ITES)
PEO2	To prepare students for research and development organizations
PEO3	To prepare students for higher studies in engineering and management
PEO4	To prepare students for starting and running enterprises

PROGRAMME OUTCOMES (POs)

National Board of Accreditation (NBA) has defined the twelve POs for an engineering graduate. These are in line with the Graduate Attributes as defined by the Washington Accord.

Graduates of the 4-year B.Tech. ICE programme offered by the department of Instrumentation and Control Engineering must demonstrate that they attain the following outcomes:

PO1	**Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
PO3	**Design/Development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct Investigations of Complex Problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern Tool Usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The Engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9	**Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

Graduates of the 4-year B.Tech. ICE programme offered by the department of Instrumentation and Control Engineering must demonstrate that they attain the following PSOs:

PSO1	To be able to apply the basic knowledge of Mathematics, Computing and Sciences to develop mathematical models and, apply appropriate techniques and Information technology (IT) tools to identify, formulate and solve real life problems faced in industries and, Research and Development
PSO2	To apply standard practices and combine the emerging technologies into the core area of Instrumentation and Control Engineering in the design and investigation of systems for sustainable development
PSO3	To commit themselves to the highest ethical standards and create and maintain professionalism in the work culture and outcome

CURRICULUM FRAMEWORK AND CREDIT SYSTEM for the 4 Year B.Tech. PROGRAMME with an option for exit at 3 Years with B.Sc. (Engineering) degree and further rejoin for B.Tech. degree

COURSE STRUCTURE for the 4 Year B.Tech. Programme

Course Category	No. of Courses	No. of Credits	Weightage (%)
General Institute Requirements (**IR**)	22	56	35.0
Programme Core (**PC**)	15	52	32.5
Programme Elective (**PE**) / Open Elective (**OE**)/ Online Course (**OC**)	12 8 PE mandatory	36	22.5
Essential Laboratory Requirements (**LR**)	8 Maximum 2 per session 3rd to 6th semester	16	10.0
Total	**57**	**160**	**100**
Honours (Optional)	Courses for 15 credits	**15 Additional credits**	-
Minor (Optional)	Courses for 15 credits	15 Additional credits	-

1. Among the 15 Programme Core (PC) courses, 7 courses would carry 4 credits each and the remaining 8 carry 3 credits each, spread during the 2nd to 6th semesters.
2. In order to fulfil the requirement of 12 Elective courses (36 credits), a minimum of 8 Programme Electives (PE) is mandatory. The requirement of remaining electives can be fulfilled through either Programme Electives or, Open Electives (OE) / Online Courses (OC).
3. Project work is mandatory in the 8th Semester for B.Tech. (ICE) students. However, the students who wish to carryout / undergo the semester exchange programme / industry attachment (preplacement offer / internship) outside the institute during the 8th semester can opt for completing two additional elective courses equivalent to 6 credits, preferably during the previous semesters, in place of the Project Work in the 8th Semester (if, they cannot do a project work in this tenure). Project work is compulsory for B.Tech. Honours degree.
4. To qualify for an Honours Degree (HO), students must: (a) register for and complete at least 12 theory courses and 4 LRs in their second year, (b) consistently maintain a minimum CGPA of 8.5 during the first four sessions, (c) maintain a minimum CGPA of 8.5 in all the subsequent 4 sessions excluding Honours courses, (d) successfully complete additional courses (inclusive of M. Tech. courses, which must be distinct and at a higher level than PC and PE courses) listed as Honours courses in the B.Tech. (ICE) curriculum, totaling a minimum of 15 credits (for example, 3 numbers of 4 credit course and 1 number of 3 credit course), and (e) achieve at least a B grade in the Honours courses. Honours courses cannot be treated as programme electives and grades from these courses do not factor into CGPA calculations.
5. To earn a Minor degree (in addition to the regular stream/branch of study), the student must earn 15 credits over and above the 160 credits specified in the B.Tech (ICE) curriculum, through courses offered by other departments. The details of Minor will be mentioned in the Transcript but not in the Degree Certificate.

CURRICULUM FRAME WORK / FLEXIBLE CURRICULUM / NEP 2020 / NCrF / 4 year B.Tech. Instrumentation and Control Engineering

Semester	GIR		PC		ELR		PE/OE		Total Credits	Credit Distribution
	Course	Credit	Course	Credit	Course	Credit	Course	Credit		
I	8	19	-	-	-	-	-	-	19	40
II	7	17	1	4	-	-	-	-	21	
III	1	4	4	14	2	4	1	3	25	47
IV	-	-	3	12	2	4	2	6	22	
V	1	3	4	12	2	4	2	6	25	49
VI	2	4	3	10	2	4	2	6	24	
VII	2	3	-	-	-	-	4	12	15	24
VIII	1	6	-	-	-	-	1	3	9	
Total	**22**	**56**	**15**	**52**	**8**	**16**	**12**	**36**	**160**	**160**

CURRICULUM FRAME WORK / FLEXIBLE CURRICULUM / NEP 2020 / NCrF / B.Tech. Instrumentation and Control Engineering after B.Sc. (Engineering)

	Sem	GIR		PC		ELR		PE/OE		Total Credits	Credit Distribution
		Course	Credit	Course	Credit	Course	Credit	Course	Credit		
Same as B.Tech.	I	8	19	-	-	-	-	-	-	19	40
	II	7	17	1	4	-	-	-	-	21	
	III	1	4	4	14	2	4	1	3	25	47
	IV	-	-	3	12	2	4	2	6	22	
B.Sc. (Engg.) Exit	V	1	3	3	9	2	4	1	3	19	35
	VI	4#	12	-	-	2	4	-	-	16	
After B.Sc. (Engg.) exit and join back for B. Tech.	VII	-	-	1	3	-	-	6	18	21	38
	VIII	1	1	3	10	-	-	2	6	17	
	Total	**22**	**56**	**15**	**52**	**8**	**16**	**12**	**36**	**160**	**160**

#(Winter internship (2), Project Work (6), Professional Ethics (3), and Industrial Lecture (1))

GENERAL INSTITUTE REQUIREMENTS (GIR) COURSES

S.No.	Course	No. of Courses	Max. Credits
1.	Mathematics	3	10
2.	Physics	1	3
	Physics Laboratory	1	2
3.	Chemistry	1	3
	Chemistry Laboratory	1	2
4.	Industrial Economics	1	3
5.	English for Communication	1	4
6.	Energy and Environmental Engineering	1	2
7.	Professional Ethics	1	3
8.	Engineering Graphics	1	3
9.	Engineering Practice	1	2
10.	Basic Engineering	2	4
11.	Introduction to Computer Programming	1	3
12.	Introduction to Instrumentation and Control Systems Engineering	1	2
13.	Internship Summer – after 6th sem; assessment in the 7th Semester for 4 year B.Tech. Winter – after 5th sem; assessment in the 6th Semester for B.Tech. after B.Sc. (Engg)	1	2
14.	Project work	1	6
15.	Comprehensive viva voce	1	1
16.	Industrial Lecture	1	1
17.	NSS/NCC/NSO	1	Pass / Fail
	Total	**22**	**56**

Curriculum Framework and Credit System / ICE / Total credits = 160

B.Tech. Instrumentation and Control Engineering

Semester I (July Session)

S. No.	Course Code	Course	Credits	Category
1.	MAIR12	Linear Algebra and Calculus	3	GIR
2.	PHIR11	Physics	3	GIR
3.	ENIR11	Energy and Environmental Engineering	2	GIR
4.	CSIR11	Introduction to Computer Programming (T + L)	3	GIR
5.	CEIR11	Basics of Civil Engineering (for EE, EC, **IC** & CS)	2	GIR
6.	MEIR11	Basics of Mechanical Engineering (for CE, EE, EC, **IC** & CS)	2	GIR
7.	PRIR11	Engineering Practice	2	GIR
8.	PHIR12	Physics Laboratory	2	GIR
		Total	**19**	

Semester II (January Session)

S. No.	Course Code	Course	Credits	Category
1.	HSIR11	English for Communication (Theory and Lab)	4	GIR
2.	MAIR21	Complex Analysis and Differential Equations	3	GIR
3.	CHIR11	Chemistry	3	GIR
4.	ICIR15	Introduction to Instrumentation and Control Systems Engineering	2	GIR
5.	MEIR12	Engineering Graphics	3	GIR
6.	CHIR12	Chemistry Laboratory	2	GIR
7.	SWIR11	NSS/NCC/NSO	0	GIR
8.	ICPC11	Circuit Theory (Programme Core – I)	4	PC
		Total	**21**	

Semester III (July Session)

S. No.	Course Code	Course	Credits	Category
1.	MAIR34	Probability and Distribution Theory	4	GIR
2.	ICPC12	Electronic Circuits (Programme Core – II)	4	PC
3.	ICPC13	Signals and Systems (Programme Core – III)	4	PC
4.	ICPC14	Sensors and Transducers (Programme Core – IV)	3	PC
5.	ICPC15	Digital Electronics (Programme Core – V)	3	PC
6.	ICPEXX	Programme Elective – I	3	PE
7.	ICLR11	Electric Circuits Laboratory (Laboratory – I)	2	ELR
8.	ICLR12	Electronic Circuits Laboratory (Laboratory – II)	2	ELR
		Total	**25**	

Semester IV (January Session)

S. No.	Course Code	Course	Credits	Category
1.	ICPC16	Microprocessors and Microcontrollers (Programme Core – VI)	3	PC
2.	ICPC17	Industrial Instrumentation (Programme Core-VII)	3	PC
3.	ICPC18	Control Systems - I (Programme Core – VIII)	4	PC
4.	ICPC19-A	Product Design and Development – 1 (Theory) (Programme Core – IX Part A)	2	PC
5.	ICPEXX	Programme Elective – II	3	PE
6.	ICPEXX	Programme Elective - III / Open Elective – I	3	PE/OE
7.	ICLR13	Sensors and Transducers Laboratory (Laboratory – III)	2	ELR
8.	ICLR14	Microprocessors and Microcontrollers Laboratory (Laboratory – IV)	2	ELR
		Total	**22**	

Semester V (July Session)

S. No.	Course Code	Course	Credits	Category
1.	HSIR13	Industrial Economics	3	GIR
2.	ICPC20	Analog Signal Processing (Programme Core – X)	4	PC
3.	ICPC21	Process Control (Programme Core – XI)	3	PC
4.	ICPC22	Control Systems - II (Programme Core – XII)	3	PC
5.	ICPC19-B	Product Design and Development – 2 (Practice) (Programme Core – IX Part B)	2	PC
6.	ICPEXX	Programme Elective – IV	3	PE
7.	ICPEXX	Programme Elective – V / Open Elective – II	3	PE/OE
8.	ICLR15	Control Engineering Laboratory (Laboratory – V)	2	ELR
9.	ICLR16	Analog Signal Processing Laboratory (Laboratory – VI)	2	ELR
		Total	**25**	

Semester VI (January Session)

S. No.	Course Code	Course	Credits	Category
1.	ICIR19	Industrial Lecture	1	GIR
2.	ICIR14	Professional Ethics	3	GIR
3.	ICPC23	Electrical and Electronic Measurements (Programme Core – XIII)	3	PC
4.	ICPC24	Digital Signal Processing (Programme Core – XIV)	3	PC
5.	ICPC25	Logic and Distributed Control Systems (Programme Core – XV)	4	PC
6.	ICPCXX	Programme Elective – VI	3	PE
7.	ICPCXX	Programme Elective – VII / Open Elective – III	3	PE/OE
8.	ICLR17	Instrumentation Laboratory (Laboratory – VII)	2	ELR
9.	ICLR18	Industrial Automation and Process Control Laboratory (Laboratory – VIII)	2	ELR
		Total	**24**	

Semester VII (July Session)

S. No.	Course Code	Course	Credits	Category
1.	ICIR16	Internship (Summer)	2	GIR
2.	ICIR18	Comprehensive Viva Voce	1	GIR
3.	ICPEXX	Programme Elective – VIII	3	PE
4.	ICPEXX	Programme Elective – IX	3	PE
5.	ICPEXX	Programme Elective – X / Open Elective – IV	3	PE/OE
6.	ICPEXX	Programme Elective – XI / Open Elective – V	3	PE/OE
		Total	**15**	

Semester VIII (January Session)

S. No.	Course Code	Course	Credits	Category
1.	ICIR17	Project Work	6	GIR
2.	ICPEXX	Programme Elective – XII / Open Elective – VI	3	PE/OE
		Total	**9**	

Minimum Credits (semester wise and total) requirement for graduation with the B. Tech. degree in ICE

Semester	Credits to be earned
I	19
II	21
III	25
IV	22
V	25
VI	24
VII	15
VIII	9
Total	**160**

Note:

1. Among the 15 Programme Core courses, 7 are of 4 credits.
2. It is mandatory to complete Eight programme elective (PE) courses while fulfilling 36 credits from the elective (PE/OE/OC) courses
3. To earn a B.Tech. Honours (HO) Degree 15 credits over and above the minimum total credits as specified by the B.Tech. curriculum (160) has to be earned, in addition to meeting all the related criteria.
4. Minor (MI): 15 credits over and above the minimum total credits from courses of another department, as specified by the B.Tech. curriculum (160).

   The details of MINOR will be mentioned in the Transcript but not in the Degree Certificate.

Exit with **B.Sc. (Engineering) in Instrumentation and Control Engineering**

The curriculum structure for B.Sc. (Engineering) degree in Instrumentation and Control Engineering at 3 years remains the same as that of 4 year B.Tech. Instrumentation and Control Engineering for the first 4 sessions.

Semester V (July Session) / B.Sc. (Engineering) Exit

Sl. No.	Course Code	Course	Credits	Category
1.	HSIR13	Industrial Economics	3	GIR
2.	ICPC20	Analog Signal Processing (Programme Core –X)	4	PC
3.	ICPC21	Process Control (Programme Core – XI)	3	PC
4.	ICPC19-B	Product Design and Development – 2 (Practice) (Programme Core – IX Part B)	2	PC
5.	ICPEXX	Programme Elective – IV / Open Elective – II	3	PE/OE
6.	ICLR15	Control Engineering Laboratory (Laboratory – V)	2	ELR
7.	ICLR16	Analog Signal Processing Laboratory (Laboratory – VI)	2	ELR
		Total	**19**	

Semester VI (January Session) / B.Sc. (Engineering) Exit

Sl. No.	Course Code	Course	Credits	Category
1.	ICIR19	Industrial Lecture	1	GIR
2.	ICIR14	Professional Ethics	3	GIR
3.	ICIR16	Internship (Winter)	2	GIR
4.	ICIR17	Project Work*	6	GIR
5.	ICLR17	Instrumentation Laboratory (Laboratory – VII)	2	ELR
6.	ICLR18	Industrial Automation and Process Control Laboratory (Laboratory – VIII)	2	ELR
		Total	**16**	

*Project work is mandatory in the 6th Semester for B.Sc. (Engineering) (ICE) students. However, the students who wish to carryout / undergo the semester exchange programme / industry attachment (preplacement offer / internship) outside the institute during the 6th semester can opt for completing two additional Programme Elective (PE) courses equivalent to 6 credits, preferably during the previous semesters, in place of the Project Work in the 6th Semester (if, they cannot do a project work in this tenure).

Note: No Honours or Minor degrees will be awarded for B.Sc. (Engineering).
But, a student can credit the Honours and Minors courses during the 6 semesters, and redeem the credits to obtain an Honours degree or Minor respectively after rejoining and completing the courses for B.Tech. programme.

The students of B.Tech. who had opted an early exit with the 3-year B.Sc. (Engineering) (ICE) degree have another option of rejoining later to pursue the 4th year to earn the B.Tech. (ICE).

Semester VII (July Session) / Rejoins B.Tech. after B.Sc. (Engineering) exit

Sl. No.	Course Code	Course	Credits	Category
1.	ICPC22	Control Systems - II (Programme Core – XII)	3	PC
2.	ICPEXX	Programme Elective – V	3	PE
3.	ICPEXX	Programme Elective – VI	3	PE
4.	ICPEXX	Programme Elective – VII	3	PE
5.	ICPEXX	Programme Elective – VIII / Open Elective – III	3	PE/OE
6.	ICPEXX	Programme Elective – IX / Open Elective - IV	3	PE/OE
7.	ICPEXX	Programme Elective – X / Open Elective - V	3	PE/OE
		Total	**21**	

Semester VIII (January Session) / Rejoins B.Tech. after B.Sc. (Engineering) exit

Sl. No.	Course Code	Course	Credits	Category
1.	ICIR18	Comprehensive Viva Voce	1	GIR
2.	ICPC23	Electrical and Electronic Measurements (Programme Core – XIII)	3	PC
3.	ICPC24	Digital Signal Processing (Programme Core – XIV)	3	PC
4.	ICPC25	Logic and Distributed Control Systems (Programme Core – XV)	4	PC
5.	ICPEXX	Programme Elective – XI	3	PE
6.	ICPEXX	Programme Elective – XII / Open Elective – VI	3	PE/OE
		Total	**17**	

Minimum Credits (semester wise and total) requirement for exit with B. Sc. (Engineering) degree and rejoin for B.Tech. degree

Semester	Credits to be earned
B. Sc. (Engineering) Exit	
I	19
II	21
III	25
IV	22
V	19
VI	16
Total	**122**
Rejoin for B. Tech. after B.Sc. (Engineering) exit	
VII	21
VIII	17
Total	**160**

ELECTIVE CHOICES

Option 1 / Regular B.Tech. (ICE)

To get a B.Tech. degree in Instrumentation and Control Engineering, possible choices of electives in Programme Electives and Open Electives/ Online Courses are,

Programme Electives	Open Electives/ Online Courses	Total
8	4	12
9	3	12
10	2	12
11	1	12
12	0	12

Option 2 / B.Tech. (ICE) with Honours

To get a B.Tech. Honours degree in Instrumentation and Control Engineering, possible choices of electives in Programme Electives, Open Electives/ Online Courses, and Honours courses are,

Programme Electives	Open Electives/ Online Courses	Honours Courses	Total
8	4	4	12 + 4
9	3	4	12 + 4
10	2	4	12 + 4
11	1	4	12 + 4
12	0	4	12 + 4

Option 3 / B.Tech. (ICE) with Minor (from other department)

To get a B.Tech. degree in Instrumentation and Control Engineering, and minor in any other programme, possible choices of electives in Programme Electives, Open Electives/ Online Courses, and Minor Courses are,

Programme Electives	Open Electives/ Online Courses	Minor Courses	Total
8	4	5	12 + 5
9	3	5	12 + 5
10	2	5	12 + 5
11	1	5	12 + 5
12	0	5	12 + 5

Option 4 / B.Tech. (ICE) with Honours and Minor

To get a B.Tech. Honours degree in Instrumentation and Control Engineering, and minor in other programmes possible choices of electives in Programme Electives, Open Electives/ Online Courses, and Honours courses, Minor courses are,

Programme Electives	Open Electives/ Online Courses	Honours Courses	Minor Courses	Total
8	4	4	5	12 + 4 + 5
9	3	4	5	12 + 4 + 5
10	2	4	5	12 + 4 + 5
11	1	4	5	12 + 4 + 5
12	0	4	5	12 + 4 + 5

Option 5 / B.Sc. (Engineering) (ICE) Exit (at the end of 3rd year)

Programme Electives	Open Electives/ Online Courses	Total
3	2	5
4	1	5
5	0	5

LIST OF COURSES

(I) PROGRAMME CORE (PC)

S.No.	Course Code	Course Title	Semester (B.Tech.)	Pre-requisites	Credits
1.	ICPC11	Circuit Theory (Programme Core – I)	2nd	-	4
2.	ICPC12	Electronic Circuits (Programme Core – II)	3rd	ICPC11	4
3.	ICPC13	Signals and Systems (Programme Core – III)	3rd	-	4
4.	ICPC14	Sensors and Transducers (Programme Core – IV)	3rd	-	3
5.	ICPC15	Digital Electronics (Programme Core – V)	3rd	-	3
6.	ICPC16	Microprocessors and Microcontrollers (Programme Core – VI)	4th	ICPC15	3
7.	ICPC17	Industrial Instrumentation (Programme Core-VII)	4th	ICPC14	3
8.	ICPC18	Control Systems - I (Programme Core – VIII)	4th	ICPC13	4
9.	ICPC19-A	Product Design and Development – 1 (Theory) Programme Core – IX Part A	4th	-	2
	ICPC19-B	Product Design and Development – 2 (Practice) Programme Core – IX Part B	5th	-	2
10.	ICPC20	Analog Signal Processing (Programme Core – X)	5th	ICPC12, ICPC13	4
11.	ICPC21	Process Control (Programme Core – XI)	5th	ICPC18	3
12.	ICPC22	Control Systems - II (Programme Core – XII)	5th	ICPC18	3
13.	ICPC23	Electrical and Electronic Measurements (Programme Core – XIII)	6th	ICPC11, ICPC12	3
14.	ICPC24	Digital Signal Processing (Programme Core – XIV)	6th	ICPC13	3
15.	ICPC25	Logic and Distributed Systems (Programme Core – XV)	6th	ICPC18, ICPC16	4

(II) ESSENTIAL PROGRAMME LABORATORY REQUIREMENT (ELR)

Sl. No.	Course Code	Course Title	Semester (B.Tech.)	Prerequisites	Credits
1.	ICLR11	Electric Circuits Laboratory (Laboratory – I)	3rd	ICPC11	2
2.	ICLR12	Electronic Circuits Laboratory (Laboratory – II)	3rd	-	2
3.	ICLR13	Sensors and Transducers Laboratory (Laboratory – III)	4th	ICPC14	2
4.	ICLR14	Microprocessors and Microcontrollers Laboratory (Laboratory – IV)	4th	-	2
5.	ICLR15	Control Engineering Laboratory (Laboratory – V)	5th	ICPC18	2
6.	ICLR16	Analog Signal Processing Laboratory (Laboratory – VI)	5th	-	2
7.	ICLR17	Instrumentation Laboratory (Laboratory – VII)	6th	ICPC17	2
8.	ICLR18	Industrial Automation and Process Control Laboratory (Laboratory – VIII)	6th	ICPC21	2

(III) ELECTIVES

a. PROGRAMME ELECTIVES

Overall List of Programme Electives:

Sl. No.	Course Code	Course Title	Pre-requisites	Credits
1.	ICPE11	Biomedical Instrumentation	ICPC14	3
2.	ICPE12	Biomedical Signal Processing	ICPC13, ICPC24	3
3.	ICPE13	Digital Image Processing	ICPC13, ICPC24	3
4.	ICPE14	Medical Imaging Systems	ICPC13, ICPC24	3
5.	ICPE15	Medical Diagnostic and Therapeutic Instrumentation	ICPE11	3
6.	ICPE16	Assistive devices	ICPE11	3
7.	ICPE17	Instrumentation Practices in Industries	ICPC17	3
8.	ICPE18	Digital Control Systems	ICPC18	3
9.	ICPE19	Neural Networks and Fuzzy Logic	-	3
10.	ICPE20	Computational Techniques in Control Engineering	ICPC18	3
11.	ICPE21	Network Control Systems	ICPC18	3
12.	ICPE22	Industrial Data Communication	ICPC25	3
13.	ICPE23	Internet of Things System Design	-	3
14.	ICPE24	Robotics	-	3
15.	ICPE25	Cyber security for industrial automation	ICPC25	3
16.	ICPE26	Real-Time Embedded Systems	ICPC15, ICPC16	3
17.	ICPE27	Optical Instrumentation	ICPC14	3
18.	ICPE28	Measurement Data Analysis	-	3
19.	ICPE29	Micro Electro Mechanical Systems	ICPC14	3
20.	ICPE30	Automotive Instrumentation and Control	ICPC14	3
21.	ICPE31	Instrumentation and Control for Power Plant	ICPC17, ICPC18	3
22.	ICPE32	Instrumentation and Control for Petrochemical Industries	ICPC17, ICPC18	3
23.	ICPE33	Instrumentation and Control for Paper Industries	ICPC17, ICPC18	3
24.	ICPE34	Instrumentation for Agricultural and Food Processing Industries	ICPC17	3
25.	ICPE35	Piping and Instrumentation Diagrams	ICPC18, ICPC21	3
26.	ICPE36	Communication and Networking in Industrial Automation	ICPC25	3
27.	ICPE37	Building Automation	ICPC25	3
28.	ICPE38	Nonlinear Control	MAIR courses, ICPC18	3

Sl. No.	Course Code	Course Title	Pre-requisites	Credits
29.	ICPE39	System Identification	ICPC13	3
30.	ICPE40	Fault Detection and Diagnosis	ICPC21	3
31.	ICPE41	Process Modeling and Optimization	ICPC18, ICPC21	3
32.	ICPE42	Control System Components	ICPC11, ICPC12	3
33.	ICPE43	Power Electronics	ICPC11, ICPC12	3
34.	ICPE44	Industrial Electric Drives	ICPC11, ICPC12	3
35.	ICPE45	Smart and Wireless Instrumentation	ICPC14	3
36.	ICPE46	Principles of Communication Systems	ICPC13	3
37.	ICPE47	Multi Sensor Data Fusion	-	3
38.	ICPE48	Energy Harvesting Techniques	ICPC14	3
39.	ICPE49	Smart Materials and Systems	ICPC14	3
40.	ICPE50	Hydraulics and Pneumatics	ICPC14	3
41.	ICPE51	Engineering Mechanics	**-**	3
42.	ICPE52	Software Design Tools for Sensing and Control	ICPC18	3
43.	ICPE53	Numerical Methods	**-**	3
44.	ICPE54	Analytical Instrumentation	ICPC14, ICPC17	3
45.	ICPE55	Data structures and algorithms	-	3
46.	ICPE56	Nuclear Instrumentation	ICPC14, ICPC17	3
47.	ICPE57	Condition Monitoring	ICPC14, ICPC17	3
48.	ICPE58	Safety Instrumented system	ICPC17	3
49.	ICPE59	Modern Optimization Techniques and Algorithms	MAIR courses	3
50.	ICPE60	Robot Dynamics and Control	ICPC18, ICPC21	3
51.	ICPE61	CMOS Analog IC Design	ICPC12, ICPC20	3
52.	ICPE62	Sensor Interface Design	ICPC11, ICPC12, ICPC17	3
53.	ICPE63	Artificial Intelligence in Instrumentation and Measurement	-	3
54.	ICPE64	Thermodynamics and Fluid mechanics	-	3
55.	ICPE65	Design and Applications of Sensors and Transducers	ICPC14	3
56.	ICPE66	Design of Instrumentation Systems	ICPC17, ICPC20	3
57.	ICPE67	Design of Micro Systems	ICPC14	3
58.	ICPE68	Design of Control Systems	ICPC18, ICPC21	3
59.	ICPE69	Advanced Process Control Methods	ICPC18, ICPC21	3
60.	ICPE70	Robust and Optimal Control Systems	ICPC18, ICPC22	3
61.	ICPE71	Design of Sensors Systems	ICPC17	3

The Programme Elective courses are distributed into two specialization streams: Stream 1 (Biomedical Instrumentation), Stream 2 (Automation) in addition to other electives which do not fall under the two streams.

Stream I (BIOMEDICAL INSTRUMENTATION)

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICPE11	Biomedical Instrumentation	ICPC14	3
2.	ICPE12	Biomedical Signal Processing	ICPC13, ICPC24	3
3.	ICPE13	Digital Image Processing	ICPC13, ICPC24	3
4.	ICPE14	Medical Imaging Systems	ICPC13, ICPC24	3
5.	ICPE15	Medical Diagnostic and Therapeutic Instrumentation	ICPE11	3
6.	ICPE16	Assistive devices	ICPE11	3

Stream II (AUTOMATION)

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICPE17	Instrumentation Practices in Industries	ICPC17	3
2.	ICPE18	Digital Control Systems	ICPC18	3
3.	ICPE19	Neural Networks and Fuzzy Logic	-	3
4.	ICPE20	Computational Techniques in Control Engineering	ICPC18	3
5.	ICPE21	Network Control Systems	ICPC18	3
6.	ICPE22	Industrial Data Communication	ICPC25	3
7.	ICPE23	Internet of Things System Design		3
8.	ICPE24	Robotics	-	3
9.	ICPE25	Cyber security for industrial automation	ICPC25	3
10.	ICPE26	Real-Time Embedded Systems	ICPC15, ICPC16	3
11.	ICPE17	Instrumentation Practices in Industries	ICPC17	3
12.	ICPE36	Communication and Networking in Industrial Automation	ICPC23	3
13.	ICPE37	Building Automation	ICPC23	3
14.	ICPE38	Nonlinear Control	MAIR courses, ICPC18	3
15.	ICPE39	System Identification	ICPC13	3
16.	ICPE40	Fault Detection and Diagnosis	ICPC21	3
17.	ICPE41	Process Modeling and Optimization	ICPC18, ICPC21	3
18.	ICPE42	Control System Components	ICPC11, ICPC12	3
19.	ICPE43	Power Electronics	ICPC11, ICPC12	3
20.	ICPE44	Industrial Electric Drives	ICPC11	3
21.	ICPE55	Data structures and algorithms	-	3
22.	ICPE57	Condition monitoring	ICPC14, ICPC17	3
23.	ICPE58	Safety Instrumented system	ICPC17	3
24.	ICPE59	Modern Optimization Techniques and Algorithms	MAIR courses	3

25.	ICPE60	Robot Dynamics and Control	ICPC18, ICPC21	3
26.	ICPE68	Design of Control Systems	ICPC18, ICPC21	3
27.	ICPE69	Advanced Process Control Methods	ICPC18, ICPC21	3
28.	ICPE70	Robust and Optimal Control Systems	ICPC18, ICPC22	3
29.	ICPE11	Biomedical Instrumentation	ICPC14	3

Stream III (NON-SPECIALIZATION ELECTIVES)

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICPE27	Optical Instrumentation	ICPC14	3
2.	ICPE28	Measurement Data Analysis	-	3
3.	ICPE29	Micro Electro Mechanical Systems	ICPC14	3
4.	ICPE30	Automotive Instrumentation and Control	ICPC14	3
5.	ICPE31	Instrumentation and Control for Power Plant	ICPC17, ICPC18	3
6.	ICPE32	Instrumentation and Control for Petrochemical Industries	ICPC17, ICPC18	3
7.	ICPE33	Instrumentation and Control for Paper Industries	ICPC17, ICPC18	3
8.	ICPE34	Instrumentation for Agricultural and Food Processing Industries	ICPC17	3
9.	ICPE35	Piping and Instrumentation Diagrams	ICPC18, ICPC21	3
10.	ICPE45	Smart and Wireless Instrumentation	ICPC14	3
11.	ICPE46	Principles of Communication Systems	ICPC13	3
12.	ICPE47	Multi Sensor Data Fusion	-	3
13.	ICPE48	Energy Harvesting Techniques	ICPC14	3
14.	ICPE49	Smart Materials and Systems	ICPC14	3
15.	ICPE50	Hydraulics and Pneumatics	ICPC14	3
16.	ICPE51	Engineering Mechanics	-	3
17.	ICPE52	Software Design Tools for Sensing and Control	ICPC18	3
18.	ICPE53	Numerical Methods	-	3
19.	ICPE54	Analytical Instrumentation	ICPC14, ICPC17	3
20.	ICPE56	Nuclear Instrumentation	ICPC14, ICPC17	3
21.	ICPE61	CMOS Analog IC Design	ICPC12, ICPC20	3
22.	ICPE62	Sensor Interface Design	ICPC11, ICPC12, ICPC17	3
23.	ICPE63	Artificial Intelligence in Instrumentation and Measurement	-	3
24.	ICPE64	Thermodynamics and Fluid Mechanics	-	3
25.	ICPE65	Design and Applications of Sensors and Transducers	ICPC14	3
26.	ICPE66	Design of Instrumentation Systems	ICPC17, ICPC20	3
27.	ICPE67	Design of Micro Systems	ICPC14	3
28.	ICPE71	Design of Sensors Systems	ICPC17	3

b. ONLINE COURSES (OC)

A committee headed by the head of the department with two faculty members can decide the online courses to be offered to the students through the Swayam portal (https://swayam.gov.in/). A student can earn a maximum of 12 credits from these online courses, in place of Open Electives (OE).

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICOE51	Laser: Fundamentals and Applications	-	3
2.	ICOE52	Data Analytics using Python	-	3
3.	ICOE53	Deep Learning	-	3
4.	ICOE54	Introduction to Internet of Things	-	3
5.	ICOE55	Programming, Data Structures and Algorithms Using Python	-	3
6.	ICOE56	Introduction to Machine Learning	-	3
7.	ICOE57	Introduction to Robotics	-	3
8.	ICOE58	Design, Technology and Innovation	-	3
9.	ICOE59	Fabrication Techniques for MEMS-based sensors: clinical perspective	-	3
10.	ICOE60	Electronics Equipment Integration and Prototype building	-	3
11.	ICOE61	Embedded System Design with ARM	-	3
12.	ICOE62	Fiber Optics	-	3
13.	ICOE63	Industrial Automation and Control	-	3
14.	ICOE64	Process Control - Design Analysis and Assessment	-	3
15.	ICOE65	Robotics and Control: Theory and Practice	-	3
16.	ICOE66	Introductory Neuroscience and Neuro-Instrumentation	-	3
17.	ICOE67	Innovation, Business Models and Entrepreneurship	-	3
18.	ICOE68	Robotics	-	3
19.	ICOE69	Automation in Manufacturing	-	3
20.	ICOE70	BioMEMS and Microfluidics	-	3
21.	ICOE71	Applied Linear Algebra for Signal Processing, Data Analytics and Machine Learning	-	3
22.	ICOE72	Reinforcement Learning	-	3
23.	ICOE73	Op-Amp Practical Applications: Design, Simulation, and Implementation	-	3
24.	ICOE74	Introduction to Fuzzy Set Theory, Arithmetic and Logic	-	3
25.	ICOE75	Robotics: Basics and *Selected* Advanced Concepts	-	3
26.	ICOE76	Sensors and Actuators	-	3
27.	ICOE77	Model Predictive Control: Theory and Applications	-	3

Note: In case any of the above listed courses are not offered in Swayam portal in a particular semester, the department will notify alternative courses offered in Swayam during the same period.

Qualification in some online/offline co-curricular certification courses conducted by professional organizations such as Microsoft, IBM, CISCO, National Instruments, International Society of Automation (ISA), IEEE, SAE, Bureau of Indian Standards (BIS), International Society for Measurement & Control, etc. can be considered for the award of up to a maximum of 3 credits in place of one Open Elective (OE), as decided by the department. The duration of the instructional course leading to the certification should be commensurate with the credits earned, with each credit typically requiring 12-14 hours of the student's attendance.

c. MICROCREDITS (MC)

(Students can opt 3 courses of 1 credit (12-14 hours) each as microcredits instead of one 3 credit OE/OC)
Students are also advised to take 4-week courses from NPTEL/SWAYAM platform

Sl. No.	Course Code	Course Title	Credit
1.	ICMC11	Essentials of Entrepreneurship for Engineers	1
2.	ICMC12	Intellectual Property Rights and Patents	1
3.	ICMC13	Medical Embedded Systems	1
4.	ICMC14	Wearable Robotics	1
5.	ICMC15	Augmented Reality (AR) and Virtual Reality (VR) in Industrial Automation	1
6.	ICMC16	Additive Manufacturing	1
7.	ICMC17	Smart Manufacturing	1
8.	ICMC18	Communication Networks in Practice	1
9.	ICMC19	Building and Infrastructure systems Automation	1
10.	ICMC20	Embedded System Design	1
11.	ICMC21	IT/OT Cyber Security	1
12.	ICMC22	Data Analytics/ Big Data	1
13.	ICMC23	Python Programming for AI/ML	1
14.	ICMC24	Advanced Driver Assistance System – An Introduction	1
15.	ICMC25	Vehicle Data Capture, Analytics & Dynamic vehicle performance Alteration	1

Note: Typically, Micro-credit courses will be offered by the department in collaboration with industry experts, in order to provide students exposure to state-of-the-art technology. They will be carried out for a duration of about 14 hours or 28 hours, carrying either 1 credit or 2 credits respectively. In place of an open elective (OE), a student is permitted to earn up to 3 credits through micro-credit courses.
The content of Micro-credit courses does not overlap with the content in the regular core / elective courses offered in the department.

The microcredit courses offered by the department can be conducted either in offline or online mode; students are also permitted to earn microcredits through courses listed in the Swayam portal.

(IV) ADVANCED LEVEL COURSES FOR B.Tech. (HONOURS)

Students who desire to obtain B.Tech. (Honours) degree in Instrumentation and Control Engineering can opt to study additional advanced level courses (from 5th to 8th semester) from the list below.

Sl. No.	Course Code	Course Title	Pre-requisites	Credits
1.	ICHO11	Design of Sensors and Transducers	ICPC14	4
2.	ICHO12	Instrumentation System Design	ICPC17, ICPC20	4
3.	ICHO13	Micro System Design	ICPC14	4
4.	ICHO14	Control System Design	ICPC18, ICPC21	4
5.	ICHO15	Advanced Process Control	ICPC18, ICPC21	4
6.	ICHO16	Optimal and Robust Control	ICPC18, ICPC22	4
7.	ICHO17	Sensors Systems Design	ICPC17	4
8.	ICHO18	Project-based Learning	-	4

(V) OPEN ELECTIVES (OE)

The courses listed below are offered by the Department of Instrumentation and Control Engineering for students of other branches.

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICOE11	Biomedical Signal Processing	-	3
2.	ICOE12	Micro Electro Mechanical Systems	-	3
3.	ICOE13	Measurement and Control	-	3
4.	ICOE14	Industrial Measurements	-	3
5.	ICOE15	Virtual Instrument Design	-	3
6.	ICOE16	Neural Networks and Fuzzy Logic	-	3
7.	ICOE17	Network Control Systems	-	3
8.	ICOE18	Control Systems	-	3
9.	ICOE19	Energy Harvesting Techniques	-	3
10.	ICOE20	Smart Materials and Systems	-	3
11.	ICOE21	Product Design and Development (Theory and Practice)	-	3
12.	ICOE22	Medical Imaging Systems	-	3
13.	ICOE23	Building Automation	-	3
14.	ICOE24	Biomedical Instrumentation	-	3

(VI) MINOR (MI) (offered for the students of other departments)

Students of other departments who desire B.Tech. Minor in Instrumentation and Control Engineering can opt to study (from 4^{th} to 8^{th} semester) any 5 of the courses listed below.

Sl. No.	Course Code	Course Title	Prerequisites	Credits
1.	ICMI11	Transducer Engineering	-	3
2.	ICMI12	Test and Measuring Instruments	-	3
3.	ICMI13	Measurements in Process Industries	-	3
4.	ICMI14	Essentials of Control Engineering	-	3
5.	ICMI15	Industrial Automation and Control	-	3
6.	ICMI16	Digital Electronics	-	3
7.	ICMI17	Microprocessor and Microcontroller	-	3
8.	ICMI18	Micro Electro Mechanical Systems	-	3
9.	ICMI19	Medical Instrumentation	-	3

GENERAL **INSTITUTE REQUIREMENT (IR)** COURSES

Department Specific IR (other than first-year courses)

Course Code	**:**	ICIR15
Course Title	**:**	**Introduction to Instrumentation and Control Systems Engineering (Branch specific course)**
Type of Course	**:**	IR
Prerequisites	**:**	-
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the students the role and values of Instrumentation Engineering in the society.
CLO2	To emphasize the importance of codes and standards in Instrumentation and Control Engineering relevant to industry
CLO3	To make the student appreciate the relation between the building blocks of instrumentation and control engineering in a device or a plant
CLO4	To make the student sketch the basic building blocks of instrumentation and control engineering for various industrial and scientific applications
CLO5	To make the student relate fundamental physical theories to the working principles behind the blocks of instrumentation and control engineering

Course Content

Place of engineers in society and in an industrial organization. The technical manpower pyramid. Introduction to the program, subjects of study and their relevance, Opportunities for training, placement and for higher studies.

Overview of industry and scope of the discipline - Preliminary project design requirements – Various process conditions. Knowing client requirements and collection of specific data for projects.

Objectives, general concepts, terminologies, types and basic block diagram of instrumentation system.

Introduction to instrumentation and control engineering codes and standards and their relevance to industry.

Case studies: Introduction to instrumentation and control in a typical application like temperature, flow or pressure control.

References

1.	Alan S Moris, Measurement and Instrumentation Principles, Butterworth-Heinemann Limited, 3rd Edition, 2001
2.	Bolton W, Industrial Control and Instrumentation, University Press, 1st Edition, 2005
3.	Chesmond C J, Basic Control System Technology, Viva Books Private Limited, 1998
4.	ISA standards https://www.isa.org/standards-and-publications/isa-standards/find-isa-standards-by-topic
5.	Bureau of Indian Standards

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Know what an engineer does for the benefit of society.
CO2	Describe the role of instrumentation and control engineering in an industrial organization.
CO3	List the standards used in instrumentation and control engineering.
CO4	Apply basic building blocks of instrumentation and control engineering for a typical application.
CO5	Identify applications of instrumentation and control engineering in advanced scientific and industrial systems

Mapping of Course Outcomes and Programme Outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	2	2	2	3	3	3	2	2	2	2
CO2	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
CO3	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
CO4	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
CO5	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1

The articulation matrix is constructed to establish the relationship between COs of the Course and Programme Outcomes (POs) / Programme Specific Outcomes (PSOs). The correlation level from 1 to 3 is defined below:

1- Slight (Low), 2 - Moderate (Medium), 3 - Substantial (High)

Course Code	:	MAIR34
Course Title	:	**Probability and Distribution theory**
Type of Course	:	IR
Prerequisites	:	-
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

To formally introduce the ideas of uncertainty and randomness that prevail in measurements and generation of controlled sequences in engineering applications.

The course objectives are: to

CLO1	Familiarize basic concepts of probability and random variables
CLO2	Identifying and analyzing random variables in practical problems
CLO3	Introduce important probability distributions for analyzing the data
CLO4	Solve real-world problem using probability techniques

Course Content

Introduction to Basic Probability, Review of set theory and combinatorics, binomial probability law, computer simulations of real-world examples – communications and quality control, Conditional Probability, Joint events, statistically independent events, Bayes theorem, applications to cluster recognition

Probability of discrete random variables, Important probability mass functions (PMFs), Approximation of the binomial PMF with Poisson PMF, Transformations, Cumulative distribution functions, expected values of discrete random variables, functions of discrete random variables, variance and moments, characteristic functions, estimating means and variances, applications to data compression

Jointly distributed random variables, expectations, joint moments, prediction of outcomes, joint characteristic functions, Conditional PMFs.

Continuous random variables, expectations, Conditional probability density functions, continuous N- dimensional random variables, applications to signal detection.

Probability and moment approximations, Law of large numbers, central limit theorem, applications to cooperative control and opinion polling.

References

1.	M.C. Douglas, and R.C. George, Applied Statistics and Probability for Engineers,7th Edition,Wiley,2018
2.	S. M. Kay, Intuitive Probability and Random Processes using MATLAB, Springer, 2017
3.	S. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition,Elsevier,2014
4.	Y. Viniotis, Probability and Stochastic Processes for Electrical Engineers, Tata McGraw Hill,1998
5.	M. Evans and J. Rosenthal, Probability and Statistics: The Science of Uncertainty, 2nd Edition, WH Freeman, 2010
6.	P. Olofson, Probabilities: The Little Numbers that Rule our Lives, Wiley, 2007

Course Outcomes (CO)

On successful completion of the course students will be able to

CO1	Identify an appropriate probability distribution for a given discrete or continuous random variable and use its properties to calculate probabilities
CO2	Evaluate probabilities for joint distributions including marginal and conditional probabilities
CO3	Derive the probability density function of random variables and use techniques to generate data from various distributions
CO4	Translate real-world problems into probability models and apply probability and statistical techniques for solving them.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	HSIR13
Course Title	**:**	**Industrial Economics**
Type of Course	**:**	IR
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

The course intends

CLO1	To provide knowledge on demand analysis and forecasting of consumer behaviour
CLO2	To provide knowledge to the students on the basic issues such as productivity, efficiency, capacity utilization and debates involved in industrial development
CLO3	To provide knowledge on inter-regional and international trade
CLO4	To give thorough knowledge about the economics of industry in a cogent and analytical manner.

Course Content

Demand Analysis and Forecasting: Cardinal Ordinal Approaches. Demand and Supply, Elasticities, Forecasting techniques, Consumer behavior.

Production, Cost, and Market structure: Variable proportions, Returns to Scale, Isoquants Analysis, Production Function, Cost Curves, Cost Function, Market Analysis and game theory.

Types, Location, Efficiency and Finance: Mergers and Amalgamations, Location of Industries and Theories, Productivity and Capacity Utilization, Shares, Debentures, Bonds, Deposits, Loan etc. FDI, Foreign Institutional Investment, Euro Issues, GDR, ADR, External Commercial Borrowings.

Introduction: Features of International Trade. Inter-regional and international Trade. Problems of International Trade. Theories

Terms of Trade- Concept, Measurement, Types, Factors affecting Terms of Trade, Exchange rate.

Free Trade, Protection and Tariffs, Balance of Payments: Free Trade, Protection-Quotas, Dumping, etc. Balance of Trade and Balance of Payments.

Regional Economic Groupings and International Institutions: BRICS, EU, SAARC, OPEC, ASEAN. International Institutions: GATT, WTO, UNCTAD, IBRD, IMF.

References

1.	Chauhan, S.P.S. Micro Economics, An Advanced Treaties, PHI, 2011
2.	Jhingan, M.L. International Economics. Vrinda Publications, 2016
3.	Francis Charunilam. International Economics-Graw Hill, 5thEdition, 2017
4.	Paul, Krugman. International Economics. Pearson, 10th Edition, 2017
5.	Kenneth D. George. Industrial Organization, Routledge, 2009

Course Outcomes (CO)

On completion of this course, the students will be able to

CO1	Define micro economics, demand analysis, supply analysis, consumption laws, in difference curve analysis and competitions.
CO2	Get knowledge on macroeconomics; differentiate with micro economics, importance,Keynes theory, functions of central and commercial bank.
CO3	Know the Contributions of Fayol, Taylor' managerial functions, balance sheet, and sources of finance.
CO4	Differentiate marketing and selling, marketing myopia, and product lifecycle.
CO5	Describe recruitment and selection, job evaluation and performance appraisal methods, communication, motivation and leadership.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	1	1	1	2	2	3	3	1	3	1	3	3	1	2	2
CO2	1	1	1	2	2	3	3	2	3	2	3	3	2	1	2
CO3	1	1	1	1	2	3	3	2	3	2	3	3	2	1	3
CO4	1	1	1	1	1	3	3	2	3	2	3	3	1	2	3
CO5	1	1	1	1	1	3	2	3	3	3	3	3	1	1	3

Course Code	:	ICIR14
Course Title	:	**Professional Ethics**
Type of Course	:	IR
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To identify the core values that shape the ethical behavior of an engineer.
CLO2	To relate the code of ethics to social experimentation and to appreciate the rights of others.
CLO3	To understand the difference between moral standards and professional ethics.
CLO4	To evaluate the need for computer ethics.

Course Content

Introduction to Ethics, Moral and Values
Occupation – Profession – Professionalism - Concept of Ethics - need for Ethics in Engineering - impact of unethical conducts on society and professional - Importance of Moral and Value in profession – core values, Hollow values and its impact - Work Ethics – Styles of Ethics -Service Learning, components, reflections, evaluation and its assessment – Civic Virtue - Respect for Others in Engineering Work Place– Living Peacefully – Caring and Sharing in engineering –- General Etiquette for students

Ethical Theories and Engineering
Kohlberg's theory – Gilligan's theory- utilitarianism and Cost Benefit analysis – Duty Ethics and Right Ethics - Its Impact on Engineering Practices – Virtue Ethics and Personal vs. Corporate Morality - moral autonomy –– Consensus and Controversy - Moral issues in Engineering – types of inquiry – moral dilemmas – Ethical Problem-Solving Techniques - Types of Issues in Engineering and Ethical Problem Solving - line-drawing technique, flow charting method with examples and applications - conflict problem solving methods - Models of Professional Roles and Professionalism

Engineering Projects and Expected Traits
Engineering as experimentation – engineers as responsible experimenters – Codes of ethics - Research ethics– Industrial Standard – purpose, types and use - Balanced outlook on law – Collegiality and loyalty–respect for authority in industry–collective bargaining–Confidentiality–conflicts of interest and conflicting interest

Safety, Responsibilities and Rights
Safety and risk–definition-subjective nature and depending factors – types of risks – types of safety in industry- Risk benefit analysis and reducing risk – Govt. Regulator's approach to risks - the challenger case study – the three mile island and Chernobyl case studies and Bhopal UCC accident – causes, ethical and safety issues – Accidents and Engineer's role - Designing for Safety - Threat of Nuclear Power – depletion of ozone, greenery effects – occupational crime – professional rights – employees' rights – whistle- blowing – condition and types of whistle blowing - Confidentiality and Proprietary Information - Intellectual Property Rights (IPR)

Ethics in Present Scenario and Engineers Role
Multinational corporations – Business ethics – Environmental ethics – computer ethics – Role in Technological Development – Ethics for Weapons development – engineers as managers – consulting engineers – engineers as expert witnesses and advisors – Leadership - sample code of conduct ethics like ASME, ASCE, IEEE, Institution of Engineers (India), Indian Institute of Materials Management, Institution of Electronics and Telecommunication Engineers (IETE), India, etc.,

References

1.	Mika Martin and Roland Scinger, Ethics in Engineering, Pearson Education/Prentice Hall, 3rd Edition, 2017
2.	Govindarajan M., Natarajan S., Senthil Kumar V. S., Engineering Ethics, Prentice Hall of India, New Delhi, 2004
3.	Charles D. Fleddermann, Ethics in Engineering, Pearson Education/Prentice Hall, New Jersey, 2004 (Indian Reprint).
4.	Charles E. Harris, Michael S. Protchard and Michael J. Rabins, Engineering Ethics – Concept and Cases, Wadsworth Thompson Learning, United States, 2000 (Indian Reprint now available). Concepts and Cases, Thompson Learning, 2000
5.	John R. Boatright, Ethics and Conduct of Business, Pearson Education, New Delhi, 2003
6.	Edmund G. Seebauer and Robert L. Barry, Fundamentals of Ethics for Scientists and Engineers, Oxford University Press, 2001

Course Outcomes (CO)

On completion of this course, the students will be able to

CO1	Understand the basic perception of profession, professional ethics, and various moral and social issues.
CO2	Demonstrate awareness of their rights and responsibility as engineers.
CO3	Acquire knowledge about various roles of engineers in a variety of global issues.
CO4	Thrive in competitive professional spaces with integrity and responsibility.
CO5	Learn to be empathetic and assertive leaders in their respective profession.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	1	1	1	2	1	3	2	3	3	2	3	3	1	2	3
CO2	1	1	1	1	1	3	2	3	3	2	2	3	1	2	3
CO3	2	1	1	1	1	3	3	3	3	3	3	3	2	3	3
CO4	1	1	2	2	2	3	3	3	3	3	3	3	1	3	3
CO5	1	1	2	2	1	3	2	3	3	3	3	3	1	2	3

Course Code	:	ICIR16
Course Title	:	**Internship / Industrial Training / Academic Attachment (Summer / Winter)**
Type of Course	:	IR
Prerequisites	:	--
Contact Hours	:	28 (2 credits)
Course Assessment Methods	:	Report and Oral examination

Course Learning Objectives (CLO)

CLO1	To provide the student an opportunity to engage in a short-term project at an industry, research organization or in an academic laboratory.
CLO2	To make the student interact with industry personnel/ academic researchers and learn about relevant standards, advanced tools and techniques.
CLO3	To inculcate in the student the values of professionalism, workplace ethics and socially and environmentally conscious behaviour.
CLO4	To develop soft skills such as making reports and presentations, engaging in team discussions

Course Regulation

Each B.Tech. (ICE) student should undergo industrial training / internship / academic attachment for a minimum period of six weeks during the summer vacation between the 6th Semester and the 7th Semester. Registration of this course shall be along with the courses for 7th semester.

A report is to be submitted to the Head of the Department and the evaluation (2 credit) will be based on the report and a viva-voce examination. The examiners for the viva voce examination shall be the Head of the Department and the Program Coordinator or their nominees.

Students opting B.Sc. (Engineering) (ICE) exit should undergo the industrial training / internship / academic attachment during the winter vacation between the 5th Semester and the 6th Semester.

Course Outcomes (CO)

On completion of the internship, the students will be able to

CO1	Interact with industrial personnel/ academic researchers, follow professional workplace behavior and build interpersonal and team skills.
CO2	Learn about industry standards, socially and environmentally relevant practices followed in industries/ research labs.
CO3	Describe the use of advanced tools and techniques encountered in industries and in academic laboratories during the internship
CO4	Prepare professional work reports and make presentations.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	_	_	_	_	_	2	2	3	3	3	_	2	2	2	3
CO2	3	3	3	3	3	3	3	2	2	2	3	3	3	3	2
CO3	3	3	3	3	3	2	2	_	_	_	_	3	2	3	2
CO4	_	_	_	_	_	2	2	3	2	3	2	2	2	2	2

Course Code	:	ICIR17
Course Title	:	**Project Work**
Type of Course	:	IR
Prerequisites	:	--
Contact Hours	:	(6 credits)
Course Assessment Methods	:	Evaluations during the reviews and, report and viva at the end of the semester

Course Learning Objectives (CLO)

CLO1	To provide the student an opportunity to formulate and work on a research problem in a preferred domain of specialization.
CLO2	To make the student aware of existing literature relevant to the research problem, frame the research hypothesis and perform the research design.
CLO3	To expose the student to standard techniques in data acquisition, interpretation and analysis in the preferred domain of specialization.
CLO4	To make the student arrive at logical conclusions and propose suitable recommendations on the research problem documented through logically coherent reports and presentations.

Course Regulation

Project work is mandatory in the 8th Semester for B.Tech. (ICE) students. At the completion of a project, the student will submit a project report which will be evaluated by duly appointed internal examiner(s). The evaluation will be based on the report and a viva-voce examination on the project. The project evaluation shall be carried out by a Project evaluation committee comprising the Head of the Department or his/her nominee (Chairperson), Project coordinator (Professor / Associate Professor) and the project guide(s).

However, the students who wish to carry out / undergo the semester exchange programme / industry attachment (preplacement offer / internship) outside the institute during the 8th semester can opt for completing two additional elective courses (PE/OE) to earn the equivalent (6) credits, preferably during the previous semesters, in place of the Project Work in the 8th Semester (if, they cannot do a project work in this tenure).

Anyhow, Project work is compulsory for B.Tech. Honours degree.

Course Outcomes (CO)

On completion of the Project Work in a chosen specialization domain, the student will be able to

CO1	Formulate and state a research problem clearly.
CO2	Compile relevant literature, frame research hypotheses and perform the research design.
CO3	Describe standard techniques in the specialization domain to acquire and compile relevant data, interpret & analyze it and test the research hypotheses.
CO4	Arrive at logical conclusions and propose suitable recommendations on the research problem.
CO5	Draft a logically coherent project report and elaborate the research work in front of a panel of examiners.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	_	2	2	_	_	2	2	2	2	3	_	1
CO2	3	2	3	2	2	2	3	2	2	-	3	2	3	3	2
CO3	3	3	3	3	3	_	2	3	2	2	3	2	3	3	2
CO4	2	2	_	3	3	2	3	3	3	3	3	2	3	3	3
CO5	_	_	_	_	2	2	3	2	3	3	2	2	2	3	3

Course Code	:	ICIR18
Course Title	:	**Comprehensive Viva-Voce**
Type of Course	:	IR
Prerequisites	:	--
Contact Hours	:	(1 credit)
Course Assessment Methods	:	Examinations with objective type questions during and at the end of the semester

Course Learning Objectives (CLO)

CLO1	To make the student recall fundamental concepts in Instrumentation and Control Engineering.
CLO2	To enable a holistic integration of learnings from different courses in the programme relevant to problem solving in Instrumentation and Control Engineering.
CLO3	To make the student apply numerical aptitude and logical reasoning skills to confidently face written examinations as part of job placements and higher degree admissions.
CLO4	To render the student capable of handling technical interviews as part of job placements and higher degree admissions.

Course Regulation

The comprehensive viva voce examination is conducted in the final year of study, i.e. in the 7th Semester for B.Tech students and in 6th Semester for students opting B.Sc.(Engineering) exit.
It shall consist of two objective tests of 25 marks each. The final examination shall have 50 marks. The examination will be of objective type similar to the GATE examination in the stream of Instrumentation (IN).

A department committee comprising the Head of the Department or his/her nominee and two faculty members of the department shall conduct the examinations.

Course Outcomes (CO)

On completion of the course, the student will be able to

CO1	Recall and apply fundamental concepts in science and engineering to model practical scenarios.
CO2	Integrate learnings from different courses in Instrumentation and Control Engineering and apply them for technical problem solving.
CO3	Develop and Apply skills related to communication and problem solving while attending technical interviews
CO4	Develop and Apply Numerical aptitude and logical reasoning skills to handle placement tests and other competitive examinations for higher degree admissions

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	_	_	_	_	_	_	3	3	3	1
CO2	3	3	3	3	2	3	2	_	_	2	2	3	3	3	2
CO3	_	_	_	2	2	2	2	2	3	3	3	2	_	2	3
CO4	2	_	2	3	3	2	_	2	2	3	3	2	2	2	3

Course Code	**:**	ICIR19
Course Title	**:**	**Industrial Lecture**
Type of Course	**:**	IR
Prerequisites	**:**	--
Contact Hours	**:**	(1 credit)
Course Assessment Methods	**:**	Quizzes at the end of each of the industrial lectures

Course Learning Objectives (CLO)

CLO1	To make the student relate theoretical knowledge and concepts in Instrumentation and Control Engineering to practical relevance and applications in the industry.
CLO2	To enable the student, learn about contemporary problems faced by the industry and systematic approaches in solving them.
CLO3	To provide a platform for the student to interact with experts from industries and research and development organizations.
CLO4	To make the student aware of different application areas in the industry and explore about different career paths relevant to Instrumentation and Control Engineering.

Course Regulation

A course based on industrial lectures shall be offered for 1 credit during the prefinal year of study in B.Tech.. A minimum of five lectures of two hours' duration by industry experts will be arranged by the Department.

The evaluation methodology, will in general, be based on quizzes at the end of each lecture. Due weightage shall be given to attendance also. The HoD or her/his nominee may devise a suitable methodology for evaluation and the same would be informed to the students before the commencement of the semester.

Course Outcomes (CO)

On completion of the Industrial lectures, the student will be able to

CO1	Connect theoretical concepts in Instrumentation and Control Engineering to practical relevance and applications in the industry.
CO2	Get exposure on various challenges faced by the modern industry and the systematic approaches to tackle them.
CO3	Enhance comprehension and communication skills during interactions with experts from the industry.
CO4	List various career paths and roles in the industry relevant to Instrumentation and Control Engineering.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	_-	-	-	-	-	-	3	3	3	1
CO2	3	3	3	3	2	3	2	3	2	2	2	3	3	3	2
CO3	_	_	_	_	_	2	2	3	3	3	_	2	_	2	3
CO4	2	_	2	3	3	2	_	2	2	3	3	2	2	2	3

PROGRAMME CORE (PC) COURSES

Course Code	:	ICPC11
Course Title	:	**Circuit Theory**
Type of Course	:	PC
Prerequisites	:	--
Contact Hours	:	57 (4 credits)
Course Assessment Methods	:	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To teach the electrical circuit laws and theorems to aid in circuit analysis
CLO2	To impart problem solving technique of linear passive electrical circuits.
CLO3	To expose the students to the transient behaviour of different R-L-C circuits.
CLO4	To teach the methods of AC circuit analysis and synthesis of 2-port networks.

Course Content

Review of Networks and Circuits, Elemental laws (V-I characteristics) for Resistors, Inductors, and Capacitors, Circuital laws (Kirchhoff's laws), Sign convention, Basic signals (dc and ac), Elementary signals (impulse, step, ramp, exponential), Synthesis of arbitrary waveforms (rectangular, triangular etc.) from elementary signals, Voltage and Current sources (Independent and Dependent), Ladder and Bridge Circuits.

Analysis of Resistive Circuits energized by dc voltages and currents – Source Transformations, Nodal and Mesh Analysis, Principle of Superposition, Network Theorems (Thevenin's and Norton's, Maximum Power Transfer), Circuits with dependent dc Sources.

Transients with Energy Storage Elements, First and Second Order Circuits – Time-constant, Damping Ratio, Natural Frequency, Emphasis on Linear Ordinary Differential Equations, Step response of RC, RL, and RLC (series and parallel) Circuits, Resonance in Second Order Circuits.

Sinusoidal Sources and Response – Behavior of elements with ac signals, Impedance and Admittance, Generalization of Network Theorems and Circuit Analysis, Introduction to 3-φ power systems. Transient and Steady-state Response of Circuits – Laplace Transformation and its application to circuit analysis, State Variables, Network Functions (Driving point impedance and admittance), Transfer function, Two- port Networks, Applications of Two-port networks, Introduction to General Linear Systems.

Network Synthesis: Properties of RC, RL, and LC driving point functions, Synthesis of networks from given transfer functions.

References

1.	Hayt, W.H, Kemmerly J.E. and Durbin, Engineering Circuit Analysis, McGraw Hill Publications, 8thEdition, 2013
2.	Franklin F. Kuo, Network Analysis and Synthesis, Wiley International, 5th Edition, 2012
3.	Van Valkenburg, Network Analysis, Prentice Hall, Revised 3rd Edition, 2019.
4.	Charles K. Alexander, Mathew N.O Sadiku, Fundamentals of Electric Circuits TMH EducationPvt. Ltd, 5th Edition, 2013
5.	Ramakalyan, A., Linear Circuits: Analysis and Synthesis, Oxford Univ. Press, 2005
6.	DeCarlo, R.A. and Lin, P.M., Linear Circuit Analysis: Time Domain, Phasor and Laplace Transform Approaches, Oxford University Press. 3rd Editions, 2009
7.	SC Dutta Roy, Circuit Theory, NPTEL video lectures

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyze and solve the DC and AC circuits using mesh and node analysis, network theorems and mathematical tools
CO2	Apply the knowledge of the time domain and frequency domain characteristics of electrical circuitsfor design
CO3	Apply Laplace Transform for circuit analysis
CO4	Design and synthesize two port networks

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	1	2	1	2	1	2	2	1	3	1	2	1
CO2	3	3	3	1	2	1	2	1	2	2	1	3	1	2	1
CO3	3	3	3	1	2	1	2	1	2	2	1	3	1	2	1
CO4	3	3	3	1	2	1	2	1	2	2	1	3	1	2	1

Course Code	**:**	ICPC12
Course Title	**:**	**Electronic Circuits**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC11
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

To make the students understand the fundamentals of Electronic Circuits. The student should be made to

CLO1	Understand the applications of diode and biasing techniques for BJTs and MOSFETs
CLO2	Design different types of amplifiers using active loads.
CLO3	Analyze the high-frequency response of various amplifier circuits.
CLO4	Understand the concepts of feedback amplifiers and oscillators

Course Content

DIODE, TRANSISTORS AND THYRISTORS
PN junction diode –structure, operation and V-I characteristics, diffusion and transition capacitance, Rectifier circuits, Filter circuits, Limiting and clamping circuits, Display devices-LED, Laser diodes, Zener diode characteristics- Zener Reverse characteristics – Zener as regulator
BJT, JFET, MOSFET- structure, operation, characteristics and Biasing UJT, Thyristors and IGBT -Structure and characteristics.
AMPLIFIERS
BJT small signal model – Analysis of CE, CB, CC amplifiers- Gain and frequency response – MOSFET small signal model– Analysis of CS and Source follower – Gain and frequency response-High frequency analysis.
MULTISTAGE AMPLIFIERS AND DIFFERENTIAL AMPLIFIER
BIMOS cascade amplifier, Differential amplifier – Common mode and Difference mode analysis – FET input stages – Single tuned amplifiers – Gain and frequency response – Neutralization methods.
Power amplifiers – Classification, Transformer coupled class A power amplifier, push pull class B and class AB power amplifiers, efficiency and distortion, Transformer-less class B and Class AB power amplifiers, Class C power amplifier
FEEDBACK AMPLIFIERS AND OSCILLATORS
Advantages of negative feedback – voltage / current, series, Shunt feedback –positive feedback – Condition for oscillations, phase shift – Wien bridge, Hartley, Colpitts and Crystal oscillators.
ELECTRONIC CIRCUITS and APPLICATIONS
Run virtual experiments on electronic circuits using EDA tools like Circuit Maker, Tina, Multisim, or Electronic Workbench. Design of Diode clippers and clampers circuits for signal shaping, Zener diode voltage regulators for stable power supplies, Transistor relay drivers for low-power control of high-power circuits, Tuned transistor amplifiers for frequency-specific amplification, Unijunction transistor timing circuits and oscillators.

References

1.	Donald. A. Neamen, Electronic Circuits Analysis and Design, 3rd Edition, Mc Graw Hill Education (India) Private Ltd., 2010
2.	Robert L. Boylestad and Louis Nasheresky, Electronic Devices and Circuit Theory, 11th Edition, Pearson Education, 2013
3.	Sedra and Smith, Micro Electronic Circuits, Sixth Edition, Oxford University Press, 2011
4.	Jacob Millman and Arvin Grabel, Microelectronics, McGraw Hill, 2nd Edition, 2009
5.	R. Spencer and Mohammed S. Ghausi, Introduction to Electronic Circuit Design, Pearson, 2003
6.	Millman J, Halkias C. and Sathyabrada Jit, Electronic Devices and Circuits, 4th Edition, Mc Graw Hill Education (India) Private Ltd., 2015
7.	David A. Bell, Electronic Devices and Circuits, 5th Edition, Oxford University Press, 2008
8.	Balbir Kumar, Shail. B. Jain, Electronic devices and circuits PHI learning private limited, 2nd edition 2014
9.	Thomas L. Floyd, Electronic devices- Conventional current version, Pearson prentice hall, 10th Edition, 2017

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Apply knowledge of diodes, transistors (BJTs and FETs), and their biasing circuits to understand amplifier operation
CO2	Analyze the performance of small signal BJT and FET amplifiers - single stage and multi stage amplifiers
CO3	Design and analyze the characteristics of MOSFET and BJT amplifiers
CO4	Design the feedback amplifiers and oscillators

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPC13
Course Title	:	**Signals and Systems**
Type of Course	:	PC
Prerequisites	:	--
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the student to identify and represent the type of signals and systems.
CLO2	To introduce the mathematical tools available to analyze continuous time signals and systems.
CLO3	To introduce the mathematical tools available to analyze discrete time signals and systems.
CLO4	To introduce about the random phenomena in the real world, the mathematical models and pseudo-random signals in identifying systems.

Course Content

Introduction to signals – Transformation of the independent variable – Basic continuous-time signals – Basic discrete-time signals – Step and Impulse functions – Sampling theorem. Introduction to systems – Properties of systems – Classification of systems – Mathematical model of systems – Concept of state variable – Normal form of system equations – Initial conditions.

Impulse response of physical systems – Stability analysis of dynamic systems – Introduction to convolution – Convolution integral – System impulse response and step response using Laplace transform – Numerical convolution. Z-transform – Convergence of Z-transform – Properties of Z-transform – Inversion of Z- transform –Application of Z-transform in analysis of discrete-time systems – Evaluation of discrete-time system frequency response – Inverse systems – Deconvolution.

Representation of signals in terms of elementary signals – Condition of orthogonality – Representation of signals by elementary sinusoids – Fourier series representation of periodic signals – Power spectrum. Fourier transform – System frequency response – Realizability of frequency response – Energy spectrum. Calculation of simple transforms. Discrete-Fourier transform (DFT) – Properties of Discrete Fourier Transform – Circular convolution.

Classification of random signals – Auto-correlation function – Properties of auto-correlation function – Measurement of auto-correlation function – Application of auto-correlation functions. Cross correlation functions. Sum of random processes- Spectral density – Relation of spectral density to auto-correlation function

Auto-correlation function of system output - Cross-correlation between system input and output. White noise - Analysis of linear systems in time-domain using white noise - Mean and mean square value of system output. Generation of pseudo random binary noise (PRBN) and its use in system identification - Analysis in frequency domain.

References

1.	Gabel R.A. and Robert R.A., Signals and Linear Systems, John Wiley and Sons, 3rd Edition, 1987
2.	Oppenheim A.V., Wilsky and Nawab, Signals and Systems, Pearson India Education ServicesPrivate limited India, 2nd Edition, 2016
3.	Chen C.T., Systems and Signal Analysis - A Fresh Look, Oxford University Press India, 3rd Edition,2004
4.	B.P. Lathi, Principles of Linear Systems and Signals, Oxford University Press, 2nd Edition, 2009
5.	Cooper G.R and Mc Gillem C.D, Probabilistic Methods of Signals and System Analysis, OxfordUniversity Press, 3rd Edition, 1999
6.	Chesmond, Wilson and Lepla, Advanced Control System Technology, Viva Books, 1st Edition,1998
7.	Ziemer R.E., Tranter W.H., and Fannin D.R., Signals and Systems: Continuous and Discrete,Prentice Hall, 4th Edition, 1998
8.	Oppenheim, Alan V and Verghes, G.G., Signals, Systems and Inference – Class Notes for 6.011: Introduction to Communication, Control and Signal Processing, MIT Open Courseware

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Classify the signals and systems based on their properties and determine the response of LTI system using convolution
CO2	Analyze the spectral characteristics of continuous and discrete time signals and systems using Fourier transforms.
CO3	Apply Laplace and Z transform to analyze continuous and discrete time systems
CO4	Understand the process of sampling, classify random signals using statistical concepts and characterize systems using pseudo-random signals.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	3	2	-	-	-	-	-	2	3	3	-
CO2	3	3	2	2	3	2	-	-	-	-	-	3	3	3	-
CO3	3	3	3	3	3	1	1	-	-	-	-	3	3	3	-
CO4	3	1	2	1	1	2	-	-	-	-	-	2	2	2	-

Course Code	**:**	ICPC14
Course Title	**:**	**Sensors and Transducers**
Type of Course	**:**	PC
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to various sensors and transducers for measuring mechanical quantities.
CLO2	To make the students familiar with the specifications of sensors and transducers.
CLO3	To teach the basic conditioning circuits for various sensors and transducers.
CLO4	To introduce about advancements in sensor technology.

Course Content

General concepts and terminology of measurement systems, transducer classification, general input-output configuration, static and dynamic characteristics of a measurement system, Statistical analysis of measurement data.

Resistive transducers: Potentiometers, metal and semiconductor strain gauges and signal conditioning circuits, strain gauge applications: Load and torque measurement.

Self and mutual inductive transducers- capacitive transducers, eddy current transducers, proximity sensors. -

Piezoelectric transducers and their signal conditioning, Ultrasonic sensors, Seismic transducer and its dynamic response, seismic accelerometers, Force-Balance transducers: Theory-servo systems for measurement of non-electrical quantities.

Photoelectric transducers, Digital displacement sensors: Position Encoders, Variable frequency sensors, Tacho-generators and stroboscope, Hall Effect sensors, Magnetostrictive transducers.

Introduction to semiconductor sensor, materials, scaling issues and basics of micro fabrication. Smart sensors. Introduction to flexible sensors and sensor fusion.

References

1.	John P. Bentley, Principles of Measurement Systems, Pearson Education, 4th Edition, 2005.
2.	Doebelin E.0, Measurement Systems - Application and Design, McGraw-Hill, 4th Edition, 2004.
3.	S.M. Sze, Semiconductor sensors, John Wiley and Sons Inc., 3rd edition, 2006.
4.	James W. Dally, Instrumentation for Engineering Measurements, Wiley, 2nd Edition,1993
5.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2nd edition, 2008
6.	Patranabis, Sensors and Transducers, Prentice Hall, 2nd edition, 2003.
7.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd, 2011.
8.	Murthy D. V. S, Transducers and Instrumentation, Prentice Hall, 2nd Edition, 2011
9.	Neubert H.K.P, Instrument Transducers - An Introduction to their Performance and Design,Oxford University Press, 2nd Edition, 1999.
10.	Waldemar Nawrocki, Measurement Systems and Sensors, Artech House, 2005
11.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition 1995.

12.	Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal Processingfor Smart Sensors, John Wiley and Sons, Chichester, UK, 2002.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the basics of measurement system- its input, output configuration and its static and dynamic characteristics.
CO2	Explain the principle and working of various sensors and transducers.
CO3	Design signal conditioning circuit for various transducers.
CO4	Identify or choose a transducer for a specific measurement application.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	2	3	-	1	-	2	-	-	-	2	-	-
CO2	2	3	3	-	-	-	-	-	2	-	-	2	2	3	-
CO3	2	3	3	-	-	-	-	-	2	-	-	2	2	3	-
CO4	-	2	3	-	-	-	-	-	2	-	-	2	2	3	-

Course Code	**:**	ICPC15
Course Title	**:**	**Digital Electronics**
Type of Course	**:**	PC
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

The subject aims to provide the student with

CLO1	An understanding of number systems, codes and their conversions.
CLO2	The capability to reduce Boolean expression using K-map and tabular methods.
CLO3	The ability to design and analyze combinational and sequential logic circuits for a given problem statement.
CLO4	An understanding of digital hardware, different types of logic families and their characteristics

Course Content

Review of number systems and logic gates, Algebraic reductions, Binary codes -Weighted and non- weighted, number complements, Binary arithmetic, Error detecting and error correcting codes, SOP, POS Canonical logic forms, Karnaugh maps and Quine-McClusky methods, Don't care conditions, minimization of multiple output functions.

Synthesis of combinational functions: Arithmetic Circuits-Adder/ Subtractor, carry look-ahead adder, signed number addition and subtraction, BCD adders. IC adders. Multiplexers, implementation of combinational functions using multiplexers, de-multiplexers, decoders, code converters, Digital ICs for combinational logic circuits.

Sequential Logic: Basic latch circuit, Debouncing of a switch, Flip-Flops: truth table and excitation table, conversion of Flip-flops, integrated circuit flip-flops. Race in sequential circuits, Shift Registers, Counters - Synchronous, Asynchronous, Up-Down, Design of counters.

Analysis of clocked sequential circuits, Design with state equations, Moore and Mealy graphs, State reduction and assignment, Sequence detection, Hazards. Complexity and propagation delay analysis of circuits. Programmable logic devices, Design using Programmable Logic Devices (PLA, PAL, CPLD and FPGA).

Digital Hardware: Logic levels, Realization of logic gates, different logic families (TTL, ECL, CMOS, HC, HCT, ACT and HSCMOS), Logic levels, voltages and currents, fan-in, fan-out, speed, power dissipation. Comparison of logic families, interfacing between different families.

References

1.	M. Morris Mano, Charles Kime, Tom Martin, Logic and Computer Design Fundamentals, Pearson,5th Edition, 2016
2.	J.P. Uyemura, A First Course in Digital Systems Design: An Integrated Approach, NelsonEngineering, 1999
3.	W. H. Gothmann, Digital Electronics - An Introduction to Theory and Practice, Prentice Hall ofIndia, 2nd Edition, 2000
4.	J.M. Rabaey, Digital Integrated Circuits: A Design Perspective, Prentice Hall of India, 2nd Edition, 2003
5.	N.H.E. Weste, and K. Eshraghian, Principles of CMOS VLSI Design: A Systems Perspective,Pearson Education Inc., (Asia), 3rd Edition, 2005

6.	S. Brown and Z Vranesic, Fundamentals of Logic Design with VHDL Design, Tata McGraw- Hill, 2002
7.	V. P. Nelson, H.T. Nagle, E.D. Caroll and J.D. Irwin, Digital Logic Circuit Analysis andDesign, Prentice Hall International, 1995
8.	Anil K Maini, Digital Electronics: Principles and Integrated Circuits , Wiley, 2019
9.	Thomas L. Floyd, Digital Fundamentals, 11th Edition, Pearson, 2015
10.	Ronald J. Tocci, Widmer Neal, Moss Greg, Digital Systems principles and Applications,12th Edition, Prentice Hall, 2010

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand various number systems, conversions and simplify the logical expressions using Boolean functions.
CO2	Design and develop arithmetic and other special functions using combinational logic circuits andPLDs.
CO3	Design and develop synchronous and asynchronous for the given problem statement.
CO4	Understand how logic gates are built from the fundamental semiconductor electronics and be able to select logic ICs from different families based on requirement.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	3	2	3	2	2	-	-	-	-	-	-	3	3	-
CO2	2	3	2	2	2	3	-	-	-	-	-	-	3	3	-
CO3	3	3	3	3	2	2	-	-	-	-	-	-	3	3	-
CO4	2	3	2	3	3	2	-	-	-	-	-	-	3	3	-

Course Code	**:**	ICPC16
Course Title	**:**	**Microprocessors and Microcontrollers**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC15
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the architecture of 8, 16 and 32-bit microprocessor and microcontroller.
CLO2	To impart microcontroller programming skills in students.
CLO3	To familiarize the students with data transfer and interrupt services.
CLO4	To Familiarize the students with communication protocols for peripheral interfacing.

Course Content

Introduction to computer architecture and organization, Architecture of 8-bit, 16-bit, 32-bit and 64-bit microprocessors, CISC/RISC design philosophy, bus configurations, CPU module. Embedded system overview.

Introduction to embedded C and assembly language, instruction set of a typical 8-bit and 16-bit microprocessor, subroutines and stacks, energy efficient ultra-low power modes, programming exercises.

Timing diagrams, Memory families, Flash Vs FRAM, on-chip peripherals- working with IO ports, ADC, comparators, timers, PWM, Watchdog, Low power modes.

Architectures of 8 and 16-bit Microcontrollers, comparison, programming exercises, applications of energy efficient systems.

Serial and parallel data transfer schemes, interrupts and interrupt service procedure. Internal peripherals of microcontrollers – SPI, I2C UART, USB and DNA. Interfacing with RTC, EEPROM and DAC.

References

1.	Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications with the 8085 6th Edition, Penram International Publishing (India) pvt. Ltd. 2013
2.	Douglas V. Hall, Microprocessors and Interfacing-Programming and Hardware, McGraw Hill Education,3rd Edition, 1 July 2017
3.	Kenneth J. Ayala, The 8051 Micro controller, Thomson Delmar Learning, 3rd Edition, 2004
4.	John H Davies, MSP430 Microcontroller Basics, Newnes, 1st Edition, 2010
5.	Jonathan W Valvano, Embedded Microcomputer Systems: Real Time Interfacing, CENGAGE LearningCustom Publishing, 3rd Edition, 2010

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the various functional blocks of microprocessor and microcontrollers.
CO2	Understand and write the assembly and C language programs.
CO3	Interface the peripherals with microprocessors and microcontrollers.
CO4	Design and develop microcontroller-based applications.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	1	1	1	1	-	1	2	3	3	1
CO2	3	3	3	3	3	1	2	1	2	-	2	2	3	3	1
CO3	3	3	3	3	2	2	2	2	1	2	1	2	3	3	1
CO4	3	3	3	3	3	2	2	1	2	2	2	2	3	3	2

Course Code	**:**	ICPC17
Course Title	**:**	**Industrial Instrumentation**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of process variable measurements.
CLO2	To expose the students to various measurement techniques used for the measurement oftemperature, flow, pressure and level in process industries.
CLO3	Make the students how to select and maintain the performance of new technology flow instruments.
CLO4	To make the students knowledgeable in the design, installation and troubleshooting of processinstruments.

Course Content

Temperature measurement: Introduction to temperature measurements, Thermocouple, Resistance Temperature Detector, Thermistor and its measuring circuits, Radiation pyrometers and thermal imaging.

Pressure measurement: Introduction, definition and units, Mechanical, Electro-mechanical and electronic pressure measuring instruments. Low pressure measurement, Transmitter definition types, I/P and P/I Converters.

Level measurement: Introduction, Differential pressure level detectors, Capacitance level sensor, Ultrasonic level detectors and Radar level transmitters and gauges.

Flow measurement: Introduction, definition and units, classification of flow meters, differential pressure and variable area flow meters, Positive displacement flow meters, Electro Magnetic flow meters.

Flow measurement: Hot wire anemometer, laser Doppler anemometer, ultrasonic, vortex and cross correlation flow meters, and measurement of mass flow rate.

References

1.	Ernest O. Doebelin and Dhanesh N. Manik, Measurement Systems, McGraw Hill Education, 6th Edition, 2011
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4th Edition, 2003
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3rd Edition, 2010
4.	B.E. Noltingk, Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition, 1995
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill,Singapore, 5th Edition, 1999
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I and Vol II, GulfPublishing Company, Houston, 2001
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3rd Edition, 2005
8.	Tony R. Kuphaldt, Lessons in Industrial Instrumentation, Version 2.02, Samurai Media Limited, April 2014
9.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd, 2011

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Explain the basic principles of instruments used for measuring temperature, pressure, flow and level in process industries.
CO2	Identify a suitable measuring instrument for an application.
CO3	Design signal condition and compensation circuits for temperature and pressure measuring instruments.
CO4	Trouble shoot and maintain temperature, flow, pressure and level measuring devices for a specific process.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	3	2	2	1	2	2	1	2	3	3	1
CO2	3	2	3	2	2	3	2	2	2	3	2	3	3	3	2
CO3	3	3	3	3	2	2	2	2	2	2	2	2	3	3	2
CO4	3	3	3	2	2	3	2	2	2	3	2	3	3	3	2

Course Code	**:**	ICPC18
Course Title	**:**	**Control Systems - I**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC13
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the concept of feedback control system.
CLO2	To impart knowledge in mathematical modeling of physical systems.
CLO3	To impart knowledge in characteristics and performance of feedback control system.
CLO4	To teach a variety of classical methods and techniques for analysis and design of control systems.

Course Content

Review of Systems, Mathematical Models – Differential Equations, Linear Approximations and Transfer Functions, Block Diagrams and Signal Flow Graphs

Feedback Control System Characteristics, and Performance Specifications on transients and steady-state, Stability of Linear Feedback Systems – Routh-Hurwitz criterion.

The Root Locus Method, Feedback Control System Analysis and Performance Specifications in Time- Domain, Design of Lead, Lag, and PID Controller using Root Locus.

Frequency Response Methods, Nyquist's Stability Criterion, Bode Plots, Performance Specifications in Frequency-Domain, Stability Margins.

Design of Lead, Lag and PID controller in Frequency Domain.

References

1.	Dorf, R.C., Bishop, R.H., Modern Control Systems, Prentice Hall, 13th Edition, 2016
2.	Katsuhiko Ogata, Modern Control Engineering, PHI Learning Private Ltd, 5th Edition, 2017
3.	Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control of Dynamic Systems, Prentice Hall, 8th Edition, 2018
4.	M. Gopal, Control Systems: Principles and Design, Mc Graw Hill Publication,4th Edition, 2012
5.	Nise, N.S., Control Systems Engineering, Wiley, 7th Edition, 2018
6.	Golnaraghi, B.C. Kuo, Automatic Control Systems, 10th Edition, McGraw-Hill Education, 2018
7.	Nagrath, M. Gopal, Control Systems Engineering, 6th Edition, New Age International Publishers, 2017
8.	Anish Deb, Srimanti Roy Choudhury., Control System Analysis and Identification with MATLAB, Block Pulse and Related Orthogonal Functions., CRC Press 1st Edition, 2018
9.	Graham C. Goodwin, Stefan F. Graebe, Mario E. Salgado., "Control System Design", 13th Edition, Prentice Hall Publication. 2000
10.	N Sivanandam and S N Deepa., Control Systems Engineering Using MATLAB, Vikas Publishing, 2nd Edition, 2018

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Generate mathematical models of dynamic control system by applying differential equations.
CO2	Analyze and characterize the behavior of a control system in terms of different system, performanceparameters and assess system stability.
CO3	Evaluate and analyze system performance using frequency and transient response analysis.
CO4	Design and simulate control systems (linear feedback control systems, PID controller, and multivariable control systems), using control software, to achieve required stability, performance and robustness.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	3	3	-	-	-	-	-	-	2	3	3	-
CO2	3	3	3	3	3	-	-	-	1	1	-	2	3	3	-
CO3	2	2	2	3	3	-	-	-	1	1	-	-	2	3	-
CO4	3	2	3	3	3	-	2	1	1	1	-	2	3	3	-

Course Code	**:**	ICPC19 – A
Course Title	**:**	**Product Design and Development - 1 (Theory)**
Type of Course	**:**	PC
Prerequisites	**:**	--
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To inculcate into the student the spirit of innovation and entrepreneurship.
CLO2	To make the students develop a marketable product on their own as a group by understanding the needs of the society and solving them using technical know-how.
CLO3	To make students learn the general concepts needed for new product development and simultaneously learning how to interact with the society and learn its needs.
CLO4	To expose students to the Entrepreneurship ecosystem in India and Intellectual Property rights

Course Content

The course consists of

I. Conceptual topics covered by lectures (by the faculty instructor)

II. Practical work outside the campus (under the guidance of assigned Mentor)

<u>CONCEPTUAL TOPICS COVERED BY LECTURES (Semester-IV)</u>

Introduction to product design – Product planning – Identifying customer needs – Project selection – Concept generation – Concept testing – Concept selection. Product specification – Product architecture – Industrial design – Robust design.

Product development economics –Design for manufacturing – Supply chain design – Intellectual property – Design for environment.

Understanding the Entrepreneurship ecosystem in India – Policies, Regulations, Opportunities for Entrepreneurial ventures

Intellectual property rights

<u>PRACTICAL WORK (Semester-IV)</u>

Interaction with public outside the campus- identifying customer needs- product selection based on customer needs- concept generation- concept testing.

Identifying fabrication requirements- Identifying fabricators for the project- costing- financial model for the product development- finding outside finance for product development if possible - patent search for the product.

During the Semester-IV, a faculty member from the department would be assigned as a Mentor (preferably an expert from industry can be co-opted as an External Mentor) for the student group to carry out the Product Design and Development activities.

<u>SUMMER VACATION WORK (between Semester-IV and Semester-V)</u>

Students shall actively get information about fabrication of their product prototype, especially if it involves fabrication units outside the campus. If they have decided on the final design, they may start work on their alpha prototypes.

Course Evaluation

- The theoretical component will be evaluated during Semester-IV.
- The practical component will be evaluated at the end of Semester-V. The students are expected to pursue practical work related to fabrication of prototypes during the summer vacation.

References

1.	Karl T. Ulrich and Steven D. Eppinger, Product Design and Development, 3rd Edition, Tata McGraw Hill. 2020
2.	Robert D. Hisrich, Michael P Peters, and Dean A Shepherd, Entrepreneurship Sixth edition, Mc Graw Hill, 2002
3.	Michael Grieves, Product Life Cycle Management, Tata McGraw Hill, 2006
4.	G. B. Reddy, Intellectual Property Rights and the Law, Gogia Law Agency, 7th Edition, 2009
5.	Baker, M. and Hart S. Product Strategy and Management. (2nd. Ed.) Edinburgh: Pearson Education, 2007

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Carry out market surveys for new product development.
CO2	Understand and plan the entire cycle of new product design and development.
CO3	Understand the economics of product design and development .
CO4	Elaborate on various opportunities and funding sources for entrepreneurial ventures

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	2	3	3	3	3	3	3	3	3	3	2
CO2	3	2	2	3	3	3	3	2	3	3	3	3	3	3	2
CO3	1	2	2	2	3	3	3	2	3	3	3	3	3	3	2
CO4	1	2	2	2	3	3	3	2	3	3	3	3	3	3	2

Course Code	:	ICPC19 – B
Course Title	:	**Product Design and Development – 2 (Practice)**
Type of Course	:	PC
Prerequisites	:	ICPC19 – A
Contact Hours	:	28 (2 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To inculcate into the student the spirit of innovation and entrepreneurship.
CLO2	To make the students develop a marketable product on their own as a group by understanding the needs of the society and solving them using technical know-how.
CLO3	To make the students fabricate an alpha prototype and test it for its conformity to the design specifications.
CLO4	To make the students fabricate a beta prototype, conforming to the design specifications, that is acceptable in the market-place.

Course Content

The course consists of

(i) Design, Development and Testing of Alpha prototypes and Beta prototypes of the Product (under the guidance of assigned Mentor)

(ii) Submission of Report for Design, Development and Testing of the prototypes

The student group would work with the Mentor assigned during Semester-IV to carry out the Product Design and Development activities, in accordance with the product specifications described in Semester-IV.

1. Alpha prototype fabrication and testing
2. Beta prototype fabrication and customer acceptance survey

The student groups shall be evaluated based on submitted reports on design, fabrication and testing of Alpha prototypes and Beta prototypes.

Course Evaluation:

- Demonstration of Alpha and Beta prototypes, and their conformance to the product specifications
- Reports pertaining to fabrication and testing of prototypes

References

1.	Karl T. Ulrich and Steven D. Eppinger, Product Design and Development, 3rd Edition, Tata McGraw Hill. 2020
2.	Clive L. Dym, Patrick Little, Engineering Design: A Project-based Introduction, 3rd Edition, John Wiley and Sons, 2009
3.	Effective Product Design and Development, Stephen Rosenthal, Business One Orwin, Homewood, 1992
4.	Michael Grieves, Product Life Cycle Management, Tata McGraw Hill, 2006
5.	Baker, M. and Hart S. Product Strategy and Management. (2nd. Ed.) Edinburgh: Pearson Education. 2007

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Carry out market surveys for new product development.
CO2	Understand and plan the entire cycle of new product design and development.
CO3	Fabricate and test prototypes of new products.
CO4	Choose an appropriate agronomy for the product and adopt methods to minimize the cost

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	3	2	3	3	3	3	3	3	3	3	3	2
CO2	3	2	3	3	2	3	3	2	3	3	3	3	2	3	2
CO3	3	3	3	3	2	3	3	3	3	3	3	3	2	3	3
CO4	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3

Course Code	:	ICPC20
Course Title	:	**Analog Signal Processing**
Type of Course	:	PC
Prerequisites	:	ICPC12
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To teach the properties of analog signals and systems and random signal analysis
CLO2	To familiarize the students to DC and AC characteristics of operational amplifiers and its influence on outputand their compensation techniques
CLO3	To impart the students to design signal conditioning circuits using Op-Amp
CLO4	To introduce the concepts of switched capacitor filters, Voltage regulator and PLL and its applications

Course Content

Introduction to analog signals and systems, Random signal analysis, application of statistical methods to the measurement of waveforms.

Analog signal processing circuits: amplifiers, analog multipliers, integrators, differentiators, active and passive filters. Universal Filters and their application

Current-to-voltage and voltage-to-current converter, analog-to-digital converter, digital-to-analog converter, voltage- to-frequency converter, frequency-to-voltage converter.

Switched capacitor filter, Phase locked loop, Schmitt trigger, automatic gain control, regulators, wave form generators, oscillators.

Case studies: bridge linearization, PLL design using divider and multipliers, regulator design with low voltage dropout, transmitter design and realization of controllers.

References

1.	Sergio Franco, Design with operational amplifiers and analog integrated circuits, 4th edition Mc-Graw HillInc. 2014.
2.	A.P. Malvino, Electronic Principles, Tata McGraw Hill Publications, 8th Edition, 2016
3.	Wai-Kai-Chen, The circuits and filters Handbook, CRC press, 2nd Edition, 2003.
4.	Gabel R.A. and Robert R.A., Signals and Linear Systems, John Wiley and Sons, 3rd Edition, 2009
5.	James M. Fiore, Op Amps and Linear Integrated Circuits – Concepts and Applications, Cengage LearningPvt, Ltd, 3rd Edition, 2016.
6.	Behzad Razavi, Design of Analog CMOS Integrated circuits, Tata McGraw Hill Edition, 2006.
7.	NPTEL - Lecture Series on Analog ICs, Analog circuits and system's by Prof. K. Radhakrishna Rao,Department of Electrical Engineering, I.I.T. Madras.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the implications of the properties of systems and signals.
CO2	Design and simulate various analog signal conditioning circuits.
CO3	Implement various analog signal conditioning circuits in real time.
CO4	Trouble shoot analog signal conditioning circuits.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	-	2	2	1	1	-	-	-	1	3	3	-
CO2	3	3	2	3	3	-	2	2	-	1	-	2	3	3	2
CO3	3	3	2	2	3	-	2	2	-	1	-	2	3	3	3
CO4	3	3	2	2	3	1	1	2	-	1	-	3	3	3	3

Course Code	**:**	ICPC21
Course Title	**:**	**Process Control**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the terminology and concepts associated with Process control domain.
CLO2	To impart knowledge in the design of control systems and PID controller tuning for processes.
CLO3	To familiarize the students with characteristics, selection, sizing of control valves.
CLO4	To elaborate different types of control schemes such as cascade control, feed forward control andModel Based control schemes.

Course Content

Process Control System: Terms and objectives, piping and Instrumentation diagram, instrument terms and symbols. Regulatory and servo control, classification of variables. Process characteristics: Process equation, degrees of freedom, modeling of simple system, Self-regulating processes, interacting and non- interacting processes, Process lag, load disturbance and their effect on processes.

Controller modes: Basic control action, two position, multi-position, floating control modes. Continuous controller modes: proportional, integral, derivative. Composite controller modes: P-I, P-D, P-I-D, Integral wind-up and prevention. Auto/Manual transfer, Bumpless transfer. Response of controllers for different test inputs. Selection of control modes for processes like level, pressure, temperature and flow.

Final control elements: Pneumatic and electrical actuators, Valve positioners. Pneumatic and electrical dampers, Control valves types, construction details, various plug characteristics. Energy efficient valves - Valve sizing - selection of control valves. Inherent and installed valve characteristics. Fail-safe operation, Cavitation and flashing in control valves, Instrument air supply specifications.

Controller tuning Methods: Evaluation criteria - IAE, ISE, ITAE. Process reaction curve method, continuous oscillation method, damped oscillation method. Auto tuning. Closed loop response of I and II order systems, with and without valve, measuring element dynamics.

Advanced control system: Cascade control, ratio control, feed forward control. Over-ride, split range and selective control. Multivariable process control, interaction of control loops. Introduction to Dynamic Matrix Control. Case Studies: Distillation column, boiler drum level control and chemical reactor control.

References

1.	G. Stephanopoulos, Chemical Process Control-An Introduction to Theory and Practice. Prentice Hallof India, New Delhi, 3rd Edition, 2008
2.	D.R. Coughanowr, Steven E LeBlanc, Process Systems Analysis and Control, McGraw Hill,Singapore, 3rd Edition,2009
3.	B.W. Bequette, Process Control Modeling, Design and Simulation. Prentice Hall of India, NewDelhi, 2004
4.	William C. Dunn, Introduction to Instrumentation, Sensors, and Process Control, Artech House publishers, 2005

5.	C.A. Smith and A.B Corripio., Principles and Practice of Automatic Process Control, John Wiley andSons, New York, 3rd Edition2005
6.	Bela G. Liptak, Instrument Engineers' Handbook, Volume II: Process Control and Optimization, CRCPress, 4th Edition, 2005
7.	D.E. Seborg, T.E. Edgar, D.A. Mellichamp. Process Dynamics and Control, Wiley India Pvt. Ltd.,Fourth Edition.2016
8.	Wolfgang Altmann, Practical Process Control for Engineers and Technicians , Elsevier/Newnespublishing, 2009
9.	Donald P. Eckman, Automatic Process Control, Wiley India Pvt Ltd, 2009.
10.	Paul W. Murril, Fundamentals of Process Control Theory, ISA press, New York, 3rd Edition, 2000

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Build models of various processes using first principles approach, and perform the analysis.
CO2	Design, tune and implement PID Controllers to achieve desired performance for variousprocesses
CO3	Analyze the systems and implement control schemes for various processes.
CO4	Comprehend advanced process control strategies.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	3	3	1	1	1	2	2	2	3	3	3	-
CO2	3	3	3	3	3	3	3	2	2	2	2	3	3	3	-
CO3	3	3	3	3	3	2	2	2	2	2	2	2	3	3	2
CO4	3	3	3	3	3	3	3	2	2	2	2	3	3	3	2

Course Code	**:**	ICPC22
Course Title	**:**	**Control Systems - II**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce about the system states and state-space modeling of dynamical systems.
CLO2	To teach the advanced methods and techniques of linear system analysis and stability using Lyapunov theory.
CLO3	To demonstrate how algebraic methods can be deployed in developing feedback controllers for a larger scale of systems.
CLO4	To develop practical control systems using digital computers through data acquisition and computing.

Course Content

State-space Models – Review of vectors and matrices, Canonical Models from Differential Equations and Transfer Functions, Interconnection of subsystems.

Analysis of Linear State Equations – First order scalar differential equations, System modes and model decomposition, State Transition Matrix, Time-varying matrix case.

Lyapunov's stability theory for Linear Systems – Equilibrium points and stability concepts, Stability definitions, Linear system stability, The Direct method of Lyapunov, Use of Lyapunov's method in feedback design.

Controllability and Observability – Definitions, Controllability/Observability Criteria, Design of state feedback control systems, Full-order and Reduced-order Observer Design, Kalman canonical forms, Stabilizability and Detectability.

Digital Control Systems, Closed-loop Feedback Sampled-Data Systems, Stability Analysis, Implementation of Digital Controllers. One detailed case study of modern control theory.

References

1.	Katsuhiko Ogata, Modern Control Engineering, PHI Learning Private Ltd, 5th Edition, 2010.
2.	Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control of Dynamic Systems, Prentice Hall, 7th Edition, 2014.
3.	Dorf, R.C., Bishop, R.H., Modern Control Systems, Prentice Hall, 13th Edition, 2016.
4.	Brogan, W.L., Modern Control Theory, Prentice Hall, 3rd Edition, 1990.
5.	John J.D., Azzo Constantine, H. and Houpis Stuart, N Sheldon, Linear Control System Analysis and Design with MATLAB, CRC Taylor and Francis Reprint ,5th Edition 2009.
6.	I.J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers, 6th Edition, 2017.
7.	William A. Wolovich, Automatic Control Systems, Oxford University Press, 1st Indian Edition 2010.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Comprehend an appropriate modern paradigm for the study of larger scale multi-input- multi- output systems.
CO2	Apply linear algebra and matrix theory in the analysis and design of practical control systems.
CO3	Determine the stability of systems using Lyapunov's theory.
CO4	Implement modern control systems using a digital computer.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	1	1	-	1	1	2	3	3	3	-
CO2	3	2	3	3	3	1	1	-	1	2	3	3	3	3	-
CO3	3	1	3	3	3	-	1	-	1	1	2	3	3	3	-
CO4	3	3	3	3	3	2	2	-	2	2	2	3	3	3	-

Course Code	**:**	ICPC23
Course Title	**:**	**Electrical and Electronic measurements**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC11, ICPC12
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To give an overview of current, voltage and power measuring electrical, electronics and digital instruments.
CLO2	To expose the students to the design of bridges for the measurement of resistance, capacitance and inductance.
CLO3	To give an overview of test and measuring instruments.
CLO4	To provide the working knowledge of various waveform generators, analyzers and display devices.

Course Content

Electrical measurements: General features and Classification of electro mechanical instruments. Principles of Moving coil, moving iron, dynamometer type, rectifier type, thermal instruments. Extension of instrument range: shunt and multipliers, CT and PT.

Measurement of Power: Electrodynamic wattmeter's, Low Power Factor (LPF) wattmeter, errors, calibration of wattmeter. Single and three phase power measurement, Hall effect wattmeter, thermal type wattmeter.

Measurement of resistance, inductance and capacitance: Low, high and precise resistance measurement, Megger, Ohmmeters, Classical AC bridges: Inductance and capacitance measurements. Detectors in bridge measurement, bridge screening, Wagner earth, transformer ratio bridges.

Electronic and digital measurements: Electronic voltmeter, current measurement with electronic instruments, Digital voltmeter, Analog and digital multi-meters, Digital frequency meters. Digital LCR meter, Q-Meter, Digital wattmeter and energy meters.

DSO, MSO, Function generators, Signal generators, Waveform analyzers, Spectrum analyzers, Distortion analyzers, LED, LCD and Organic LED displays.

References

1.	Golding's, Electrical Measurements and Measuring Instruments, 6th Edition, (Revised and Enlarged): With Solved Examples and MCQ's (In M.K.S. Units), MedTech, Jan 2019.
2.	Shawney A K, A course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai and Sons, Jan 2015.
3.	David A. Bell, Electronic Instrumentation and Measurements, Oxford University Press India; 3rd Edition, 2013.
4.	Prithwiraj Purkait, Budhaditya Biswas, Santanu Das, Chiranjib Koley, Electrical and Electronics Measurements and Instrumentation, by McGraw Hill Education (India) Private Limited, 2013
5.	H. S. Kalsi, Electronic Instrumentation, McGraw Hill Education; 3rd Edition, 2017.
6.	Albert D. Helfrick, William D. Cooper, Modern Electronic Instrumentation and Measurement Techniques, 1st Edition, Pearson, 2016.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Demonstrate familiarity with various measuring instruments (ammeters, voltmeters, wattmeters, energy meters, extension of meters, current and voltage transformers) used to measure electrical quantities.
CO2	Design suitable DC and AC bridges for the measurement of R, L, C and Frequency measurement.
CO3	Suggest the kind of instrument suitable for typical measurements.
CO4	Use the test and measuring instruments effectively.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	2	2	1	1	1	1	1	2	2	2	1
CO2	3	2	2	2	2	2	1	1	1	1	1	2	2	1	1
CO3	2	3	1	1	3	2	2	1	1	1	1	2	1	2	1
CO4	2	3	1	2	2	2	1	1	1	1	1	2	1	2	1

Course Code	**:**	ICPC24
Course Title	**:**	**Digital Signal Processing**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC13
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide higher level of understanding of discrete-time and digital signal in time and frequencydomains.
CLO2	To provide knowledge to analyze linear systems with difference equations
CLO3	design and implement different structures of FIR and IIR filters.
CLO4	To introduce about DSP processors and FFT processors.

Course Content

Signal Processing Fundamentals: Discrete-time and digital signals, A/D, D/A conversion and Nyquist rate, Frequency aliasing due to sampling, Need for anti-aliasing filters. Discrete Time Fourier transform and frequency spectra, Spectral computation, Computational complexity of the DFT and the FFT, Algorithmic development and computational advantages of the FFT, Inverse FFT, Implementation of the FFT, Correlation of discrete-time signals.
Discrete-time systems, Difference equations and the Z-transform, Analysis of discrete-time LTIL systems, Stability and Jury's test.

FIR Filters: Ideal digital filters, Realizability and filter specifications, Classification of linear phase FIR filters, Design using direct truncation, window methods and frequency sampling, Least-squares optimal FIR filters, Minimax optimal FIR filters, Design of digital differentiators and Hilbert transformers, comparison of design methods.

IIR Filters: Design of analog prototype filters, Analog frequency transformations, Impulse invariance method and digital frequency transformations, Bilinear transformation, Analog prototype to digital transformations, Difficulties in direct IIR filter design, Comparisons with FIR filters.

Filter Realization: Structures for FIR filters, Structures for IIR filters, State-space analysis and filter structures, fixed point and floating-point representation of numbers, Errors resulting from rounding and truncating, Quantization effects of filter coefficients, Round-off effects of digital filters.

DSP Processors: Computer architectures for signal processing – Harvard architecture and pipelining, General purpose digital signal processors, Selection of DSPs, Implementation of DSP algorithms on a general purpose DSP, Special purpose hardware – hardware digital filters and hardware FFT processors, Evaluation boards for real-time DSP.

References

1.	Chen, C.T., Digital Signal Processing: Spectral Computation and Filter Design, Oxford Univ. Press,2001
2.	Proakis, J.G., Manolakis, D.G., Digital Signal Processing: Principles, Algorithms, and Applications,Prentice Hall of India, 4th Edition, 2007
3.	Ifeachor, E.C., and Jervis, B.W., Digital Signal Processing: A Practical Approach, Pearson EducationAsia, 2nd Edition, 2009

4.	McClellan, J.H., Schafer, R.W., and Yoder, M.A., DSP First: A Multimedia Approach, Prentice HallUpper Saddle River, NJ, 2nd Edition, 2003
5.	Mitra, S.K., Digital Signal Processing: A Computer-Based Approach, McGraw Hill, NY, 4thEdition, 2011
6.	Embree, P.M., and Danieli, D., C++ Algorithms for Digital Signal Processing, Prentice Hall UpperSaddle River, NJ, 2nd Edition, 1999

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyze the signals in both time and frequency domain
CO2	Design FIR and IIR filters for signal pre-processing
CO3	Implement and realize the filters using different structures.
CO4	Explain the selection of DSP processor for signal processing applications.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	3	3	1	2	-	2	1	2	3	3	3	-
CO2	3	3	3	3	3	1	3	-	2	2	3	3	3	3	-
CO3	3	3	3	3	3	2	3	-	2	2	3	3	3	3	-
CO4	3	3	3	3	3	2	3	1	3	3	3	3	3	3	1

Course Code	**:**	ICPC25
Course Title	**:**	**Logic and Distributed Control Systems**
Type of Course	**:**	PC
Prerequisites	**:**	ICPC16
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the importance of process automation techniques.
CLO2	To impart knowledge in PLC based programming.
CLO3	To introduce distributed control system and different communication protocols.
CLO4	To have adequate information with respect to interfaces used in DCS

Course Content

Review of PC based control design for process automation: Functional Block diagram of Computer control of process - Mathematical representation – Sampling Consideration- Data Acquisition system and SCADA, Hybrid, Direct Digital Control System, Distributed Control System architecture and Comparison with respect to different performance attributes.

Programmable logic controller (PLC) basics: Definition, overview of PLC systems, Block diagram of PLC. General PLC programming procedures: ON/OFF instruction, Timer instruction sets, Counter Instruction sets -Design, development and simulation of PLC programming using above instruction sets for simple applications.

PLC Data manipulation instruction - Arithmetic and comparison instruction- Skip, Master Control Reset (MCR) and Zone Control Last state (ZCL) instruction – PID and other important instruction set. PLC Installation, troubleshooting and maintenance. Design of alarm and interlocks, networking of PLC – Case studies using above instruction sets.

Distributed Control System: Local Control Unit (LCU) architecture - Comparison of different LCU architectures – LCU Process Interfacing Issues: - Block diagram, Overview of different LCU security design approaches, secure control output design, Manual and redundant backup designs.

LCU communication Facilities - Communication system requirements – Architectural Issues – Operator Interfaces – Engineering Interfaces. Development of Field Control Unit (FCU) diagram for simple control applications.

Introduction to Networking and components of Computer Networks – Industrial Data communication protocols - Introduction to HART and Field bus protocol. Interfacing Smart field devices (wired and wireless) with DCS controller. Introduction to Object Linking and Embedding (OLE) for Process Control -Automation in the cloud with case studies.

References

1.	John W. Webb and Ronald A. Reis, Programmable Logic Controllers - Principles andApplications, Prentice Hall Inc., New Jersey, 5th Edition,2003
2.	Lukcas M.P Distributed Control Systems, Van Nostrand Reinhold Co., New York, 1986
3.	Frank D. Petruzella, Programmable Logic Controllers, McGraw Hill, New York, 6th Edition, 2023
4.	Deshpande P. Band Ash R.H., Elements of Process Control Applications, ISA Press, NewYork 1995
5.	Curtis D. Johnson, Process Control Instrumentation Technology, Pearson New International, 8th Edition, 2013

6.	Krishna Kant, Computer-based Industrial Control, Prentice Hall, New Delhi, 2nd Edition, 2011

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand various process automation technologies.
CO2	Design and develop a PLC ladder programming for simple process applications.
CO3	Apply different security design approaches, engineering and operator interface issues fordesigning of Distributed Control System.
CO4	Describe the operation of latest communication technologies like HART and Field bus protocol.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	3	2	1	3	1	1	3	3	3	1
CO2	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
CO3	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
CO4	3	2	2	2	2	1	1	1	2	1	1	3	3	2	1

ESSENTIAL PROGRAMME **LABORATORY REQUIREMENT (LR)** COURSES

Course Code	**:**	ICLR11
Course Title	**:**	Electrical Circuits Laboratory
Type of Course	**:**	LR
Prerequisites	**:**	ICPC11
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand and analyze the basic theorems of Circuit theory
CLO2	To analyze the transient and frequency response of the circuit
CLO3	To realize and verify the AC circuits
CLO4	To determine the parameters of one port and two port network.

List of Experiments

1. Verification of Kirchhoff's Current and Voltage law
2. Verification of Superposition Theorem
3. Verification of Thevenin and Maximum Power Transfer Theorem
4. Transient characteristics of RC, RL, and R-L-C circuit
5. Frequency Response of RL, RC and RLC circuits and studying resonance condition.
6. Realization and verification of AC circuits
7. Verification of AC Network theorems
8. Determination of Z, Y, and ABCD parameters of linear two port network
9. Determination the driving point impedance of one port network by Frequency response method
10. Experiment on three phase networks.

References

1.	Charles K. Alexander and Matthew N. O. Sadiku, Fundamentals of Electric Circuits, Boston, MA, USA: McGraw-Hill Higher Education, 2007
2.	M.E. Van Valkenburg, Introduction to Modern Network Synthesis, Wiley, 1960
3.	Robert L. Boylestad, Electronic Devices and Circuit Theory, 11e, Pearson Education India, 1999
4.	M.E. Van Valkenburg, Network Analysis, Prentice Hall, 3rd Edition, 2006
5.	Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, Wiley,6th Edition, 2006

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design and analyze electrical circuits based on circuit and network theorems.
CO2	Analyze the time response and frequency response of RL, RC and RLC circuits.
CO3	Determine the parameters of one port and two port network.
CO4	Choose the appropriate instrument for measuring electrical quantities and verify the same for different circuits.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	2	3	1	2	2	2	2	3	2	1
CO2	3	3	3	3	3	2	3	1	2	2	2	2	3	2	1
CO3	3	3	3	3	3	2	3	1	2	2	2	2	3	2	1
CO4	3	2	3	3	3	2	3	1	2	2	2	2	3	2	1

Course Code	**:**	ICLR12
Course Title	**:**	**Electronic Circuits Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	--
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand characteristics of diodes and transistors
CLO2	To design the amplifier circuits and analyze its frequency response
CLO3	Understand and analyze different applications of combinational circuits.
CLO4	Understand the basics of digital design sequential circuits

List of Experiments

1. Verification of characteristics of P-N junction diode and designing the Half/ Full rectifier with and without filter
2. Studying of clipping/ clamping circuits and design a voltage regulator using Zener diode
3. Verification of Input and output characteristics of transistor (BJT) in CE configuration
4. Verification of characteristics of FET
5. Studying the biasing and frequency response of CE amplifier
6. Characterization of basic and Cascode current mirror circuits (with BJT and MOSFET)
7. Design of differential amplifier with resistive load (BJT) and active load (MOSFET)
8. Verification of different types of logic gates
9. Design and verification of combinational logic circuits
10. Design and verification of synchronous sequential logic circuits
11. Design and verification of asynchronous sequential logic circuits

References

1.	Adel S. Sedra and Kenneth C. Smith, Microelectronic Circuits, Holt, 7 Edition Oxford University Press, 2017
2.	Robert L. Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory, 10th Edition, Pearson India 2009
3.	Paul Horowitz and Winfield Hill, The Art of Electronics, 3^{rd} Edition Cambridge: Cambridge university press, 2015
4.	Behzad Razavi, Fundamentals of Microelectronics, John Wiley and Sons, 2021
5.	Sung-Mo Kang and Yusuf Leblebici, CMOS Digital Integrated Circuits: Analysis and Design, 3^{rd} Edition New York, NY, USA, McGraw-Hill, 2003

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design and analyze electronic circuits using diode, BJT and FET
CO2	Analyze the characteristics and frequency response of electronic circuits
CO3	Design and verify combinational logic circuits.
CO4	Design and verify sequential logic circuits

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	2	2	3	1	2	2	2	2	3	2	1
CO2	3	2	3	3	2	2	2	1	2	2	2	2	3	2	1
CO3	3	3	3	3	3	2	3	1	2	2	2	2	3	2	1
CO4	3	3	3	3	3	2	3	1	2	2	2	2	3	2	1

Course Code	**:**	ICLR13
Course Title	**:**	**Sensors and Transducers Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	ICPC14
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the students to the basic principles of various transducers.
CLO2	To impart knowledge in static and dynamic characteristics of sensors.
CLO3	To impart knowledge in the design of signal conditioning circuits for transducers.
CLO4	To study the characteristics of micro sensing devices

List of Experiments

1. Characteristics of (Resistive and Thermo-emf) temperature sensor
2. Characteristics of Piezoelectric measurement system
3. Measurement of displacement using LVDT
4. Characteristics of Hall effect sensor
5. Measurement of strain using strain gauges
6. Measurement of torque using Strain gauges
7. Measurement using proximity sensors
8. Characteristics of capacitive measurement systems
9. Loading effects of Potentiometer
10. Design of Opto-coupler using photoelectric transducers
11. Characteristics of Micro pressure and Micro accelerometer sensing device
12. Study of speed measuring devices and Gyroscope

References

1.	John P. Bentley, Principles of Measurement Systems, Pearson Education, 4th Edition, 2005.
2.	Ernest O. Doebelin and Dhanesh N. Manik, Measurement Systems, McGraw Hill Education, 7th Edition, 2019.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyze the static characteristics of different measurement systems
CO2	Design the signal conditioning circuits for transducers
CO3	Choose the appropriate measuring meter to avoid loading
CO4	Formulate the design specification of transducer for a given application

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	2	1	2	-	1	1	2	2	3	2	-
CO2	3	3	3	3	3	1	1	2	1	1	2	2	3	3	2
CO3	3	2	3	3	2	1	2	-	1	1	2	2	3	2	-
CO4	3	3	3	3	3	2	2	-	1	2	3	3	3	3	-

Course Code	**:**	ICLR14
Course Title	**:**	**Microprocessors and Microcontrollers Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	ICPC16
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide practical experience with 16bit/32bit microcontrollers / microprocessors
CLO2	To provide hands-on experience on constructing signal conditioning circuit for the given peripheral devices
CLO3	To enable the students to program, simulate and test various input output devices using a C language-based compiler.
CLO4	To provide a platform for the students to do multidisciplinary projects.

List of Experiments

1. Familiarization with the given micro-controller board and its assembler.
2. Basic I/O operations using switches, LEDs and LCD.
3. Programming exercises using interrupts and timers
4. ADC and DAC Interfacing.
5. I/O interfaces- parallel, Serial, SPI, I2C data Transmission.
6. Real time clock and memory interfacing with microcontroller
7. Interfacing microcontroller with stepper motor
8. Building microcontroller-based system for various applications

References

1.	Kenneth J. Ayala, The 8051 Micro controller, Thomson Delmar Learning, 3rd Edition, 2004.
2.	Andrew N. Sloss, Dominic Symes, and Chris Wright, ARM System Developer's Guide: Designing and Optimizing System Software, Morgan Kaufmann Publishers, 2004.
3.	Joseph Yiu, The Definitive guide to ARM Cortex-M3 and Cortex-M4 Processors PB, Elsevier India Pvt Ltd, 3rd Edition, 2014
4.	John H. Davies, MSP430 microcontroller basics, Newnes, 1st Edition, 2008.
5.	C.P. Ravikumar, MSP430 Microcontroller in Embedded system projects, Elite publishing house Pvt. Ltd., 2012.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Program microprocessor/ micro-controller using a C language-based compiler.
CO2	Understand the key concepts of embedded systems like IO, timers, interrupts, and interaction with peripheral devices
CO3	Design appropriate signal conditioning circuit for peripheral devices to prepare the data to processor
CO4	Design and develop embedded system for given applications

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	1	2	2	2	2	3	3	3	3	1
CO2	3	3	3	2	2	1	2	2	2	2	2	3	3	3	1
CO3	3	3	3	3	2	1	2	2	3	2	3	3	3	3	1
CO4	3	3	3	3	2	1	2	2	3	2	3	3	3	3	1

Course Code	**:**	ICLR15
Course Title	**:**	**Control Engineering Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	ICPC18
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge on analysis and design of control system in time and frequency domain.
CLO2	To impart knowledge in classical control and state space-based control system design.
CLO3	To study the characteristics of compensating networks
CLO4	To familiarize the students with MATLAB Real-time programming to collect and process data.

List of Experiments

1. Time response characteristics of a second order system.
2. Frequency response characteristics of a second order system.
3. Constant gain compensation in time and frequency domain.
4. Compensating Networks - Characteristics
5. Design of compensation networks - Lead, Lag, Lead-lag
6. Design of state feedback controller.
7. Observer design - full order and reduced order.
8. Real time control of AC/DC servo system
9. Real Time control of 2 DOF Helicopter control
10. Real Time vibration control of cantilever beam at resonance with piezoelectric sensing and actuation
11. Real time control of 3DOF GYRO
12. Real time control of Inverted Pendulum

References

1.	Dorf, R.C., and Bishop, R.H., Modern Control Systems, 14th Edition, Prentice Hall,Pearson,2022.
2.	Daniel H. Sheingold, Transducer Interfacing Handbook – A Guide to Analog Signal Conditioning, Analog Devices Inc. 1980.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design control systems in both classical and modern techniques.
CO2	Design and implement controllers to regulate and control various systems.
CO3	Design full order and reduced order state observer.
CO4	Demonstrate real-time control of various electro-mechanical systems

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	1	-	2	3	3	2	2	3	3	-
CO2	3	2	3	3	3	1	-	2	3	3	2	2	3	3	-
CO3	3	1	3	3	3	1	-	2	3	3	2	2	3	3	-
CO4	3	2	3	3	3	1	-	2	3	3	2	2	3	3	-

Course Code	**:**	ICLR16
Course Title	**:**	**Analog Signal Processing Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	-
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge on design and test the Op-amp and other ICs based circuits.
CLO2	To impart knowledge on the design of filters
CLO3	To understand the working of data converters
CLO4	To familiarize the students in simulation tools and evaluation boards available for analog signal processing.

List of experiments

1. Design of amplifiers using various modes and its implementation issues
2. Filter design using various methodologies for different set of specifications
3. Sensor linearization and bridge linearization using op-amps
4. Design of waveform generators using op-amp
5. PLL design
6. Regulator design
7. Analog to digital conversion and digital to analog conversion
8. Regenerative feedback circuit design - Schmitt trigger and Multivibrator
9. Transmitter design

References

1.	Sergio Franco, Design with operational amplifiers and analog integrated circuits, 4th edition Mc-Graw Hill Inc. 2014.
2.	Wai-Kai-Chen. The circuits and filters Handbook, CRC press, 3rd edition, 2009.
3.	Arie F. Arbel, Analog Signal Processing and Instrumentation, Cambridge University press, 1980.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design analog and digital system level circuit.
CO2	Simulate and validate analog circuits using simulation software
CO3	Implement various signal processing functions using analog electronic components
CO4	Apply the basic IC circuit design concepts for application

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	3	2	3	3	2	3	2	2	3	2	3	3	3	3
CO2	3	3	3	3	3	3	3	3	2	3	2	3	3	3	2
CO3	3	3	3	2	2	3	2	2	2	2	2	3	3	3	3
CO4	2	3	3	2	2	3	2	2	2	2	2	3	3	3	3

Course Code	**:**	ICLR17
Course Title	**:**	**Instrumentation Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	ICPC17
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the students with different signal conditioning circuits for temperature and pressure measurement system.
CLO2	To familiarize the students to the calibration practices used in industries.
CLO3	To impart knowledge in the transmitter design.
CLO4	To design the alarms and annunciators for measurements

List of Experiments

1. Design of temperature transmitter using RTD.
2. Design of cold junction compensation circuit for Thermocouple.
3. Design of IC temperature transmitters.
4. Design of Linearization circuit for thermistor.
5. Study of zero elevation and suppression in differential pressure transmitter
6. Performance evaluation of pressure gauges using Dead weight tester.
7. Measurement of level using differential pressure transmitter.
8. Design of alarms and annunciators for process variable measurements.
9. Design of pressure/force transmitter

References

1.	Doebelin E.O, Measurement Systems: Application and Design, McGraw Hill, 7th Edition, 2019
2.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3rd Edition, 2010
3.	Roy D. Choudary and Shail Jain, Linear Integrated Circuits, New Age International,6th Edition,2021

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Suggest a suitable temperature sensor for an application.
CO2	Evaluate various temperature and pressure measuring sensors.
CO3	Design and implement signal conversion and manipulation circuits for temperature and pressure measurement systems.
CO4	Perform calibration of pressure and level measuring instruments

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	2	2	1	1	1	3	1	2	3	3	3	1
CO2	3	1	3	3	3	2	2	1	3	3	3	3	3	3	2
CO3	3	3	3	2	2	1	1	1	3	3	3	3	3	3	1
CO4	3	1	3	3	3	2	2	1	3	3	3	3	3	3	2

Course Code	**:**	ICLR18
Course Title	**:**	**Industrial Automation and Process Control Laboratory**
Type of Course	**:**	LR
Prerequisites	**:**	ICPC21
Contact Hours	**:**	28 (2 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge on the time and frequency analysis of first order and second order system
CLO2	To impart practical knowledge in PC based data acquisition, analysis and control of different process trainers.
CLO3	To teach the industrial automation concept and programming techniques.
CLO4	To familiarize the process modelling and control using simulation tools.

List of Experiments

1. Identification of FOPDT and SOPDT process using time domain and frequency domain techniques.
2. Design of different PID controller for FOPDT and SOPDT process using different standard technique and evaluate qualitative and quantitative performance.
3. Study of Different Process trainers.
4. Design and Verification of Combinational and Sequential Circuits Using PLC.
5. Design of PID Controller for a Level Process/Temperature/Flow/Pressure process stations and evaluate servo/regulatory responses.
6. Study the effect of different PID Controller Parameters using real time process trainer.
7. Pressure to Current and Current to Pressure Convertor using real time process trainer.
8. Design of Timer and Counter Using PLC.
9. Design of PLC programming for practical applications.
10. Design of Cascade and Feed forward-feedback Controller using simulation software.
11. Verification of Control Valve Characteristics using pneumatic and electronic control value trainer.
12. Development of P and I control design using Distributed control system (DCS).

References

1.	G. Stephanopoulos, Chemical Process Control-An Introduction to Theory and Practice Prentice Hall of India, New Delhi, 2nd Edition, 2005
2.	D. R. Coughanowr, Process Systems Analysis and Control, McGraw Hill, Singapore, 3rd Edition, 2009
3.	B.W. Bequette, Process Control Modeling, Design and Simulation, Pearson,2nd Edition 2023

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Perform identification of processes using time domain and frequency domain techniques.
CO2	Design, implement and tune PID controller for various processes.
CO3	Implement sequential logic control using PLC for a required application.
CO4	Use simulation tools for the design of controllers for various processes.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	1	2	2	2	3	3	3	3	3	2
CO2	3	2	3	3	3	1	2	1	2	3	3	3	3	3	2
CO3	3	3	3	3	3	2	2	2	2	2	3	3	3	3	2
CO4	3	2	3	3	3	1	2	2	2	2	3	3	3	3	1

PROGRAMME ELECTIVE (PE) COURSES

Course Code	**:**	ICPE11
Course Title	**:**	**Biomedical Instrumentation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To educate the students on the different medical instruments
CLO2	To familiarize the students with the analysis and design of instruments to measure bio-signals like ECG, EEG, EMG, etc.
CLO3	To have a basic knowledge in therapeutic devices
CLO4	To introduce about the clinical laboratory instruments and familiar about electrical safety.

Course Content

Electro physiology**:** Review of physiology and anatomy, resting potential, action potential, bioelectric potentials, electrode theory, bipolar and uni-polar electrodes, surface electrodes, needle electrode and microelectrode, physiological transducers-selection criteria and its application.

Bioelectric potential and cardiovascular measurement**s**: ECG recording system, Heart sound measurement - stethoscope, phonocardiograph (PCG), Foetal monitor-ECG-phonocardiography, vector cardiograph, cardiac arrhythmia's monitoring system. EMG, EEG - Evoked potential response, ERG and EOG recording system. Measurement of blood pressure using sphygmomanometer instrument based on Korotkoff sound, indirect measurement of blood pressure, automated indirect measurement, and direct measurement techniques.

Clinical Laboratory Equipment**:** Chemical tests in clinical laboratory, Spectrophotometry and its type of instrument, Automated Biochemical Analysis System, Flame photometer. Blood gas analyzer, Acid – base balance, Blood, pH measurement, blood pCO2, blood pO2, Intra – arterial blood gas analyzers, Blood cell counters- types of blood cells, - methods of cell counting -coulter counter- Automatic recognition and differential blood cell counting.

Respiratory and pulmonary measurements: Physiology of respiratory system, respiratory rate measurement- artificial respirator- oximeter, pulmonary function measurements–spirometer–photo plethysmography and body plethysmography. Principal and techniques of impedance pneumography, Apnea monitor.

Electrical safety: Sources of electrical hazards in medical environment and safety techniques for checking safety parameters of biomedical equipment.

References

1.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 4th Edition,John Wiley and sons, New York, 2010.
2.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 5th Edition,Wiley, 2020. (e book).
3.	Arthur Guyton, John E. Hall, Text Book of Medical Physiology, 14th Edition, Elsevier Saunders,2020.

4.	Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Prentice Hall of India, New Delhi, 2nd Edition,1990.
5.	Jerry. L.Prince, Jonathan M. Links, Medical Imaging Signals and Systems, 2ndEdition, Pearson/Prentice Hall, 2014.
6.	Shakti Chatterjee and Aubert Miller, Biomedical Instrumentation Systems, CENGAGE Learningpublishing, 2010.
7.	Onkar N. Pandey and Rakesh Kumar, Bio-Medical Electronics and Instrumentation, Katson Books,3rd edition, 2007.
8.	Joseph J. Carr and John M. Brown, Introduction to Biomedical Equipment Technology ,4thEdition,Pearson publishing, 2000.
9.	R.S. Khandpur, Hand Book of Biomedical Instrumentation, 3rd edition, McGraw Hill Education(India) Private Limited, 2014.
10.	Cromwell, Biomedical Instrumentation and Measurement, 2nd Edition, Pearson India 2015.
11.	Andrew G. Webb, Principles of Biomedical Instrumentation, Cambridge University Press, 2018.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	To understand, design and evaluate systems and devices that can measure, test and/or acquire bio-signal information from the human body.
CO2	Familiar with patient monitoring equipment used in hospitals.
CO3	Ability to explain the medical diagnostic and therapeutic techniques
CO4	Familiar with various clinical laboratory instruments used for diagnosis.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	2	3	3	3	3	2	1	2	2	3	3	3	1
CO2	3	3	3	2	3	3	3	2	2	2	2	3	3	3	2
CO3	3	2	3	-	-	-	-	-	-	-	-	2	3	3	-
CO4	3	2	3	2	3	2	2	1	1	2	2	3	3	3	1

Course Code	:	ICPE12
Course Title	:	**Biomedical Signal Processing**
Type of Course	:	PE
Prerequisites	:	ICPC13, ICPC24
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of biomedical signals and analysis
CLO2	To introduce different types of bio signals and their characteristics
CLO3	To study different noise removal mechanisms for biomedical signals
CLO4	To analyse the signals using time and frequency domain measures

Course Content

Introduction to signals, Continuous time and discrete time signals and LTI systems, Introduction and properties of Fourier transform, Laplace transform and Z-transform

Nature of biomedical signals; origin and dynamics of electroneurogram (ENG), electromyogram (EMG), electrocardiogram (ECG), electroencephalogram (EEG), event related potentials (ERP), electrogastrogram (EGG), phonocardiogram (PCG), vibromyogram (VMG) and vibroarthogram (VAG), Objectives of biomedical signal analysis and difficulties in biomedical signal analysis

Random, structured and physiological noise, noises and artefacts in ECG, EMG and EEG signals, Filtering for removal of artefacts; Introduction to filter design; Time domain filters, Frequency domain filters, and optimal filters and selection of appropriate filters

Event detections in ECG, EEG and heart sounds, Analysis of wave shape and waveform complexity, QRS complex, analysis of ERPs and analysis of electrical activity using time and frequency domain measures

Analysis of nonstationary and multicomponent signals, heart sound and murmurs, EEG rhythms and waves and case studies

References

1.	Rangayyan, R. M and Sridhar Krishnan. (2024). Biomedical signal analysis (3rd Edition). Wiley
2.	Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, A Wiley-Interscience Publication JOHNWILEY and SONS, INC. ISBN 0-471-34540-7.2001
3.	B.P. Lathi, Principles of Linear Systems and Signals, Oxford University Press, 3rd Edition, 2017.
4.	Le Cerutti, S., and Marchesi, C. (Eds.). (2011). Advanced methods of biomedical signal processing (Vol. 27). JohnWiley and Sons.
5.	Webster, J. G. (2009). Medical instrumentation application and design. John Wiley and Sons.
6.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 5th Edition,Wiley, 2020. (e book).
7.	Mitra, S.K., Digital Signal Processing: A Computer-Based Approach, McGraw Hill, NY, 4th Edition, 2010.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the issues associated with the interpretation of biomedical signals
CO2	Familiar with different signals such as ECG, EMG and EEG
CO3	Remove the noises in bio signals by selecting appropriate filters
CO4	Implement appropriate signal processing methods to extract reliable information

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE13
Course Title	:	**Digital Image Processing**
Type of Course	:	PE
Prerequisites	:	ICPC13, ICPC24
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamentals of image processing
CLO2	To introduce to the concept of image restoration and reconstructions
CLO3	To introduce the concepts of image segmentation and compressions
CLO4	To impart knowledge on the design and realization of various image processing algorithms.

Course Content

Introduction and Digital Image Fundamentals:
Introduction to image processing, origin, examples of fields, steps in image processing, components of image processing system, digital image fundamentals – elements of visual perception, light and electromagnetic spectrum, image sensing and acquisition, mathematical tools used in image processing.

Intensity Transformations, Spatial Filtering and Filtering in frequency domain:
Basics intensity transformation functions, histogram processing, fundamentals of spatial filtering, smoothing and sharpening spatial filtering, combinations of image enhancement method, filtering in the frequency domain – Fourier transform of sample functions, DFT of one variable, extension to two variables, properties of 2 D DFTs, selective filtering, realization of FDT, FFT, filter design aspects.

Image Restoration and Reconstruction:
Model of the image degradation / restoration process, noise models, restoration in the presence of noise only – spatial filtering, periodic noise reduction by frequency domain filtering, estimating the degradation functions, inverse filtering, image reconstruction from projections.

Image Segmentation:
Image segmentation - point, line and edge detection, Thresholding, Regions Based segmentation, segmentation using morphological watersheds, usage of motion in segmentation, edge linking and boundary detection, Hough transform, chain codes, boundary segments, skeletons, boundary descriptors, Fourier descriptors.

Image Compression:
Image compression - image compression - data redundancies elements of information, variable-length coding, predictive coding, transform coding, image compression standards, wavelets and multi-resolution processing - image pyramids, sub-band coding.

Object Recognition and Case studies:
Object Recognition- patterns and pattern classes, recognition based on decision – theoretic methods, structural methods, case studies – image analysis

References

1.	Gonzalez and Woods, Digital Image Processing, Pearson education, 4th Edition, 2017.
2.	Jain Anil K., Fundamentals of Digital Image Processing, Prentice Hall India, 4th Edition, 1989.
3.	Milan Sonka, Vaclav Hlavav, Roger Boyle, Image Processing, Analysis and Machine Vision,Cengage Learning, 4td Edition, 2014.
4.	Rangaraj M. Rangayyan, Biomedical Image Analysis, CRC Press, 2005.
5.	Pratt W.K, Digital Image Processing, Wiley-Interscience, 4th Edition, 2007.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the importance of image processing
CO2	Perform image restoration and reconstruction
CO3	Perform image segmentation and compressions
CO4	Design, realize and troubleshoot various algorithms for the case studies based on image processing

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	:	ICPE14
Course Title	:	**Medical Imaging Systems**
Type of Course	:	PE
Prerequisites	:	ICPC13, ICPC24
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the methods of medical imaging.
CLO2	To impart knowledge in the physics behind the various imaging techniques.
CLO3	To teach the construction and working of various imaging techniques.
CLO4	To study the methods of image reconstruction

Course Content

Introduction to image processing in medical applications, X-Ray tubes, cooling systems, removal of scatters, Fluoroscopy- construction of image Intensifier tubes, angiographic setup, mammography, digital radiology, DSA.

Need for sectional images, Principles of sectional scanning, CT detectors, Methods of reconstruction, Iterative, Back projection, convolution and Back-Projection. Artifacts, Principle of 3D imaging

Alpha, Beta and Gamma radiation, Radiation detectors, Radio isotopic imaging equipments, Radio nuclides for imaging, Gamma ray camera, scanners, Positron Emission tomography, SPECT, PET/CT.

Wave propagation and interaction in Biological tissues, Acoustic radiation fields, continuous and pulsed excitation, Transducers and imaging systems, Scanning methods, Imaging Modes, Principles and theory of image generation.

NMR, Principles of MRI, Relaxation processes and their measurements, Pulse sequencing and MR image acquisition, MRI Instrumentation, Functional MRI.

References

1.	D.N. Chesney and M.O.Chesney, Radio graphic imaging, CBS Publications, New Delhi,4th Edition, 2007.
2.	Dwight G. Nishimura, Lulu, Principles of Magnetic Resonance Imaging, Stanford Univ,2010
3.	Flower M.A., Webb's Physics of Medical Imaging, CRC Press, New York, 2ndEdition, 2012.
4.	Prince and Links, Medical Imaging Signals and Systems, 2nd Edition, Pearson,2022
5.	Rangaraj M. Rangayyan, Biomedical Image Analysis", CRC Press, Boca Raton, FL, 2005.
6.	Donald W. McRobbice, Elizabeth A. Moore, Martin J. Grave and Martin R. Prince, MRI from picture to proton, Cambridge University press, New York, 2nd Edition, 2007.
7.	Kavyan Najarian and Robert Splinter, Biomedical signals and Image processing, CRC press, New York, 2nd Edition, 2012.
8.	Jerry L. Prince and Jonathan M. Links, Medical Imaging Signals and Systems- Pearson Education Inc., 2nd Edition, 2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire basic domain knowledge about the various medical imaging techniques.
CO2	Understand the construction and working of various medical imaging equipments.
CO3	Provide a foundational understanding of algorithms used in medical imaging
CO4	Analyze the medical images for diagnosis.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE15
Course Title	**:**	**Medical Diagnostic and Therapeutic Instrumentation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPE11
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarise on patient monitoring systems and telemedicine
CLO2	To understand medical imaging systems
CLO3	To explain extracorporeal devices used in critical care
CLO4	To educate the importance of patient safety against electrical hazard

Course Content

Patient monitoring systems, Intensive cardiac care, bedside and central monitoring systems - Infusion pumps, Central consoling controls. Patient monitoring through telemedicine.

X ray machine, Computer tomography, ultrasonic imaging system, magnetic resonance imaging system, thermal imaging system, positron emission tomography.

Cardiac Pacemaker, Defibrillator, Pneumotachometer, Thoracic pressure measurements, Heart lung machine - functioning of bubble, disc type and membrane type oxygenators, finger pump, roller pump, electronic monitoring of functional parameters. Types of Ventilators, Humidifiers, Nebulizers, Inhalators, Hemo Dialyser unit, Incubators.

IR, UV lamp and LASER application, Short wave diathermy, ultrasonic diathermy, Microwave diathermy, Electro surgery machine - Current waveforms, Tissue Responses, Lithotripsy, Principles of Cryogenic technique and application, Endoscopy, Laparoscopy, Otoscopes, Audiometer, Tonometer

Sources of electrical hazards and safety techniques, Built-in safety features for medical instruments, physiological effects of electricity, Patient 's electrical environment, Electrical safety codes and standards.

References

1.	James E. Moore Jr., Biomedical Technology and Devices , 2nd Edition ,2014, CRC Press.
2.	John G. Webster, Medical Instrumentation Application and Design‖ , 5thedition, Wiley India PvtLtd, New Delhi,2020.
3.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 5th Edition,Wiley, 2020. (e book).
4.	Robert B. Northrop, Non-Invasive Instrumentation and Measurement in Medical Diagnosis , 2ndedition, CRC Press,. 2019.
5.	Joseph J.Carrand ,John M. Brown, ―Introduction to Biomedical Equipment Technology,4th Edition,Pearson education,2000.
6.	Raghbir Singh Khandpur., Compendium of Biomedical Instrumentation, 3 Volume Set, 3rd Edition,Wiley IndiaPvt. Ltd, 2020
7.	Leslie Cromwell, Biomedical Instrumentation and Measurement‖, 2nd Edition, Prentice hall of India,New Delhi, 2015.
8.	L.A. Geddes and L.E. Baker, Principles of Applied Biomedical Instrumentation, John Wiley, NewYork, 3rd Edition, 1991.
9.	Khandpur R.S, Handbook of Biomedical Instrumentation‖, 3rd Edition, Tata McGraw-Hill, New Delhi,2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Familiar with patient monitoring equipment used in hospitals and in telemedicine.
CO2	Familiar with various imaging techniques used for diagnosis.
CO3	Explain the types of diathermy and its applications.
CO4	Explain the importance of patient safety against electrical hazard

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE16
Course Title	**:**	**Assistive Devices**
Type of Course	**:**	PE
Prerequisites	**:**	ICPE11
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the concepts of various rehabilitation equipments for human movements andapplications
CLO2	To understand and gain knowledge about different hearing aids
CLO3	To study various assist devices for visually and auditory impaired
CLO4	Understand key terminology used by various aids within the disability community and its roles.

Course Content

Introduction to the Human body system, Principles of Assistive and Rehabilitation Technology, Design considerations, standards and key approaches to rehabilitation and Assistive Technology.

Assistive Devices for Persons with Engineering Heart and Circulatory problem - Anatomy of Heart and circulatory system, Heart Assist Technology- Blood Pumps and Prosthetic Heart Valves.

Assistive Devices for Persons with Visual Impairments - Anatomy of eye, Categories of visual impairment – Cortical and retinal implants, Blind mobility aids –reading writing - graphics access and Braille Reader, Tactile devices for visually challenged, Text to voice converter, Orientation and navigation Aids –Ultra sonic canes and laser canes.

Assistive Devices for Persons with Hearing Impairments - Anatomy of ear -hearing functional assessment, Types of deafness, Hearing aids- Cochlear implants, Assistive technology for hearing Tactile -Information Display- Voice synthesizer and speech trainer.

Anatomy of upper and lower extremities, Classification of amputation types, Prosthesis prescription - Components of upper and lower limb prosthesis, Different types of models for limb prosthetics- Body powered prosthetics- Myoelectric controlled prosthetics and Externally powered limb prosthetics. Functional Electrical Stimulation Systems-Restoration of hand function, restoration of standing and walking, Hybrid Assistive Systems (HAS).

Concepts of Manipulation and mobility Aids, Grabbers, feeders, and page turners, Classification of manual and special purpose wheelchairs -Manual wheelchairs – Electric power wheel chairs - Power assisted wheel chairs -Wheel chair standards and tests, sports and racing wheel chairs.

References

1.	M. Cook and Janice M. Polgar, Assistive Technologies Principles and Practice, 5th Edition, mosby,2020.
2.	Cooper Rory A, An Introduction to Rehabilitation, Taylor and Francis, London, 2012
3.	Joseph D. Bronzino, Handbook of Biomedical Engineering, 2nd Edition –Volume II, CRC press, 2000
4.	Muzumdar A, Powered Upper Limb Prostheses – Control, Implementation and Clinical Application,Springer, 2004.

5.	Cook A.M. and Hussey S.M., Assistive Technologies: Principles and Practice, Mosby, USA, 1995.
6.	Teodorescu H.L.and Jain L.C., Intelligent systems and technologies in rehabilitation engineering, CRCPress, 2001.
7.	Warren E. Finn, Peter G. LoPresti, Handbook of Neuroprosthetic Methods, CRC; 1st edition 2002.
8.	Rory A Cooper, Hisaichi Ohnabe, Douglas A. Hobson, "An Introduction to Rehabilitation Engineering",CRC Press, 2006.
9.	Marion A Hersh, Michael A, Johnson, Assistive Technology for Visually impaired and blind people",Springer Publications, 1st Edition, 2008.
10.	Albert M. Cook, Janice Miller Polgar, Essentials of Assistive Technologies, Elsevier 2012.
11.	Roberto Manduchi, Sri Kurniawan , Assistive Technology for Blindness and Low Vision, 1st Edition,CRC Press, 2017.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Gain adequate fundamental knowledge about the needs of rehabilitations and its futuredevelopment.
CO2	Gain in-depth knowledge about various assistive technologies for vision and hearing
CO3	Select the appropriate rehabilitation concept for various disabilities.
CO4	Acquire basic design and analytical skills to model various types of Wheel Chairs for varied needs

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	-	3	3	3	1	1	1	-	-	-	3
CO2	3	3	3	2	-	3	3	3	1	1	1	-	-	-	3
CO3	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE17
Course Title	**:**	**Instrumentation Practices in Industries**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to requirement of standards and calibration techniques, safety mechanismsin instruments used in process industries.
CLO2	To impart knowledge about EMI and EMC problems in industrial measurements.
CLO3	To make the students to draw the specification of the industrial instruments and prepare theinstrumentation project documents

Course Content

Selection and Application: Selection and application of temperature, pressure, flow and level measuring instruments.

Standards and Calibration: Introduction to standards and calibration, calibration of temperature, pressure and flow measuring devices. Introduction to ISO, IEC and API standards pertaining to temperature, pressure and flow instrumentation.

EMI and EMC: Introduction, interference coupling mechanism, basics of circuit layout and grounding, concepts of interfaces, filtering and shielding.

Safety: Introduction, electrical hazards, hazardous areas and classification, non-hazardous areas, enclosures-NEMA types, fuses and circuit breakers. Protection methods: Purging, explosion proofing and intrinsic safety.

Specifications: Specification of instruments, preparation of project documentation, process flow sheet, instrument index sheet, instrument specifications sheet, panel drawing and specifications, instrument specifications. Project procedure, schedules, vendor drawing, tender documentation, selection of measurement method and control panels.

References

1.	Noltingk B.E., Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition, 1995.
2.	Liptak B.G, Process Measurement and Analysis,CRC Press, 5thEdition, 2016.
3.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I andVol II, GulfPublishing Company, Houston, 2001
4.	Spitzer D. W., Industrial Flow measurement, ISA press, 3rd Edition, 2005
5.	Patranabis D., Principles of Industrial Instrumentation, Tata McGraw Hill Publishing Company Ltd,3rd Edition, 2010.
6.	Lawrence D. Goettsche, Maintenance of Instruments and Systems, International society ofautomation, 2nd Edition, 2005.
7.	Henry W.Ott, Electromagnetic Compatibility Engineering, A John Wiley and Sons, INC.,Publication, 2009.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Select the appropriate instrument for a given process measurement problem.
CO2	Classify the use of instruments in process industries according to the safety practices inindustry.
CO3	Prepare instruments specification and understand the procedure and process involved in project documentation.
CO4	Understand and implement the safety standards and preventive action in industries

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-
CO2	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-
CO3	3	3	3	3	3	-	-	-	-	3	3	3	3	3	-
CO4	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-

Course Code	**:**	ICPE18
Course Title	**:**	**Digital Control Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the digital implementation of control systems
CLO2	To review the classical techniques and highlight the practical difficulties
CLO3	To emphasize on the time-domain and state-space implementation using digital processors, and exposethe students to industrial practice using PLCs.
CLO4	To design discrete-time controllers for hybrid systems

Course Content

Introduction to digital control systems, Review of discrete-time signals and systems, difference equations, transfer functions, Z-transforms

Digital Controller Design using root locus and Bode plot, digital PID controllers design using time domain and frequency domain techniques.

Review of Modern Control systems, Modelling multi-variable difference equations as state-space canonical models, Solution of discrete-time state equation. Computational methods.

Stability analysis of discrete-time systems, Jury ‘s criterion, Lyapunov theory

Design using state-space methods: controllability and observability, control law design, pole placement, Full order and reduced order discrete observer design – Introduction to Kalman filter

Implementation of digital control systems using DSPs and Microcontrollers, Large-scale industrial applications using PLCs and SCADA, Introduction to Discrete-event systems and Hybrid Systems

References

1.	M. Gopal, Digital Control and state variable methods, Tata McGraw Hill, 4th edition., 2014.
2.	M.S. Santina, A.R. Stubberud, and G.H. Hostetter, Digital Control System Design, 2ndEdition, Oxford Univ. Press,
3.	B. C. Kuo, Digital Control System, Oxford University Press, 2nd Edition., 2007.
4.	G. F. Franklin, J. D. Powell and M. L. Workman, Digital Control of Dynamic Systems, Pearson Education,3rd Edition, 2000.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyze the performance and stability of a discrete-time control system.
CO2	Design state-space digital controllers and implement using processors and PLCs.
CO3	Learn about event driven and hybrid systems.
CO4	Understand implementation issues for computer-based control systems

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE19
Course Title	:	**Neural Networks and Fuzzy Logic**
Type of Course	:	PE
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide an overview of intelligent techniques.
CLO2	To develop skills to gain a basic understanding of neural network and fuzzy logic theory.
CLO3	To introduce different architectures and algorithms of Neural Networks.
CLO4	To impart knowledge on Fuzzy set theory and Fuzzy rules.

Course Content

Introduction to fuzzy logic and neural networks, Classification, Merits and demerits of intelligent techniques compared to conventional techniques. Need of an intelligent technique for real world Engineering applications.

Supervised and Unsupervised Neural networks: Perceptron, Standard back propagation Neural network: Architecture, Algorithm and other issues. Discrete Hopfield’s networks, Kohnen’s self-organizing maps, adaptive resonance theory (ART1).

Neural networks for control systems: Schemes of Neuro-control, identification and control of dynamical systems, case studies.

Fuzzy set and operations, Fuzzy relations, Fuzzifications, Fuzzy rule-based systems, defuzzification fuzzy learning algorithms.

Fuzzy logic for control system with case studies. Introduction to neuro-fuzzy system and genetic algorithm.

References

1.	Timothy J. Ross, Fuzzy Logic with Engineering Applications, John Wiley and Sons Ltd Publications, 4th edition, 2016.
2.	Laurene Fausett, Fundamentals of Neural networks, Pearson education, Eight Impression, 2012.
3.	S. Haykin, Neural Networks and Learning Machines, Prentice Hall Inc., New Jersey, 3rd Edition, 2008.
4.	Klir G.J and Folger T.A, Fuzzy sets, Uncertainty and Information, Prentice Hall, New Delhi, 1994.
5.	Kovacic, Stjepan Bogdan, Fuzzy Controller Design Theory and Applications, CRC Press, 1st Edition, 2006.
6.	Satish Kumar, Neural Networks–A classroom approach, Tata McGraw-Hill Publishing Company Limited,2013.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Familiar with the basic concepts of Neural Network and Fuzzy logic.
CO2	Develop Neural Network based modelling and control for different process applications.
CO3	Design Fuzzy logic-based control system for process applications.
CO4	Design hybrid neuro-fuzzy architecture for engineering optimization problems.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	3	3	2	2	1	1	1	1	3	3	3	1
CO2	3	2	3	3	3	3	2	2	2	2	2	3	3	3	2
CO3	3	2	3	3	3	3	2	2	2	2	2	3	3	3	2
CO4	3	2	3	3	3	3	3	-	-	-	-	-	3	3	-

Course Code	**:**	ICPE20
Course Title	**:**	**Computational techniques in control engineering**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge with an emphasis on control system design in the current computer era.
CLO2	To teach the interdisciplinary necessity of linear algebra, control theory, and computer science.
CLO3	To demonstrate that control problems in practice demand efficient algorithms
CLO4	To discuss about algorithms useful for practicing engineers for easy implementation on a range ofcomputers.

Course Content

Review of Linear Algebra – Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product.

Numerical Linear Algebra – Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear system Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations.

Control Systems Analysis – Linear State-space models and solutions of the state equations, Controllability, Observability, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Control Systems Design – Feedback stabilization, Eigen value assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical methods and conditioning, State estimation and Kalman filter.

Large scale Matrix computations, Some Selected Software – MATLAB, MATHEMATICA, SCILAB.

References

1.	B.N. Datta, Numerical Methods for Linear Control Systems, Academic Press/Elsevier, 2005
2.	G.H. Golub and C.F. Van Loan, Matrix Computations, 4th Edition, John Hopkins University Press,2007
3.	A. Quarteroni, F. Saleri, Scientific Computing with MATLAB, Springer Verlag, 2003.
4.	www.scilab.org
5.	Strang, Linear Algebra and Learning from Data, Wellesley-Cambridge Press, 2019
6.	N. Higham, Accuracy and Stability of Numerical Algorithms, 2nd Edition, SIAM, 2002

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire skills and numerical solutions of state equations and frequency response computations.
CO2	Be able to develop numerical algorithms for evaluation of controllability, observability, andstability.
CO3	Acquire skills in numerical solutions for conditioning of Lyapunov and algebraic Riccati equation
CO4	Be able to obtain large-scale solutions of control problems

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE21
Course Title	**:**	**Network Control Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the emerging field of multi-agent and network control systems
CLO2	To expand the scope of traditional control systems to include large-scale interconnected systems
CLO3	To demonstrate consensus and leader-follower paradigms in a distributed environment
CLO4	To introduce different applications that fall in the gamut of network control systems.

Course Content

Introduction to multi-agent systems, Information exchange via local interactions, Basics of graph theory

Reaching agreement in undirected and directed networks, Agreement via Lyapunov functions, Agreement over random networks

Formation control, Shape based control, Dynamic formation selection, Assigning roles, Cooperative robotics, Wireless sensor networks

Graph theoretic controllability, Network formation, Optimizing the weighted agreement, Planning over proximity graphs, Higher order networks

Introduction to social networks, opinion dynamics, epidemics, games etc.

References

1.	Mehran Mesbahi and Magnus Egerstedt, Graph Theoretic Methods in Multiagent Networks,Princeton University Press, 2010.
2.	F. Bullo, J. Cortes, and S. Martinez, Princeton, Distributed Control of Robotic Networks,University Press, 2009.
3.	P. J. Antsaklis and P. Tabuada, Networked Embedded Sensing and Control, Springer, 2006.
4.	A.L. Barabasi, Network Science, Cambridge University Press, 2016

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design control system in the presence of quantization, network delay or packet loss.
CO2	Understand distributed estimation and control suited for network control system.
CO3	Develop simple application suited for network control systems.
CO4	Technically understand larger-scale techno-socio-economic networks and models prevalent intoday’s society.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	2	3	1	2	1	3	3	3	3	1
CO2	3	2	3	3	3	2	2	2	2	2	2	3	3	3	2
CO3	3	2	3	3	3	2	2	1	2	2	3	3	3	3	1
CO4	3	2	3	3	3	3	3	3	2	2	2	3	3	3	3

Course Code	:	ICPE22
Course Title	:	**Industrial Data Communication**
Type of Course	:	PE
Prerequisites	:	ICPC25
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

This course gives an overview to real-time communication between systems in industries and to adopt suitable protocol thereby prepare the students to take up challenges in industrial environment.

CLO1	To expose the students to communication systems emerging in the field of instrumentation.
CLO2	To introduce to the system interconnection and protocol standards.
CLO3	To give an overview of HART Protocols
CLO4	To impart knowledge in Field bus and Profibus protocol

Course Content

Interface: Introduction, Principles of interface, serial interface and its standards. Parallel interfaces and buses.

Fieldbus: Use of fieldbuses in industrial plants, functions, international standards, performance, use of Ethernet networks, fieldbus advantages and disadvantages. Fieldbus design, installation, economics and documentation.

Instrumentation network design and upgrade: Instrumentation design goals, cost optimal and accurate sensor networks. Global system architectures, advantages and limitations of open networks, HART network and Foundation fieldbus network.

PROFIBUS-PA: Basics, architecture, model, network design and system configuration. Designing PROFIBUS-PA and Foundation Fieldbus segments: general considerations, network design.

References

1.	Noltingk B.E., Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition, 1995
2.	B.G. Liptak, Process software and digital networks, CRC press, Florida, 3rd Edition 2011.
3.	Behrouz Forouzan, Data Communications and Networking, Tata McGraw Hill Education, New Delhi, 2010.
4.	Steve Mackay, Edwin Wright, Deon Reynders, John Park, Practical Industrial Data Networks: Design,Installation and Troubleshooting, Newnes, An imprint of Elsevier, 2004.
5.	Andrew S. Tanenbaum, David J. Wetherall, Computer Networks, Prentice Hall of India Pvt. Ltd., 6th Edition. 2021

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Explain the rationale behind the technological development of industrial networks.
CO2	Understand various buses and serial//parallel interface.
CO3	Exposure to the HART, Field Bus and Profibus protocols functions and their features.
CO4	Evaluate and select protocol for particular application

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	2	2	3	1	1	1	1	2	3	3	3	1
CO2	3	2	3	3	2	2	2	1	1	2	2	3	3	3	1
CO3	3	2	3	3	2	2	2	1	1	2	2	3	3	3	1
CO4	2	1	3	3	3	3	2	1	2	2	3	3	3	3	2

Course Code	**:**	ICPE23
Course Title	**:**	**Internet of Things System Design**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a good understanding of Internet of Things (IoT) and its envisioned deploymentdomains.
CLO2	To provide an understanding of smart sensors/actuators with their internet connectivity forexperimentation and designing systems.
CLO3	To provide a overview about the various protocol standards deployed in the Internet of Things (IoT)domain and to make informed choices.
CLO4	To impart knowledge in the design and development of IoT systems with enablement ensuringsecurity and assimilated privacy

Course Content

Introduction to Internet of Things: Overview of Internet of Things- the Edge, Cloud and the Application Development, Anatomy of the Thing, Industrial Internet of Things (IIoT - Industry 4.0), Quality Assurance, Predictive Maintenance, Real Time Diagnostics, Design and Development for IoT, Understanding System Design for IoT, Design Model for IoT.

System Design of Connected Devices: Embedded Devices, Embedded Hardware, Connected Sensors and Actuators, Controllers, Battery Life Conservation and designing with Energy Efficient Devices, SoCs, CC3200, Architecture, CC3200 Launchpad for Rapid Internet Connectivity with Cloud Service Providers.

Understanding Internet Protocols: Simplified OSI Model, Network Topologies, Standards, Types of Internet Networking – Ethernet, Wi-Fi, Local Networking, Bluetooth, Bluetooth Low Energy (BLE), Zigbee,6LoWPAN, Sub 1 GHz, RFID, NFC, Proprietary Protocols, SimpliciTI, Networking Design – Push, Pull and Polling, Network APIs.

System Design Perspective for IoT – Products vs Services, Value Propositions for IoT, Services in IoT, Design views of Good Products, Understanding Context, IoT Specific Challenges and Opportunities.

Advances Design Concepts for IoT – Software UX Design Considerations, Machine Learning and Predictive Analysis, Interactions, Interusability and Interoperability considerations, Understanding Security in IoT Design, Design requirements of IoT Security Issues and challenges, Privacy, Overview of Social Engineering.

References

1.	Joe Biron andJonathan Follett, Foundational Elements of an IoT Solution – The Edge, The Cloud andApplication Development, Oreilly,1st Edition, 2016.
2.	Designing Connected Products, Elizabeth Goodman, Alfred Lui, Martin Charlier, Ann Light, ClaireRowland,1st Edition.
3.	The Internet of Things (A Look at Real World Use Cases and Concerns), Kindle Edition, LucasDarnell, 2016.
4.	The Internet of Things – Opportunities and Challenges http://www.ti.com/ww/en/internet_of_things/pdf/14-09-17-IoTforCap.pdf - -

5.	Single Chip Controller and Wi-Fi SOC http://www.ti.com/lit/ds/symlink/cc3200.pdf
6.	Wireless Connectivity Solutions http://www.ti.com/lit/ml/swrb035/swrb035.pdf
7.	Wireless Connectivity for the Internet of Things – One size does not fit all http://www.ti.com/lit/wp/swry010/swry010.pdf
8.	Arshdeep Bahga, Vijay Madisetti, Internet of Things –A hands-on approach, UniversitiesPress, 2015.
9.	Raj Kamal, Internet of Things, Architecture and Design Principles, McGraw-Hill, 2017,
10.	Marco Schwartz, Internet of Things with the Arduino Yun, Pack Publishing, 2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the design architecture of IoT
CO2	Make choice of protocols and deployment in solutions
CO3	Comprehend the design perspective of IoT based products /services
CO4	Understand the importance of security requirements for IoT design

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	3	3	3	1	2	1	2	2	1	3	3	3	1
CO2	2	2	3	3	3	2	2	2	2	3	2	3	3	3	2
CO3	3	3	3	3	3	2	3	1	2	3	2	3	3	3	2
CO4	2	2	2	3	3	2	2	3	2	3	2	3	3	3	3

Course Code	:	ICPE24
Course Title	:	**Robotics**
Type of Course	:	PE
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To trace the development of machines that have been aiding humans to simplify mundane jobs
CLO2	To introduce the importance of automation in the modern world.
CLO3	To introduce robotics in the fields of manufacturing, medicine, search and rescue, service, andentertainment.
CLO4	To teach robotics as the synergistic integration of mechanics, electronics, controls, and computerscience

Course Content

Introduction: Basic concepts, definition and origin of robotics, different types of robots, robot classification, applications, robot specifications.

Introduction to automation: Components and subsystems, basic building block of automation, manipulator arms, wrists and end-effectors, user interface, machine vision, implications for robot design, controllers. Kinematics, dynamics and control:

Robot programming: Robot programming languages and systems, levels of programming robots, problems peculiar to robot programming, control of industrial robots using PLCs.

Automation and robots: Case studies, multiple robots, machine interface, robots in manufacturing and non- manufacturing applications, robot cell design, selection of a robot.

Robotic network models, complexity notion, connectivity, maintenance, and rendezvous

References

1.	Corke, P., Robotics, Vision and Control, 2nd edition, Springer,2017
2.	Spong, M.W., Hutchinson, H., and Vidyasagar, M., Robot Modeling and Control, JohnWiley (Wiley India Ed.), 2nd Edition, 2020.
3.	Asfahl C.R, Robots and Manufacturing Automation, John Wiley and Sons, New York,1992.
4.	F. Bullo, J. Cortes, and S. Martinez, Princeton, Distributed Control of Robotic Networks, Princeton University Press,2009.
5.	Mikell P, Weiss G.M, Nagel R.N and Odrey N.G, Industrial Robotics, McGraw Hill, New York, 2nd Edition, 2012.
6.	Deb S.R, Robotics Technology and Flexible Automation, Tata McGraw Hill, New Delhi, 1994.
7.	N. Bostrom, Superintelligence: Paths, Dangers, Strategies, Oxford University Press, 2016.
8.	H. Bray, You Are Here: From Compass to GPS, The History and Future of How We Find Ourselves, Basic Books, New York 2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand robot dynamics and multivariable control.
CO2	Learn how control theoretic ideas can be extended to design automation systems.
CO3	Be introduced to the most popular methods for motion planning and obstacle avoidance.
CO4	Be familiar with robot programming, computer vision, and robotic networks and applications in theindustry.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	1	3	3	3	1	2	1	1	1	1	3	3	3	1
CO2	3	2	3	3	3	2	2	1	2	1	2	3	3	3	1
CO3	3	2	3	3	3	2	2	1	2	1	2	3	3	3	1
CO4	3	2	3	3	3	3	3	1	2	2	2	3	3	3	2

Course Code	**:**	ICPE25
Course Title	**:**	**Cyber security for industrial automation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC25
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the Industrial security environment and cyberattacks
CLO2	To analyze and assess risks in the industrial environment
CLO3	To access, design and implement cybersecurity
CLO4	To test and troubleshoot the industrial network security system

Course Content

INTRODUCTION: Industrial security environment-Industrial automation and control system (IACS) culture Vs IT Paradigms-Cyberattacks: Threat sources and steps to successful cyberattacks

RISK ANALYSIS: Risk identification, classification and assessment, Addressing risk: Cybersecurity Management System (CSMS), organizational security, physical and environmental security, network segmentation, access control, risk management and implementation.

ACCESSING THE CYBERSECURITY OF IACS: Identifying the scope of the IACS- generation of cybersecurity information-identification of vulnerabilities- risk assessment-evaluation of realistic threat scenarios- Gap assessment-capturing Ethernet traffic- documentation of assessment results

CYBERSECURITY DESIGN AND IMPLEMENTATION; Cybersecurity lifecycle- conceptual design process- detailed design process- firewall design remote access design- intrusion detection design

TESTING AND MAINTENANCE; Developing test plans- cybersecurity factory acceptance testing- site acceptance testing- network and application diagnostics and troubleshooting- cybersecurity audit procedure- IACS incident response

References

1.	Ronald L. Krutz,, Industrial Automation and Control System Security Principles, ISA, 2013.
2.	David J. Teumim,, Industrial Network Security, Second edition, ISA, 2nd Edition, 2010
3.	Edward J.M. Colbert and Alexander Kott, Cyber-security of SCADA and other industrial control systems, Springer, 2016.
4.	Perry S. Marshall and John S. Rinaldi, Industrial Ethernet, Second edition, ISA, 2nd Edition, 2004

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Apply basis of science and engineering to understand Industrial security environment and cyberattacks.
CO2	Analyze and assess risks in the industrial environment and implementation of Cyber attack
CO3	Test and troubleshoot the industrial network security system.
CO4	Understand, investigate and explore feasible solution for a moderate industrial problem

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	:	ICPE26
Course Title	:	**Real-Time Embedded Systems**
Type of Course	:	PE
Prerequisites	:	ICPC15, ICPC16
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic concepts of Embedded Systems
CLO2	To expose to the design principles of advanced level ARM processors.
CLO3	To provide basic understanding of the concepts of OS and RTOS.
CLO4	To develop the embedded systems for real time system

Course Content

Embedded system architecture and classifications, challenges, choice and selection of microcontrollers for embedded systems design. ARM Processor – Evolution, Architecture versions, Processor Families, Instruction Set – ARM state and Thumb state instructions, Software development tools.

ARM Cortex Architecture, Programming: Internal blocks – Processor core features, system peripherals, Memory map, bus system, debug support, User Peripherals, Serial Interfaces, Programming the peripherals using C – examples. Case studies of hardware design and software development.

OS Concepts and types, tasks and task states, process, threads, inter process communication, task synchronization, semaphores, role of OS in real time systems, scheduling, resource allocation, interrupt handling, other issues of RTOS. Examples of RTOS. Working with RTOS with ARM Cortex embedded controllers

References

1.	Johnathon M Valvano, Embedded Systems: Introduction to ARM Cortex M Microcontrollers, 5th Edition, 2017
2.	Johnathon M. Valvano, Real Time Operating Systems for ARM Cortex M Microcontrollers, 4th Edition, 2017
3.	Joseph Yiu, The Definitive Guide to ARM Cortex M3 and ARM Cortex M4 Processors, 3rd Edition,2019
4.	Cortex M4 Technical Reference Manual: ARM Rev r0p0 ,2010 https://documentation-service.arm.com/static/5f19da2a20b7cf4bc524d99a .
5.	ARMv7-M Architecture Reference Manual.2019 https://developer.arm.com/documentation/ddi0403/latest/

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design an embedded system for simple applications.
CO2	Develop applications using embedded ‘C’ language.
CO3	Understand RTOS structure and types
CO4	Develop the real time embedded systems

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE27
Course Title	**:**	**Optical Instrumentation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students on the basics of optical sources and detectors, optical fiber and fiberoptic sensors.
CLO2	impart knowledge on the characteristics of optical sources and detectors.
CLO3	To provide adequate knowledge about the optical fiber and their characteristics.
CLO4	To introduce about the Industrial applications of fiber optic sensors and lasers.

Course Content

Introduction: Characteristics of optical radiation, luminescence.

Optoelectronic sources: LED – LED power and efficiency, structures- planar, dome, ELED, SLED, super luminescent LEDS, characteristics and applications.

LASERS – structures- gain guided and index guided lasers, types- semiconductor- homo and hetero junction lasers. Non-semiconductor lasers - gas, liquid and solid. Single frequency Lasers, characteristics, Q switching and mode locking, cavity dumping.

Optoelectronic detectors: General characteristics of photodetectors, Photodiode, junction photodiodes – heterojunction diode and PIN diode, APD, Special detectors- Schottky barrier diode, photo- transistor and photo-thyristor, solar cells.

Optical fiber- Fundamentals, types, transmission characteristics. Fibers splicing, connector and couplers. Optocouplers and optrodes.

Industrial applications – Fiber optic sensors -temperature, pressure, flow and level measurement. LASERS – Distance, length, velocity, acceleration, current and voltage measurements. Material processing: Laser heating, melting, scribing, splicing, welding and trimming of materials, removal and vaporization, calculation of power requirements. Laser gyroscope.

References

1.	Djafar.K. Mynbaev, Lowell. Scheiner, Fiber-Optic Communications Technology, PearsonEducation Pvt. Ltd., 1st Edition, 2008.
2.	John M Senior, Optical Fiber Communications: Principles and Practice, 3rd Edition, 2010.
3.	Eric Udd, William B., and Spillman, Jr., Fiber Optic Sensors: An Introduction for Engineers and Scientists , John Wiley and Sons, 2011
4.	R.P. Khare, Fiber optics and optoelectronics, Oxford University Press,2016
5.	Wilson and Hawkes, Opto Electronics An Introduction, Prentice Hall, New Delhi, 3rd Edition, 2003.
6.	Fukuda, Optical Semiconductor Devices, John Wiley, 2005.
7.	Safa Kasap, Optoelectronics and Photonics: Principles and Practices: International Edition 2ndedition, 2013
8.	Bhattacharya Pallab, Semiconductor Optoelectronic Devices, Pearson Education; 2ndEdition 2017

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Have familiarity with the fundamental principles of various types of optical sources, characteristicsand its applications.
CO2	Understand the operation of different types of optical detectors and its limitations in industrial use.
CO3	Apply the gained knowledge on optical fibers for its use as communication medium inindustrial use.
CO4	Have knowledge on fiber-optical components and systems and its industrial applications.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	-	1	1	1	3	3	3	-
CO2	3	3	3	3	2	3	2	-	2	2	2	3	3	3	-
CO3	3	3	3	2	2	3	2	-	2	2	2	3	3	3	-
CO4	3	3	3	2	2	3	2	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE28
Course Title	**:**	**Measurement Data Analysis**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To give basic information about measuring instruments
CLO2	To expose the students about the Statistical methods for estimating errors and uncertainties of realmeasurements:
CLO3	To introduce the fundamental techniques of measurement for data analysis
CLO4	To apply different measurement techniques that are performed in industry, commerce andexperimental research for determination of parameters

Course Content

General information about measurements, measuring instruments and their properties.

Statistical methods for Experimental Data Processing: Estimation of the parameters, Construction of confidence intervals, Methods for testing Hypotheses and sample homogeneity, Trends in applied statistics and experimental data processing.

Direct measurements: Method for calculating the errors and uncertainties, Methods for combining systematic and random errors.

Indirect measurements: Correlation coefficient and its calculation, the method of reduction, method of transformation, errors and uncertainty of indirect measurement. Examples of measurements and measurement data processing.

Combined Measurements:
Method of least squares, linearization of nonlinear conditional equations, and determination of the parameters in formulas from empirical data and construction of calibration curves. Combining the results of measurements. Calculation of the errors of measuring instruments.

References

1.	Semyon G. Rabinovich, Measurement Errors and Uncertainties – Theory and Practice, SpringerPublication, 3rd Edition, 2010.
2.	L. Kirkup, R. B. Frenkel, An Introduction to Uncertainty in Measurement: Using the GUM (Guideto the Expression of Uncertainty in Measurement), Cambridge University Press,2010
3.	S.V. Gupta, Measurement Uncertainties: Physical Parameters and Calibration of Instruments,Springer, 2012.
4.	Ernest O Doebelin and Dhanesh N Manik, Measurements systems Application and design, McGrawHill publication, 5th Edition, 2015.
5.	Julius S. Bendat, Allan G. Piersol, Random Data: Analysis and Measurement Procedures, 4thEdition, Wiley, 2010.
6.	Ifan Hughes and Thomas Hase, Measurements and Their Uncertainties: A Practical Guide toModern Error Analysis, Oxford University Press, 2010.
7.	Patrick F. Dunn, Measurement, Data Analysis, and Sensor Fundamentals for Engineering andScience., CRC Press , 3rd Edition, 2019

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Estimate measurement inaccuracies.
CO2	Evaluate the measurement system based on its quality and cost.
CO3	Acquire both theoretical knowledge and practical skills in working with measurement data.
CO4	Design and conduct experiments to analyze and interpret the data and generate reports

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE29
Course Title	**:**	**Micro Electro Mechanical Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamental concepts of MEMS and Micro systems and their relevance to currentscientific needs.
CLO2	To introduce the state-of-art micromachining techniques including surface micromachining, bulkmicromachining, and related methods.
CLO3	To make the students knowledgeable in the design concepts of micro sensors and micro actuators.
CLO4	To introduce the challenges and limitations in the design of MEMS devices

Course Content

Introduction, emergence, MEMS application, scaling issues, materials for MEMS, Thin film deposition, lithography and etching.

Bulk micro machining, surface micro machining and LIGA process.

MEMS devices, Engineering Mechanics for Micro System Design – static bending of thin plates, Mechanical vibrational analysis, Thermomechanical analysis, fracture mechanics analysis, thin film mechanics.

Theory and design: Micro Pressure Sensor, micro accelerometer – capacitive and piezoresistive, micro actuator. Electronic interfaces, design, simulation and layout of MEMS devices using CAD tools.

References

1.	Tai Ran Hsu, MEMS and Microsystem Design and Manufacture, Tata McGraw Hill, New Delhi 2002.
2.	Marc Madou, Fundamentals of Microfabrication and Nanotechnology, Three-Volume Set , CRC Press, 3rd Edition, 2018.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS, and Smart Devices, John Wiley and SonsLtd, 1st Edition, reprinted 2007.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1stEdition, 2001.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1st Edition, 2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2nd Edition, 2011.
7.	Stephen D. Senturia., Microsystem Design, Kluwer Academic Publishers, 2001 (Available now at Springer https://link.springer.com/book/10.1007/b117574).
8.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre., Micro and SmartSystems, Wiley-India, 2010.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the fundamental principles behind the working of micro devices/ systems and theirapplications.
CO2	Have knowledge in the standard micro fabrication techniques.
CO3	Identify micro sensors and actuators for a specific application.
CO4	Acquire skills in computer aided design tools for modeling and simulating MEMS devices

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	1	1	1	1	3	3	3	2
CO2	3	2	3	2	2	3	2	1	2	1	1	3	3	3	1
CO3	3	3	3	3	2	2	3	1	2	2	2	3	3	3	2
CO4	3	2	3	3	3	2	3	1	2	2	2	3	3	3	2

Course Code	**:**	ICPE30
Course Title	**:**	**Automotive Instrumentation and Control**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge on automobile system, its subsystems and components.
CLO2	To expose the students to the concepts of various sensors used in automobile systems.
CLO3	To teach the basic and advanced controls in automotive systems.
CLO4	To impart knowledge about the electronics and software involved in automotive systems.

Course Content

Automobile Fundamentals:

Introduction, Electronics in automotive and its evolution, Automotive physical configuration, Engine block, Cylinder head, Piton, Crankshaft, Camshaft, Connecting rod, Valve, 4-stroke cycle, Engine control, Ignition system, Spark plug, High voltage circuit and distribution, Spark pulse generation, Ignition timing, Drivetrain, Transmission, Drive shaft, Differential, Suspension, Brakes, Steering system.

Electronic engine control:

Motivation, Exhaust emission, Fuel economy, Concept of electronic engine control, Performance parameters and variables, Torque, Power, BSFC, Fuel consumption, Efficiency, Calibration, Engine mapping, Effect of air-fuel ratio, Spark timing, EGR on engine performance, Exhaust Catalytic converter, Oxidizing catalytic and Three- way type, Electronic fuel control, Open and Close Loop, EGO concentration, Intake manifold pressure, Speed density method, EGR, Electronic ignition.

Sensors and actuators:

Automotive variable, Air flow rate sensor, Pressure measurement, Strain gauge MAP sensor, Engine crankshaft angular position sensor, Magnetic reluctance position sensor, Engine angular speed sensor, Timing sensor for ignition and fuel delivery, Hall effect and optical position sensor, Optical crankshaft position sensor, Throttle angle sensor, temperature sensor, coolant sensor, Exhaust gas oxygen (EGO) sensor, Desirable and switching characteristics, Knock sensor, Angular rate sensor, LIDAR, Flex fuel sensor, Acceleration sensor, Fuel injection, Exhaust gas recirculation actuator, Variable valve timing, Electric motor actuator, Ignition system.

Vehicle power train and motion control:

Electronic transmission control, adaptive power Steering, adaptive cruise control, safety and comfort systems, anti-lock braking, traction control and electronic stability, active suspension control.

Active and passive safety system:

Body electronics including lighting control, remote keyless entry, immobilizers etc., electronic instrument clusters and dashboard electronics, aspects of hardware design for automotive including electro-magnetic interference suppression, electromagnetic compatibility etc., (ABS) antilock braking system, (ESP) electronic stability program, air bags.

Automotive standards and protocols:

Automotive standards like CAN protocol, LIN protocol, FLEX RAY, Head-Up Display (HUD), OBD-II, CAN FD, automotive Ethernet etc. Automotive standards like MISRA, functional safety standards (ISO 26262).

References

1.	William B. Ribbens, Understanding Automotive Electronics, Butterworth-Heinemann publications,8th Edition, 2017.
2.	Young A.P., Griffiths L., Automotive Electrical Equipment, ELBS and New Press, 2010.
3.	Tom Weather Jr., Cland C. Hunter, Automotive computers and control system, Prentice Hall Inc.,New Jersey,2009.
4.	Crouse W.H., Automobile Electrical Equipment, McGraw Hill Co. Inc., New York, 2005.
5.	Bechtold, Understanding Automotive Electronic, SAE, 2010.
6.	BOSCH, Automotive Hand Book, Bentely Publishers, Germany, 10th Edition, 2018.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Identify the automotive system and its components.
CO2	Attain knowledge of various sensors and conditioning circuit used in automotive systems.
CO3	Gain knowledge about various control strategies, the electronics and software used in automotiveapplication.
CO4	Gain the basic ideas about the standards and protocols and energy management.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE31
Course Title	**:**	**Instrumentation and Control for Power Plant**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17, ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to various power generation methods.
CLO2	To impart knowledge on various processes/systems involved in thermal power generation.
CLO3	To provide the knowledge on specific measurement techniques and control systems practiced inboiler and turbine units.
CLO4	To impart basic knowledge in nuclear power plant and associated instrumentation.

Course Content

Brief survey of methods of power generation-hydro, thermal, nuclear, solar and wind power – Introduction to thermal power plant processes – building blocks - ideal steam cycles – Boilers – types – sub-critical and super critical, Boiler - turbine units and its range systems, feed water systems, steam circuits, combustion process, products of combustion process, fuel systems, treatment of flue gases, steam turbine, condensate systems, alternator, feed water conditioning, turbine bypass valves. Importance of instrumentation in power generation – details of boiler processes, major P and I diagram for a boiler – combined cycle power plant, power generation and distribution.

Measurement in boiler and turbine: Metal temperature measurement in boilers, impulse-piping system for pressure measuring devices, flame monitoring. Introduction to turbine supervising system, pedestal vibration, shaft vibration, eccentricity measurement. Installation of non-contracting transducers for speed measurement, rotor and casing movement and expansion measurement.

Controls in boiler: Problems associated with control of multiple pulverizes. Draught plant: Introduction, natural draught, forced draught, induced draught, balanced draught, power requirements for draught systems. Fan drives and control, control of airflow. Combustion control: Fuel/Air ratio, oxygen, CO and CO2 trimming, combustion efficiency, excess air, parallel and cross limited combustion control, control of large systems.

Controls in boiler: Boiler drum level measurement methods, feedwater control, soot-blowing operation, steam temperature control, coordinated control, boiler following mode operation, turbine following mode operation, constant/ sliding pressure operation, selection between boiler and turbine following modes. Distributed control system in power plants-interlocks in boiler operation. Turbine control: Shell temperature control-steam pressure control – lubricant oil temperature control – cooling system.

Nuclear power plant instrumentation: Piping and instrumentation diagram of different types of nuclear power plant, Nuclear reactor control loops, reactor dynamics, excess reactivity, pulse channel and logarithmic instrumentation, control and safety instrumentation, reliability aspects.

References

1.	Sam. G.Dukelow, The Control of Boilers, ISA Press, New York, 2nd Edition, 1991
2.	Gill A.B, Power Plant Performance, Butterworth, London, 1984.
3.	P.C Martin, I.W Hannah, Modern Power Station Practice, British Electricity International Vol. 1 andVI, Pergamon Press, London, 1992.
4.	David Lindsley, Power-plant Control and Instrumentation: The Control of Boilers and HRSGSystems, IET, London, 2000.
5.	Jervis M.J, Power Station Instrumentation, Butterworth Heinemann, Oxford, 1993.
6.	Swapan Basu Ajay Debnath, Power Plant Instrumentation and Control Handbook, 1st Edition,Academic Press, 2014.
7.	G. F. Gilman, Jerry Gilman, Boiler Control Systems Engineering, ISA, 2010.
8.	Elonka, S.M.and Kohal A.L, Standard Boiler Operations, McGraw-Hill, New Delhi, 1994.
9.	Philip Kiameh, Power Plant Instrumentation and Controls, McGraw-Hill Professional, 2014.
10.	Dipak.K. Sarkar, Thermal Power Plant, Design and Operation, Elsevier, ISBN: 978-0-12-801575-9,2015

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand Various power generation processes.
CO2	List important parameters to be monitored and controlled in a thermal power plant.
CO3	Understand major control systems involved in the thermal power plant and nuclear power plants.
CO4	Understand Piping and Instrumentation diagram for power plant instrumentation

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	1	2	1	2	3	3	1	1	2	2	3	3	3	1
CO2	3	1	3	2	2	3	3	2	1	2	2	3	3	3	1
CO3	3	2	3	3	3	2	3	2	2	2	2	3	3	3	2
CO4	3	2	3	3	3	2	3	2	2	2	2	3	3	3	2

Course Code	**:**	ICPE32
Course Title	**:**	**Instrumentation and Control for Petrochemical Industries**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17, ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to various petroleum production processes.
CLO2	To impart knowledge on various processes involved in petroleum refinery.
CLO3	To provide knowledge on specific measurement techniques practiced, control systems and automationinvolved in petrochemical industry.

Course Content

Brief survey of petroleum formation, petroleum exploration, Petroleum production, Petroleum refining and its methods, refining capacity and consumption in India, constituents of Crude Oil, Recovery techniques – Oil – Gas separation, Processing wet gases.

P and I diagram of petroleum refinery, Atmospheric distillation process, Vacuum distillation process, Thermal cracking, Catalytic cracking, Catalytic reforming, and Utility plants – Air, N2, and cooling water.

Basics of field instruments, Parameters to be measured in Petrochemical industry, Distillation Column control, Selection of instruments, Basics of intrinsic safety of instruments, Area classification.

Control of furnace, Reboiler Control, Reflux Control, Control of catalytic crackers, Control of heat exchanger, Control of cooling tower.

Basics of PLC, and Safety interlocks in furnace, separator, pump, and compressor. Basics of SIL, Introduction to Standards.

References

1.	Waddams A. L, Chemical from petroleum, Butter and Janner Ltd., 1968.
2.	Balchan.J.G. and Mumme K.I., Process Control Structures and Applications, Van Nostrand ReinholdCompany, New York, 1988
3.	Liptak B.G., Instrument Engineers' Handbook, CRC PRESS, 4th Edition, 2003.
4.	Austin G.T. Shreeves, Chemical Process Industries, McGraw Hill International student edition, Singapore,1985.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand various petrochemical processes and important parameters to be monitored and controlled.
CO2	Understand various instruments involved in the design and measurement of petrochemical process.
CO3	Understand various control systems involved in the petrochemical process.
CO4	Understand the automation and safety standards of a petrochemical industry.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	2	1	2	3	3	1	1	2	2	3	3	3	1
CO2	3	1	3	2	2	3	3	2	1	2	2	3	3	3	1
CO3	3	1	3	2	2	3	3	2	1	2	2	3	3	3	1
CO4	3	2	3	3	3	2	3	2	2	2	2	3	3	3	2

Course Code	**:**	ICPE33
Course Title	**:**	**Instrumentation and Control for Paper Industries**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17, ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the students to the paper making process.
CLO2	To expose the students to the instrumentation used in Paper industries.
CLO3	To expose the students to the control operations employed in paper industries.

Course Content

Paper making process: Raw materials, pulping and preparation, screening – bleaching, cooking, chemical addition, approach system, paper machine, drying section, calenders, drive, finishing, other after treatment processes, coating.
Properties of paper: physical, electrical, optical and chemical properties.

Wet end Instrumentation: Conventional measurements at wet end, pressure and vacuum, temperature, liquid density and specific gravity, level, flow, consistency measurement, pH and ORP measurement, freeness measurement.

Dry end Instrumentation: Conventional measurements, moisture, basis weight, caliper, coat thickness, optical variables, measurement of length and speed.
Digester: Rotary and Batch type.

Control aspects: Machine and cross direction control techniques, control of pressure, vacuum, temperature, liquid density and specific gravity, level, flow, pH, freeness, thickness, consistency, basis weight and moisture.

Pumps and control valves used in paper industry, flow box and wet end variables, evaporator feedback and feed forward control, lime mud density control, stock proportioning system, refiner control instrumentation, basic pulper instrumentation, headbox – rush/drag control. Instrumentation for size preparation, coating preparation, coating weight control. Batch digester, K/Kappa number control, Bleach plant chlorine stage control.

References

1.	E. J. Cole, William Harold Mehaffey. Pulp and Paper Mill Instrumentation, Lockwood TradeJournal Company. (1957)
2.	John R. Lavigne, An introduction to paper industry Instrumentation, Miller Freeman Publications,California,1977.
3.	Robert J. McGill, Measurement and Control in Papermaking, Adam Hilger Limited, Bristol, 1980.
4.	John R. Lavigne, Instrumentation Applications for the Pulp and Paper Industry, Backbeat Books,California,1979.
5.	Dr. Nancy J. Sell , Process Control Fundamentals for the Pulp and Paper Industry , TAPPI Press,1995
6.	James P. Casey, Pulp and Paper: Chemistry and Chemical Technology, John Wiley Sons, NewYork, 3rd Edition, 1983.

7.	Sankaranayanan P.E, Pulp and Paper Industries–Technology and Instrumentation, Kothari'sDeskbook series,1995.
8.	Liptak B.G, Instrument Engineers Handbook, volume 2: Process Control, CRC press, London, 4th Edition,2005.
9.	H. N. Koivo, Automation and Control of Pulp and Paper Process, Helsinki University ofTechnology Publication, Espoo. (2002)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Appreciate the need of instrumentation and control in paper making.
CO2	Understand the instrumentation and control used in paper and pulp industry.
CO3	Understand the control used in paper and pulp industry.
CO4	Suggest and analyse new instruments and control options in paper and pulp industry.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1

Course Code	**:**	ICPE34
Course Title	**:**	**Instrumentation for Agricultural and Food Processing Industries**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide an understanding on the need of instrumentation in agriculture and food processingsector.
CLO2	To provide an understanding of food quality assessment and instruments used for the same.
CLO3	To provide an understanding on agriculture associated activities and instruments used for the same.
CLO4	To provide some knowledge in food processing equipment.

Course Content

Introduction: Necessity of instrumentation and control for food processing and agriculture sensor requirement, remote sensing, biosensors in Agriculture, standards for food quality.

Instrumentation for food quality assurance: Instrumental measurements and sensory parameters. Inline measurement for the control of food processing operations: color measurements of food, food composition analysis using infrared, microwave measurements of product variables, pressure and temperature measurement in food process control, level and flow measurement in food process control, ultrasonic instrumentation in food industry. Instrumental techniques in the quality control, Major Processes: Flow diagram of sugar plant, sensors and instrumentation set-up for it, Oil extraction plant and instrumentation set-up, Juice extraction control set-up.

Instrumentation for Agriculture: Irrigation systems: necessity, irrigation methods: overhead, centre pivot, lateral move, micro irrigation systems and it's performance, comparison of different irrigation systems, soil moisture measurement methods. Major Processes: Application of SCADA for DAM parameters and control, Water distribution and management control, Auto-Drip irrigation systems, Irrigation Canal management, upstream and downstream control concepts, supervisory control.

Green houses and Instrumentation: Ventilation, cooling and heating wind speed, temperature and humidity, rain gauge, carbon dioxide enrichment measurement and control.

Design considerations of agricultural and food Processing Equipments: Design of Food Processing equipments, dryers, design of dryers PHTC, RPEC, LSU and Drum Dryer, determination of heat and air requirement for drying grains.

References

1.	Erika Kress-Rogers, Christopher J.B. Brimelow., Instrumentation and Sensors for the Food Industry,Woodhead Publishing, 2001 .
2.	Manabendra Bhuyan., Measurement and control in food processing, CRC/Taylor and FrancisPublications, 2007
3.	P.J. Fellows, Food Processing Technology Principles and Practice, Woodhead Publishing,3rdEdition, 2009.
4.	Semioh Otles, Methods of analysis of food components and additives, CRC Press, Taylor andFrancis group, 2nd Edition, 2012.

5.	McMillan G. K., Considine D. M., Process/Industrial Instruments and Controls Handbook, McGrawHill International, 5th edition,1999.
6.	Liptak B. G., Instrument Engineers Handbook, Process Measurement Volume I and Process ControlVolume II, CRC press, 4th Edition,2005.
7.	Hall C. W., Olsen W. C, The literature of Agriculture Engineering, Cornell University Press, 1992.
8.	Sahu J. K., Fundamentals of Food Process Engineering, Alpha Science Intl Ltd, 2016.
9.	G.E. Meyer and Yufeng Ge., Instrumentation and Controls for Agricultural and Biological Engineering Applications, using LabVIEW® and other Modern tools as Support Systems, (2008)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the necessity of instrumentation in agriculture and food processing.
CO2	Have familiarity with instrumentation requirement in agriculture and food processing.
CO3	Analyse and design systems/instruments for agriculture and food processing.
CO4	Understand problems in agriculture and food processing and provide technological solution to the same.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
CO2	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	-	-	-	-	-	3	3	3	1	1	1	-	-	-	3

Course Code	**:**	ICPE35
Course Title	**:**	**Piping and Instrumentation Diagrams**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18, ICPC21
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce various flow sheet design using process flow diagram.
CLO2	To impart knowledge on PandI D symbols for pumps, compressors and process vessels.
CLO3	To teach the line diagram symbols, logic gates of instruments.
CLO4	To learn the simulation software for PandID implementations

Course Content

Flow sheet design: Types of flow sheets, flow sheet presentation, flow sheet symbols, line symbols and designation, process flow diagram, synthesis of steady state flowsheet, flow sheeting software.

Piping and instrumentation diagram evaluation and preparation: P and I D Symbols, line numbering, line schedule, PandI D development, various stages of PandI D, PandI D for pumps, compressors process vessels, absorber, evaporator.

Control systems and interlocks for process operation: Introduction and description, need of interlock, types of interlocks, interlock for pumps, compressor, heater-control system for heater, distillation column, expander

Instrument line diagram: Line diagram symbols, logic gates, representation of line diagram.

Application of Pand ID'S: Applications of Pand ID in design state, construction stage, commissioning state, operating stage, revamping state, applications of PandID in HAZAMPS and risk analysis

References

1.	Ernest E. Ludwig, Applied Process Design for Chemical and Petrochemical Plants Vol-1, GulfPublishing Company, Hoston,1989.
2.	Max. S. Peters and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers,McGraw Hill Inc., New York,1991.
3.	Moe Toghraei., Piping and Instrumentation Diagram Developmen ., Wiley-AIChe Publication. 2019.
4.	Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill, NewDelhi,1981.
5.	A.N. Westerberg et al., Process Flow sheeting, Cambridge University Press, NewDelhi,1979.
6.	Jagadeesh Pandiyan., Introduction to Smart Plant (R) P and ID: The Piping and Instrumentation Diagrams (P and ID)Handbook ,. APJ Books Publisher 2020 Edition,

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand of PandI diagrams standards involved and its preparation.
CO2	Select different fittings for instruments installation used for the preparation of P and IDs.
CO3	Apply software for preparation of P and IDs.
CO4	Apply the P and ID concepts for industrial applications

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE36
Course Title	**:**	**Communication and Networking in Industrial Automation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC25
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce students to principles behind communication systems and techniques in handling analog and digital communication signals
CLO2	To introduce students to the communication protocols and standards that are relevant to industrial automation
CLO3	To provide an overview of state-of-the-art communication protocols used in the industrial environment
CLO4	To provide the relevant knowledge to establish, operate and maintain an industrial data communication network.

Course Content

Introduction to networks and data communications, modulation- amplitude, frequency phase modulation, description of data and signals, media - wired and wireless, connectivity devices, multiplexing, noise in signals and their mitigation, error correction and detection

Principles of interface, serial interface and its standards. Parallel interfaces and buses. Balanced and unbalanced transmission lines, Synchronous and asynchronous communication, RS 232,422,485 standards.

Instrumentation network design and upgrade: Instrumentation design goals, cost optimal and accurate sensor networks. Global system architectures, advantages and limitations of open networks.

Network architectures - LAN, WAN, inter-networks, OSI Reference Model, The operations and protocols of the Internet - TCP/IP, Network security, Internetworking issues, Peer-to-peer communication, Class-based Addressing and Class-less Addressing

Industrial protocols: XON/OFF Signaling, Binary Synchronous Protocol (BSC), HDLC/SDLC protocol, CSMA/CD, CA protocol, OSI implementation for Industrial communications, Industrial control applications: ASCII-based protocol – ANSI –X 3.28 -2.5.

Industrial Ethernet: 10Mbps, 100Mbps Ethernet, Gigabit Ethernet, Industrial Ethernet.
DNP and ModBus protocols, CAN Bus, MQTT

PROFIBUS-PA: Basics, architecture, model, network design and system configuration. PROFIBUS types – PA, DP & FMS and their comparison, Designing PROFIBUS-PA and Foundation Fieldbus segments: general considerations, network design.

Foundation fieldbus: Fieldbus requirement, features, advantages, fieldbus components, types, architecture–physical, data link, application layer, system and network management, wiring, segment functionality checking, function block application process.

References

1.	K. Nolting, Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition, 1995.
2.	B.G. Liptak, Process software and digital networks, CRC press, Florida, 3rd Edition 2011.
3.	Behrouz Forouzan, Data Communications and Networking, Tata McGraw Hill Education, New Delhi, 2010.
4.	Steve Mackay, Edwin Wright, Deon Reynders, John Park, Practical Industrial Data Networks: Design, Installation and Troubleshooting, Newnes, An imprint of Elsevier, 2004.
5.	Andrew S. Tanenbaum, David J. Wetherall, Computer Networks, Prentice Hall of India Pvt. Ltd., 5th Edition. 2011
6.	Lawrence M. Thompson and Tim Shaw, "Industrial Data Communications", Fifth Edition, International Society of Automation, 2015.
7.	Dick Caro, "Automation Network Selection: A Reference Manual", 3rd Edition, Paperback, International Society of Automation, 2016.
8.	David J. Teumim, "Industrial Network Security, Second Edition", International Society of Automation, 2010.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the principles behind analog and digital communication employed in industrial networks
CO2	Illustrate the salient features of state-of-the-art communication protocols and standards relevant to industrial automation
CO3	Elaborate the operation and architecture of various subsystems in industrial communication networks
CO4	Establish and configure a secure industrial communication network based on Ethernet

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
CO2	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
CO3	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
CO4	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1

Course Code	**:**	ICPE37
Course Title	**:**	**Building Automation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC25
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic blocks of Building Management System.
CLO2	To impart knowledge in the design of various sub systems (or modular system) of buildingautomation.
CLO3	To provide insight into some of the advanced principles for safety in automation.
CLO4	To design energy management system.

Course Content

Introduction:
Concept and application of Building Management System (BMS) and Automation, requirements and design considerations and its effect on functional efficiency of building automation system, architecture and components of BMS.

HVAC system:
Different components of HVAC system like heating, cooling system, chillers, AHUs, compressors and filter units and their types. Design issues in consideration with respect to efficiency and economics, concept of district cooling and heating.

Access control and security systems:
Concept of automation in access control system for safety, Physical security system with components, Access control components, Computer system access control – DAC, MAC, and RBAC.

Fire and alarm system:
Different fire sensors, smoke detectors and their types, CO and CO2 sensors, Fire control panels, design considerations for the FA system, concept of IP enabled fire and alarm system, design aspects and components of PA system.

CCTV system and energy management system:
Components of CCTV system like cameras, types of lenses, typical types of cables, controlling system, concept of energy management system, occupancy sensors, fans and lighting controller. Introduction to structural health monitoring and methods employed.

References

1.	Jim Sinopoli, Smart Buildings, Butterworth-Heinemann imprint of Elsevier,2nd Edition., 2010.
2.	Albert Ting Pat So, WaiLok Chan, Intelligent Building Systems, Kluwer Academic publisher, 3rdEdition., 2012.
3.	Reinhold A. Carlson, Robert A. Di Giandomenico, Understanding Building Automation Systems,published by R.S. Means Company, 1991.
4.	Morawski, E, Fire Alarm Guide for Property Managers, Publisher: Kessinger Publishing, 2007.
5.	Building Automation: Control Devices and Applications by In Partnership with NJATC (2008).

6.	Building Control Systems, Applications Guide (CIBSE Guide) by The CIBSE (2000).
7.	Phil Zito., Building Automation Systems a to Z: How to Survive in a World Full of Bas, CreateSpace Independent Pub, 2016.
8.	James Backer (Translator), Viktoriya Moser (Translator), Leena Greefe (Translator).,Building Automation: Communication systems with EIB/KNX, LON and BACnet (Signals and Communication Technology), Springer publication. (2018)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the concept behind building automation.
CO2	Plan for building automation.
CO3	Design sub systems for building automation and integrate those systems.
CO4	Learn to design energy efficient system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE38
Course Title	:	**Nonlinear Control**
Type of Course	:	PE
Prerequisites	:	MAIR courses, ICPC18
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce and elaborate the characteristics of nonlinear systems.
CLO2	To gain understanding in the methods (both classical and modern) of analysis of stability and performance ofnonlinear systems
CLO3	To study the design of controllers as applicable to various case studies in robotics, aerospace and otherdomains.
CLO4	To introduce the notion of complex systems theory and large-scale real-world problems

Course Content

Introduction – Modeling one-dimensional and two-dimensional dynamics, Existence and uniqueness of solutions

Approximate analysis methods: The phase plane, Index theory, Poincare-Bendixson theorem, Describing function analysis

Lyapunov theory for autonomous and non-autonomous systems, Attractors and Basins, Poincare maps

Nonlinear control system design: Sliding control, Basics of Differential geometry, feedback linearization, single- input and multi-input cases

Introduction to Chaos, Bifurcations, Hamiltonian Systems. Cases of Mechanisms, Robotics

References

1.	Jitendra R Raol, Ramakalyan Ayyagari, Control Systems: Classical, Modern, and AI-Based Approaches,CRC Press (Taylor and Francis), 2019
2.	Jean-Jacques E. Slotine, Applied Nonlinear Control, Prentice Hall Englewood Cliffs, New Jersey, 1991.
3.	Khalil, H.K., Nonlinear Systems, Prentice Hall Englewood Cliffs, New Jersey, 3rd Edition, 2002.
4.	Meiss, J.D., Differential Dynamical Systems, SIAM, 2007
5.	Strogatz, S. H., Nonlinear Dynamics and Chaos, with Applications to Physics, Biology, Chemistry andEngineering, 2nd Edition, Westview Press, 2014.
6.	Vidyasagar.M, Nonlinear System Analysis, 2nd Edition, SIAM, 2002.
7.	Sontag, Mathematical Control Theory, 2nd Edition, Springer Verlag, 1998

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Differentiate between linear and nonlinear systems and their behaviour.
CO2	Apply various graphical and analytical tools to describe and analyse nonlinear systems
CO3	Understand Lyapunov theory.
CO4	Learn a range of controller design techniques suitable for nonlinear control systems

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE39
Course Title	:	**System Identification**
Type of Course	:	PE
Prerequisites	:	ICPC13
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce empirical and data-based modeling of large-scale systems.
CLO2	To train the students in parametric and nonparametric statistical models and estimation techniques.
CLO3	To expose to the students, the algorithms and computational overheads involved in large-scale systemmodeling and control.

Course Content

Introduction, Development of parameter estimators, Least-Squares estimation – linear least-squares, generalized least-squares, nonlinear least-squares, Sufficient statistics, Analysis of estimation errors, MMSE, MAP and ML estimators, sequential least-squares, asymptotic properties, General convergence results.

Introduction to system identification: identification based on differential equations, Laplace transforms, frequency responses, difference equations. Stationarity, auto-correlation, cross-correlation, power spectra. Random and deterministic signals for system identification: pulse, step, pseudo random binary sequence (PRBS), signal spectral properties, persistent excitation.

Estimates of the plant impulse, step and frequency responses from identification data, Correlation and spectral analysis for non-parametric model identification, parametric Models-Equation error, output error models, and determination of model order.

Parametric estimation using one-step ahead prediction error model structures and estimation techniques for ARX, ARMAX, Box-Jenkins, FIR, Output Error models. Residual analysis for determining adequacy of the estimated models. Recursive system identification.
Kalman filtering and other nonlinear filters

References

1.	Arun K. Tangirala, Principles of System Identification: Theory and Practice, First Edition, CRC Press, 2014
2.	Karel J. Keesman, System Identification: An Introduction, Springer-Verlag London, 2011
3.	L.Ljung, System Identification: Theory for the User, 2nd Edition, Prentice-Hall, 1999
4.	Y. Zhu, Multivariable System Identification for Process Control, Pergamon, 2001
5.	T. Söderström and P. Stoica, System Identification, Prentice Hall International, Hemel Hempstead, PaperbackEdition, 1994
6.	O. Nelles, Nonlinear System Identification, Springer-Verlag, Berlin, 2001

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Conduct experiments, design suitable inputs and generate data for system identification.
CO2	Identify the model structure and order determination for an unknown process from empirical data.
CO3	Apply estimation techniques for parametric and nonparametric models.
CO4	Identify and validate the model for practical process applications

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE40
Course Title	**:**	**Fault Detection and Diagnosis**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC21
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge in fault detection and identification.
CLO2	To introduce different structure residual technique for the fault identification.
CLO3	To introduce different directional residual technique for the fault identification.
CLO4	To impart the knowledge in soft computation technique based FDI design

Course Content

Introduction to Fault Detection and Diagnosis: Scope of FDD: Types of faults and different tasks of Fault Diagnosis and Implementation - Different approaches to FDD: Model free and Model based approaches. Classification of Fault and Disturbances- Different issues involved in FDD- Typical applications.

Analytical Redundancy Concepts: Introduction- Mathematical representation of Fault and Disturbances: Additive and Multiplicative types – Residual Generation: Detection, Isolation, Computational and stability properties – Design of Residual generator – Residual specification and Implementation.

Design of Structured Residuals: Introduction- Residual structure of single fault Isolation: Structural and Canonical structures- Residual structure of multiple fault Isolation: Diagonal and Full Row canonical concepts – Introduction to parity equation implementation and alternative representation.

Design of Directional Residuals: Introduction – Directional Specifications: Directional specification with and without disturbances – Parity Equation Implementation – Linearly dependent column.

Advanced level issues and design involved in FDD: Introduction of Residual generation of parametric fault – Robustness Issues –Statistical Testing of Residual generators – Application of Neural and Fuzzy logic schemes in FDD – Case study.

References

1.	Janos J. Gertler, Fault Detection and Diagnosis in Engineering systems, Macel Dekker, 2nd Edition,1998.
2.	Rolf Isermann, Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance,Springer Verlag, 2011.
3.	Sachin. C. Patwardhan, Fault Detection and Diagnosis in Industrial Process – Lecture Notes, IITBombay, February 2005.
4.	Rami S. Mangoubi, Robust Estimation and Failure detection. Springer-Verlag-London 1998.
5.	Steven X. Ding, Model based Fault Diagnosis Techniques: Schemes, Algorithms, and Tools,Springer Publication, 2012.
6.	Hassan Noura, Didier Theilliol, Jean-Christophe Ponsart, Abbas Chamseddine, Fault Tolerant Control Systems: Design and Practical Applications, Springer Publication, 2009.
7.	Mogens Blanke, Michel Kinnaert, Jan Lunze, Marcel Staroswiecki., Diagnosis and Fault-TolerantControl, Springer, 2016.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Identify the different type of faults occurred in a system.
CO2	Apply mathematical techniques to detect faults.
CO3	Apply structured and directional techniques for FDI design.
CO4	Apply soft computation technique for FDI development.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	2	2	-	-	-	-	-	3	3	
CO2	3	3	3	3	3	2	2	-	-	-	-	-	3	3	
CO3	3	3	3	3	3	2	2	-	-	-	-	-	3	3	
CO4	3	3	3	3	3	2	2	-	-	-	-	-	3	3	

Course Code	:	ICPE41
Course Title	:	**Process Modelling and Optimization**
Type of Course	:	PE
Prerequisites	:	ICPC18, ICPC21
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge with an emphasis on control system design in the current computer era.
CLO2	To teach the interdisciplinary necessity of linear algebra, control theory, and computer science.
CLO3	To demonstrate that control problems in practice demand efficient algorithms
CLO4	To discuss about algorithms useful for practicing engineers for easy implementation on a range ofcomputers.

Course Content

Review of Linear Algebra – Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product.

Numerical Linear Algebra – Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear system Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations.

Control Systems Analysis – Linear State-space models and solutions of the state equations, Controllability, Observability, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Control Systems Design – Feedback stabilization, Eigen value assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical methods and conditioning, State estimation and Kalman filter.

Large scale Matrix computations, Some Selected Software – MATLAB, MATHEMATICA, SCILAB.

References

1.	B.N. Datta, Numerical Methods for Linear Control Systems, Academic Press/Elsevier, 2005 (Low costIndian edition available including CD ROM).
2.	G.H. Golub and C.F. Van Loan, Matrix Computations, 4th Edition, John Hopkins University Press, 2007 (Lowcost Indian edition available from Hindustan Book Agency).
3.	A. Quarteroni, F. Saleri, Scientific Computing with MATLAB, Springer Verlag, 2003.
4.	www.scilab.org
5.	G. Strang, Linear Algebra and Learning from Data, Wellesley-Cambridge Press, 2019
6.	Jitendra R. Raol, Ramakalyan Ayyagari, Control Systems – Classical, Modern and AI-Based Approaches,CRC Press Taylor and Francis Group

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire skills and numerical solutions of state equations and frequency response computations.
CO2	Develop numerical algorithms for evaluation of controllability, observability, and stability.
CO3	Acquire skills in numerical solutions for conditioning of Lyapunov and algebraic Riccati equation
CO4	Obtain large-scale solutions of control problems.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE42
Course Title	:	**Control System Components**
Type of Course	:	PE
Prerequisites	:	ICPC11, ICPC12
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to various electrical components used in industrial control systems.
CLO2	To expose the students to various mechanical components used in industrial control systems
CLO3	To teach various mechanical and pneumatic systems used in industrial control systems.
CLO4	To introduce the concept of hydraulic pumps, actuators and valves.

Course Content

Motors: Types, working principle, characteristic, and mathematical model of following: Motors AC/DC motors, Brushless DC motor, stepper, servo, linear, Synchronous, Generators, and Alternator

Types, working principle, characteristics, and symbolic representation of following: Switches: Toggle, Slide, DIP, Rotary, Thumbwheel, Selector, Limit, Proximity, Combinational switches, zero speed, belt sway, pull cord. Relays: Electromechanical, Solid state relays, relay packages. Contactors: Comparison between relay and contactor, contactor size and ratings. Timers: On Delay, off delay and Retentive.

Sequencing and Interlocking for motors: Concept of sequencing and Interlocking, Standard symbols used for Electrical Wiring Diagram, Electrical Wiring diagrams for Starting, Stopping, Emergency shutdown, (Direct on line, star delta, soft starter) Protection devices for motors: Short circuit protection, Over load Protection, Over/ under voltage protection, Phase reversal Protection, high temperature and high current Protection, over speed, Reversing direction of rotation, Braking, Starting with variable speeds, Jogging/Inching Motor Control Center: Concept and wiring diagrams

Pneumatic components: Pneumatic Power Supply and its components: Pneumatic relay (Bleed and Non- bleed, Reverse and direct), Single acting and Double acting cylinder, Special cylinders: Cushion, Double rod, Tandem, Multiple position, Rotary Filter Regulator Lubricator (FRL), Pneumatic valves (direction- controlled valves, flow control etc.), Special types of valves like relief valve, pressure reducing etc. Hydraulic components: Hydraulic supply, Hydraulic pumps, Actuators (cylinder and motor), Hydraulic valves

References

1.	M. D. Desai, Control System Components, PHI, 2008.
2.	J. E. Gibson and F. B. Tuteur, Control system components, McGraw Hill, 2013
3.	S. R. Majumdhar, Pneumatic Systems, Tata McGraw-Hill Publisher, 2009.
4.	Meixner H and Sauer E, Intro to Electro-Pneumatics, Festo didactic, 1st Edition,1989.
5.	Hasebrink J P and Kobler R, Fundamentals of Pneumatic Control Engineering, FestoDidactic: Esslinger (W Germany), 1989.
6.	Petruzella, Industrial Electronics, McGraw-Hill International 1st Edition, 1996.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Select and use of different process control components for electrical systems.
CO2	Select and use of different process control components for mechanical system.
CO3	Identify, formulate and solve a problem using pneumatic system in instrumentation and controlengineering.
CO4	Identify, formulate and solve a problem using hydraulic system in instrumentation and controlengineering.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE43
Course Title	:	**Power Electronics**
Type of Course	:	PE
Prerequisites	:	ICPC11, ICPC12
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the students about the theory and applications of power electronic systems for highefficiency, renewable and energy saving conversion systems.
CLO2	To impart knowledge on the characteristics of different power electronics switches, drivers andselection of components for different applications.
CLO3	To teach about the switching behavior and design of the converter, inverter and chopper circuits.
CLO4	To foster the ability to understand the use of power converters in commercial and industrialapplications

Course Content

Power semiconductor switches: SCRs - series and parallel connections, driver circuits, turn-on characteristics, turn off characteristics.

AC to DC converters: Natural commutation, single phase and three phase bridge rectifiers, semi controlled and fully controlled rectifiers, dual converters.

DC to DC converters: Voltage, Current, load commutation, thyristor choppers, design of commutation elements, MOSFET/IGBT choppers, AC choppers.

DC to AC converters: Thyristor inverters, McMurray-Mc Murray Bedford inverter, current source inverter, voltage control, inverters using devices other than thyristors, vector control of induction motors.

AC to AC converters: Single phase and three phase AC voltage controllers, integral cycle control, single phase cyclo-converters - effect of harmonics and Electro Magnetic Interference (EMI).

Applications in power electronics: UPS, SMPS and Drives.

References

1.	Rashid M. H, Power Electronics - Circuits, Devices and Applications, Prentice Hall, New Delhi,4thEdition, 2017.
2.	Dubey G. K, Doradla S.R, Joshi and Sinha R.M, Thyristorised Power Controllers, New AgeInternational Publishers, New Delhi, 2012.
3.	John G. Kassakian, Principles of Power electronics, Addison Wesley, 2010.
4.	P. S. Bimbhra, Power Electronics, Khanna Publishers, 5th Edition, 2012. Vedam Subramanyam K, Power Electronics, New Age International Publishers, New Delhi, 2ndEdition, 2022.
5.	Mohan, Undeland and Robbins, Power Electronics: Converters, Applications and Design, JohnWiley and Sons, New York, 3rd Edition, 2022.
6.	Joseph Vithyathil, Power Electronics, McGraw Hill, New York, 1995.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Work professionally in the area of power and power related fields.
CO2	Have good understanding of the basic principles of switch mode power conversion.
CO3	Apply knowledge of mathematics and engineering and identify formulas to solve power and power electronics engineering problems.
CO4	Choose appropriate power converter topologies and design suitable power stage and feedback controllers for various applications like microprocessor power supplies, renewable energy systems and control of motor drives.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE44
Course Title	:	**Industrial Electric Drives**
Type of Course	:	PE
Prerequisites	:	ICPC11, ICPC12
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce to the students on the concept of employing power convertors for the design of electricdrives.
CLO2	To impart knowledge on the analysis of electric drive system dynamics.
CLO3	To apply the knowledge of drives to choose the right solid-state drive for a given application.
CLO4	To impart knowledge on the design and development of control methods for electric drive systems.

Course Content

Electric Drive System - Dynamics and steady state stability

Components of electrical Drives – electric machines, power converter, controllers - dynamics of electric drive - torque equation - equivalent values of drive parameters - components of load torques types of load - four quadrant operation of a motor –– steady state stability – load equalization – classes of motor duty- determination of motor rating.

DC motor drives – dc motors and their performance (shunt, series, compound, permanent magnet motor, universal motor, dc servomotor) – braking – regenerative, dynamic braking, plugging –Transient analysis of separately excited motor – converter control of dc motors – analysis of separately excited and series motor with 1-phase and 3-phase converters – dual converter –analysis of chopper controlled dc drives – converter ratings and closed loop control – transfer function of self, separately excited DC motors – linear transfer function model of power converters – sensing and feeds back elements – current and speed loops, P, PI and PID controllers – response comparison – simulation of converter and chopper fed DC drive.

Induction motor drives – stator voltage control of induction motor – torque-slip characteristics – operation with different types of loads – operation with unbalanced source voltages and single phasing – analysis of induction motor fed from non-sinusoidal voltage supply – stator frequency control – variable frequency operation – V/F control, controlled current and controlled slip operation – effect of harmonics and control of harmonics.

PWM inverter drives for Induction Motors – multi quadrant drives – rotor resistance control – slip torque characteristic – torque equations, constant torque operation – slip power recovery scheme – torque equation – torque slip characteristics – power factor – methods of improving power factor – limited sub synchronous speed operation – super synchronous speed operation.

Synchronous motor drives – speed control of synchronous motors – adjustable frequency operation of synchronous motors – principles of synchronous motor control – voltage source inverter drive with open loop control – self-controlled synchronous motor with electronic commutation – self -controlled synchronous motor drive using load commutated thyristor inverter.

References

1.	R. Krishnan, Electrical Motor Drives, PHI-2003.
2.	G.K. Dubey, Power semiconductor-controlled drives, Prentice Hall- 2007.
3.	G.K. Dubey, Fundamentals of Electrical Drives, Narosa- 2010.
4.	S.A. Nasar, Boldea, Electrical Drives, Second Edition, CRC Press – 2017.
5.	M. A. ElSharkawi, Fundamentals of Electrical Drives, Thomson Learning.2nd edition 2019.
6.	W. Leohnard, Control of Electric Drives, Springer- 2019.
7.	Murphy and Turnbull, Power Electronic Control of AC motors, Pergamon Press, 2021.
8.	Vedam Subrahmaniam, Electric Drives, TMH-2nd edition 2017.
9.	G. K. Dubey, Power semiconductor-controlled drives, Prentice Hall – 2007.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design suitable power electronic circuit for an electric drive system
CO2	Analyse the dynamics and steady state stability of motors
CO3	Select appropriate control method for the electric drives.
CO4	Select a suitable electric drive for a particular industrial application.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE45
Course Title	**:**	**Smart and Wireless Instrumentation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose to the basics of sensors used in industries.
CLO2	To provide adequate knowledge on smart instrumentation and wireless sensor networks.
CLO3	To impart knowledge on various standard protocols used in wireless instrumentation.
CLO4	To apply the knowledge of sensors, transceivers, controllers and power supplies to implement a WSN for arequired application.

Course Content

Sensor Classification-Thermal sensors -Humidity sensors -Capacitive Sensors-Planar Inter digital Sensors-Planar Electromagnetic Sensors-Light Sensing Technology-Moisture Sensing Technology-Carbon Dioxide (CO2) sensing technology-Sensors Parameters

Frequency of Wireless communication -Development of Wireless Sensor Network based Project-Wireless sensor based on microcontroller and communication device-Zigbee Communication device.

Power sources- Energy Harvesting –Solar and Lead acid batteries-RF Energy /Harvesting-Energy Harvesting from Vibration-Thermal Energy Harvesting-Energy Management Techniques-Calculation for Battery Selection

Brief description of API mode data Transmission-Testing the communication between coordinator and remote XBee- Design and development of graphical user interface for receiving sensor data using C++;
A brief review of signal processing techniques for structural health monitoring.

WSN based physiological parameters monitoring system- Intelligent sensing system for emotion recognition-WSN based smart power monitoring system. Digital light processor (DLP)

References

1.	Subhas Chandra Mukhopadhyay, Smart Sensors, Measurement and Instrumentation, Springer Heidelberg,New York, Dordrecht London, 2013.
2.	Halit Eren, Wireless Sensors and Instruments: Networks, Design and Applications, CRC Press, Taylor andFrancis Group, 2018.
3.	Uvais Qidwai, Smart Instrumentation: A data flow approach to Interfacing, Chapman and Hall, 1st Edition,2019.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand about smart instrumentation system and wireless technologies in WSN
CO2	Design self-diagnosing instrumentation system.
CO3	Identify the issues in power efficient systems and implement energy management techniques in WSN
CO4	Design wireless instrumentation systems for the given requirement.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE46
Course Title	**:**	**Principles of Communication Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC13
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the concept of communication systems.
CLO2	To understand the need for modulation.
CLO3	To impart knowledge in the different methods of analog and digital communications and their significance.
CLO4	To make students familiar with various sources of noise and its characteristics.

Course Content

Modulation - need for modulation. Principles of amplitude modulation: modulation and demodulation of AM, DSBSC, SSB signals, VSB and FDM systems. AM transmitter and Receiver.
Essence of industrial data communication.

Principles of angle modulation: frequency and phase modulation, narrow and wide band FM, generation and demodulation of FM signals. FM transmitter and Receiver.

Pulse modulation systems- Sampling theorem, Pulse Amplitude Modulation (PAM), Pulse width modulation (PWM), Pulse time modulation (PTM): PDM and PPM. TDM systems.

Pulse code modulation- Pulse Code Modulation - quantization - PCM systems- DPCM and Delta modulation. Digital modulation schemes: ASK-PSK-FSK-Generation and detection

Noise-Source and classification, atmospheric noise, thermal noise and shot noise. Noise equivalent bandwidth, noise figure and equivalent noise temperature of a two-terminal network.

References

1.	S. Haykin, Communication Systems, John Wiley and Sons, 4th Edition, 2009.
2.	H. Tauband D. Schilling, Principles of Communication System, Tata McGraw Hill, 4th Edition, 2017
3.	J.S. BeasleyandG.M. Miler, Modern Electronic Communication, Prentice-Hall, 9th Edition, 2009.
4.	B.P. Lathi, Modern Analog and Digital Communication systems, Oxford University Press, 3rd Edition, 2011
5.	B. Carlson, Communication Systems, McGraw Hill Book Co., 5th Edition, 2001.
6.	Sam Shanmugam, Digital and analog Communication Systems, John Wiley, 2019.
7.	John G. Proakis, Masoud Salehi - Fundamentals of Communication Systems, 2nd Edition, Pearson, 2015.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Explain the basic concepts of communication systems.
CO2	Understand various analog and pulse modulation and demodulation techniques.
CO3	Understand digital modulation and demodulation techniques
CO4	Describe different types of noise and calculate the noise equivalent bandwidth and noise figure of a two-port network.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE47
Course Title	**:**	**Multi Sensor Data Fusion**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamentals of data fusion and multisensor data fusion
CLO2	To expose the students to the different techniques used in sensor data fusion.
CLO3	To impart skills needed to develop and apply data fusion algorithms.
CLO4	To expose the students, the state of the art in multi sensor/ source integration, target tracking and identification.

Course Content

Multisensor data fusion: Introduction, sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta - heuristics. Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration.

Estimation: Kalman filtering, practical aspects of Kalman filtering, extended Kalman filters. Decision level identify fusion. Knowledge based approaches.

Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

High performance data structures: Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems with in dependability bounds. Implementing data fusion system.

References

1.	David L. Hall, Sonya A H McMullen, Mathematical techniques in Multisensor data fusion, Artech House,Boston, 2nd Edition, 2004.
2.	R.R. Brooks and S.S. Iyengar, Multisensor Fusion: Fundamentals and Applications with Software, PrenticeHall Inc., New Jersey, 1998.
3.	Jitendra R. Raol, Multi sensor data fusion with MATLAB, CRC Press, 2010.
4.	Arthur Gelb, Applied Optimal Estimation, M.I.T. Press, 2012.
5.	James V. Candy, Signal Processing: The Model Based Approach, McGraw –Hill Book Company, 1988.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the importance of data fusion
CO2	Identify and characterise the principle components of data fusion and information systems.
CO3	Apply the concepts of data fusion in sensing.
CO4	Select fusion techniques appropriate to system and mission needs.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	:	ICPE48
Course Title	:	**Energy Harvesting Techniques**
Type of Course	:	PE
Prerequisites	:	ICPC14
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce basic energy harvesting techniques using smart materials and structures andcombining with mechanisms.
CLO2	To impart knowledge in the design of power converter circuits for ambient energy harvesters.
CLO3	To introduce mathematical modelling of piezoelectric based energy harvesters.
CLO4	To introduce on certain case studies.

Course Content

Energy Harvesting Basics, Analysis of ambient energy- Vibration, shock, wind, Thermal, RF, energy transducers- electromagnet, photovoltaic, piezoelectric and other smart materials- working principle, equivalent circuit models.

Vibrational energy harvesting- Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvester for Persistent Base Motion-lumped parameter model, correction factors, coupled distributed parameter model, modelling assumptions, closed form solution for unimorph and bimorph configuration, harvesting techniques for broadband excitation

Piezoelectric energy harvesting circuits-low power rectifier circuits with resistive, linear and nonlinear reactive input impedance, piezoelectric pre-biasing, self-tuning, DC-DC switch mode converters, impedance matching circuits for maximum output power.

Electromagnetic energy harvesting- Wire wound coil properties, micro fabricated coils, magnetic materials, scaling of electromagnetic vibration generators and damping, maximizing power from an EM generator, micro and macro scale implementation.

Thermoelectric Energy harvesting- Harvesting Heat, thermoelectric theory, thermoelectric generators and its efficiency, matched thermal resistance, heat flux, design consideration, optimization for maximum output, matching thermoelectric to heat exchangers- thin film devices.

Case study- harvester driven by muscle power, knee joint movement harvesting, etc. strategies to improve energy conversion efficiency for different ambient sources.

References

1.	Shashank Priya and Daniel J. Inman, Energy Harvesting Technologies, Springer-Verlag New York,Inc., 1st Edition, 2010.
2.	Danick Briand, Eric Yeatman, and Shad Roundy, Micro energy Harvesting, Wiley-VCH VerlagGmbH and Co, 2015.
3.	Stephen Beeby, Neil white, Energy Harvesting for Autonomous Systems, Artech house,Norwwood,1st Edition ,2010.
4.	Alper Erturk and Daniel J Inman, Piezoelectric Energy Harvesting, John Wiley and Sons.Ltd.1stEdition ,2011.
5.	Tom J. Kazmiershi, Steve Beeby, Energy Harvesting System, Principles, Modelling andApplication, springer, New York, 2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Comprehend in the concept of various ambient energy harvesting techniques.
CO2	Design optimal power converting circuits for different harvesters.
CO3	Design vibration, electromagnetic and thermoelectric based energy harvesters.
CO4	Apply the energy harvesting concepts to common engineering problems.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE49
Course Title	**:**	**Smart Materials and Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize the students with the different smart materials and their characteristics.
CLO2	To expose the students to understand the functionalities through the mathematical equations.
CLO3	To teach the students about the significant features of smart materials in sensing, actuation andcontrol.
CLO4	To teach the students to design and develop smart structures using smart material-based actuatorsand sensors.

Course Content

Introduction to Smart Materials and Structures: smart materials for sensing and actuation, the role of Smart Materials in developing Intelligent Systems and Adaptive Structures. Piezoelectric Materials: constitutive relationship, electromechanical coupling coefficients, piezoelectric constants, piezoceramic materials, variation of coupling coefficients in hard and soft piezoceramics, polycrystalline vs single crystal piezoelectric materials, polyvinyldene fluoride, piezoelectric composites.

Actuators and Sensor based on Piezoelectric Materials: Induced Strain actuation model, Unimorph and Bimorph Actuators, Actuators embedded in composite laminate, Impedance matching in actuator design, Feedback Control, Pulse Drive, Resonance Drive, Piezoelectric as a Sensor and its applications.

Magnetostrictive Materials – constitutive relationship, magneto-mechanical coupling coefficients, Joule Effect, Villari Effect, Matteuci Effect, Wiedemann effect, Giant magnetostriction in Terfenol-D, Terfenol- D particulate composites, Galfenol and Metglas materials. Magnetostrictive Mini Actuators, Thermal instabilities, discretely distributed actuation, Manetostrictive Composites. Magnetostrictive Sensors

Shape Memory Alloys (SMA) – Phase Transformations, Basic Material Behavior and Modelling Issues, A Comprehensive Model for Uniaxial Stress, Properties of SMAs for Biomedical Applications Shape Memory Alloy based actuators for Shape Control. Electro-active Polymers (EAP): Electro-active Polymers for Work-Volume Generation, EAP as actuator and sensor. Electro-Rheological (ER) fluids, Magneto- Rheological (MR) fluids.

Integration of Smart Sensors and Actuators to Smart Structures **–** Optimal Placement of Sensors and Actuators, Design of Controller for Smart Structure, Techniques of Self-Sensing using piezoelectric and SMA, SMA based encoders, micro robotics, micro devices. Case Studies to Advanced Smart Materials: Active Fiber Composites (AFC), Energy Harvesting Actuators and Energy Scavenging Sensors, Self- healing Smart Materials

References

1.	Mukesh V Gandhi, Brian S Thompson, Smart Materials and Structures, Chapman and HallPublishers, 1st Edition, 1992.
2.	Mel Schwartz, Encyclopaedia of smart materials, John Wiley and Sons, 1st Edition,2002.
3.	Srinivasan A.V., Michael McFarland D., Smart Structures Analysis and Design, CambridgeUniversity Press, 1st Edition, 2010.
4.	Culshaw B., Smart structures and Materials, Artech house, 1st Edition, 2004.
5.	Leo, D.J. Engineering Analysis of Smart Material Systems, John Wiley and sons, 1st Edition 2008.
6.	R.C. Smith, smart material systems: model development, frontiers in applied mathematics, SIAM,2005.
7.	H. Janocha, Adaptronics and smart structures: Basics, Materials, Design, and Applications,springer, 2nd Edition, 2007.
8.	www.iop.org/sms
9.	http:jim.sagepub.com.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire knowledge about the smart materials, their characteristics and design aspects.
CO2	Design, model and control smart materials-based structures/systems, through simulation andexperimentation.
CO3	Choose appropriate smart materials for sensing and actuation.
CO4	Analyze and design techniques, to offer solutions to industrial problems using smart materials.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE50
Course Title	**:**	**Hydraulics and Pneumatics**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide an understanding of the working of hydraulic and pneumatic systems.
CLO2	To provide an understanding of energy transfer in hydraulic actuators and motors
CLO3	To provide knowledge about controlling components of hydraulic and pneumatic systems.
CLO4	To provide knowledge of design of hydraulic and pneumatic systems and analyze them.

Course Content

Introduction to Hydraulic Power: Pascal's law and problems on Pascal's Law, continuity equations, Introduction to conversion of units, Structure of Hydraulic Control System. The Source of Hydraulic Power: Pumps Pumping theory, pump classification, gear pumps, vane pumps, piston pumps, pump performance, pump selection. Variable displacement pumps. Hydraulic Actuators: Linear Hydraulic Actuators [cylinders], Mechanics of Hydraulic Cylinder loading.

Hydraulic Motors: Hydraulic Rotary Actuators, Gear motors, vane motors, piston motors, Hydraulic motor theoretical torque, power and flow rate, hydraulic motor performance. Control Components in Hydraulic Systems: Directional Control Valves – Symbolic representation, Constructional features, pressure control valves – direct and pilot operated types, flow control valves.

Hydraulic Circuit Design and Analysis: Control of single and double – acting hydraulic cylinder, regenerative circuit, pump unloading circuit, counter balance valve application, hydraulic cylinder sequencing circuits. Cylinder synchronizing circuits, speed control of hydraulic cylinder, speed control of hydraulic motors, Accumulators. Maintenance of Hydraulic Systems: Hydraulic oils; desirable properties, general type of fluids, sealing devices, reservoir system, filters and strainers, problem caused by gases in hydraulic fluids, wear of moving parts due to solid particle contamination, temperature control, trouble shooting.

Introduction to Pneumatic Control: Choice of working medium, characteristics of compressed air. Structureof pneumatic control system. Compressed air: Production of compressed air – compressors, preparation of compressed air- Driers, filters, regulators, lubricators, distribution of compressed air. Pneumatic Actuators: Linear cylinders – types, conventional type of cylinder working, end position cushioning, seals, mounting arrangements applications.

Directional Control Valves: Symbolic representation as per ISO 1219 and ISO 5599. Design and constructional aspects, poppet valves, slide valves spool valve, suspended seat type slide valve. Simple Pneumatic Control: Direct and indirect actuation pneumatic cylinders, use of memory valve. Flow control valves and speed control of cylinders supply air throttling and exhaust air throttling, use of quick exhaust valve. Signal Processing Elements: Use of Logic gates – OR and AND gates pneumatic applications, practical examples involving the use of logic gates, Pressure dependent controls types construction– practical applications, time dependent controls – principle, construction, practical applications.

References

1.	Anthony Esposito, Fluid Power with applications, Pearson education, Inc., 5th Edition, 2008.
2.	Andrew Parr, Pneumatics and Hydraulics, Jaico Publishing Co. 2005.
3.	Dr. Niranjan Murthy and Dr.R.K. Hegde, Hydraulics and Pneumatics, Sapna Publications, 2013.
4.	Majumdar S.R., Oil Hydraulics Systems - Principles and Maintenance, Tata McGraw-Hill, 2017.
5.	Majumdar, S.R., Pneumatic Systems – Principles and Maintenance, Tata McGraw Hill, 2017.
6.	Srinivasan. R, Hydraulic and Pneumatic Control, Tata McGraw - Hill Education, 2nd Edition, 2019.
7.	Shanmugasundaram.K, Hydraulic and Pneumatic controls, ChandandCo,2006.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire knowledge about working of hydraulic and pneumatic systems.
CO2	Identify the controlling components of hydraulic and pneumatic systems.
CO3	Analyse and compile the design of hydraulic and pneumatic systems
CO4	Demonstrate the need of pressure and time dependent controls.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE51
Course Title	:	**Engineering Mechanics**
Type of Course	:	PE
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamentals of mechanics and machines to the instrumentation and control engineeringstudents.
CLO2	To explain the application of basic mechanical science concepts
CLO3	To apply different physical principles to the analysis of mechanics and machines
CLO4	To identify the different element of a mechanical system and write the mathematical equations for them.

Course Content

Forces and equilibrium – Free body diagram – Forces in equilibrium. Stress and strain – Poisson's ratio – Bulk modulus. Beams – Types of beams – Bending moment and shearing force – Bending stresses. Torsion – Torsion of circular shafts – Transmission of power.

Strain energy – Dynamic loading – Strain energy due to shear – Impact torsional loading – Strain energy due to bending – Impact loading of beams.

Linear and angular motion – Linear motion – Curvilinear motion – Relative velocity – Angular motion – Torque and angular motion – Balancing of rotational masses – Momentum – Work and energy.

Mechanisms – Velocity diagrams – Acceleration diagrams. Coriolis acceleration. Flywheels. Machines – Transmission of rotational motion. Geared systems – Gear trains. Friction – Friction clutches. Bearings. Belt drives. Gyroscopic motion – Gyroscopic couple.

Free vibrations – Simple harmonic motion. Linear and torsional vibrations of an elastic system. Transverse vibrationsof beams – Whirling of shafts.

Damped and forced oscillations – Free oscillations – Damped oscillations – Undamped forced oscillations – Damped forced oscillations.

Degrees of freedom – Two rotor system – Forced vibrations.

References

1.	Bolton WC, Mechanical Science, Wiley-Blackwell Publishing, 3rd Edition. 2006.
2.	R. C. Hibbeler, Engineering Mechanics - Statics, Pearson Education Inc. 14th Edition. 2015.
3.	R. C. Hibbeler, Engineering Mechanics - Dynamics, Pearson Education Inc. 14th Edition 2015.
4.	Timoshenko and Young, Engineering Mechanics, McGraw-Hill Book Company, 5th Edition, 2016.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyze simple mechanisms and their principles of operation.
CO2	Write the mathematical equations for static and dynamic loading in simple mechanical systems.
CO3	Write the equations for energy and power in simple mechanical systems.
CO4	Analyze free and forced oscillations in simple dynamic systems.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE52
Course Title	**:**	**Software Design Tools for Sensing and Control**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the software tools available for sensor and control system design.
CLO2	To teach the analytical and numerical modelling of various sensors in macro, meso and micro scaleand to study its characteristics through simulation.
CLO3	To expose the students to modelling of physical systems, design and evaluation of various controlmethods.
CLO4	To expose the students to real time control implementation platforms and to practice onimplementation of simple controllers.

Course Content

Software tools for sensor design: Introduction to history of sensor design software tools, importance and need of software tools. Recent developments in sensor design and analysis software tools. Introduction to COMSOL Multiphysics. Structural Mechanics: Analysis of mechanical structures to static or dynamic loads. Stationary, transient, eigenmode/modal, parametric, quasi-static and frequency-response analysis. Electrical: AC/DC Module for simulating electric, magnetic, and electromagnetic fields in static and low- frequency applications. Design and simulation of sensors and actuators using COMSOL.

Software tools for micro sensor design: Introduction to IntelliSuite, mechanism design, development of sensors and actuators. Introduction to Coventorware, Description of main modules, Architect, Designer, Analyzer and Integrator. System-level and physical-level design approaches. Introduction to meshing and result visualization. Design and simulation of sensors using Coventorware.

Software tools for control design: Introduction to MATLAB, Simulink and Scilab. Introduction to toolboxes. Control design problems using classical control. Control design problems using state space approach.

Implementation of controllers in real time: Introduction to various hardware platforms, control design and implementation for electrical/mechanical/electromechanical/chemical processes using dSPACE, LabVIEW and OPAL-RT.

References

1.	Roger W. Pryor, Multiphysics Modeling Using COMSOL®: A First Principles Approach, Jonesand Bartlett Publishers, 1st Edition, 2011.
2.	Tamara Bechtold, Gabriela Schrag and Lihong Feng, System-level Modeling of MEMS, Wiley-VCH verlag GmbH and Co, 1st Edition, 2013.
3.	Holly Moore, MATLAB for Engineers, Pearson Education, 6th Edition, 2022.
4.	Brian Hahn and Daniel Valentine, Essential MATLAB for Engineers and Scientists, Elsevier,Academic press, 7th edition, 2019.
5.	Mehrzad Tabatabaian, COMSOL 5 for Engineers, Mercury Learning and Information, 1stEdition,2015.
6.	S R Otto and J P Denier, An Introduction to Programming and Numerical Methods in MATLAB,Springer-verlag, 1st Edition,2005.
7.	Stephen J Chapman, MATLAB Programming for Engineers, Bookware Companion Series, 7thEdition, 2024.
8.	Amos Gilat, MATLAB – An Introduction with Applications, John Wiley and Sons, Inc., 6th Edition,2017.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Select an appropriate software tools for sensor and actuator design.
CO2	Design, model and simulate various sensing and actuating mechanisms.
CO3	Design and evaluate the performance of cascade and state-pace controller
CO4	Acquire knowledge in the selection and usage of hardware for real time implementation ofcontrollers.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	1	1	1	1	1	1	1	1	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE53
Course Title	**:**	**Numerical Methods**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Numerical methods for Solving Linear Systems
CLO2	Numerical methods to solve equations of one variable as well as system of equationswith two variables.
CLO3	Interpolating Polynomials and best curve fitting methods for the given data.
CLO4	Numerical differentiation and integration
CLO5	Numerical solutions of Ordinary Differential Equations.

Course Content

Digital representation of numbers, Finite precision arithmetic, Machine Precision, Measuring errors, convergence of iterative sequences, Taylor series, Order Notation. Numerical Solution of $(x) = 0$: Bisection method, Secant method, Newton's method, Newton's method for $(x, y)=0$, $g(x, y) =0$. Order of convergence.

Solution of linear system of equations –Direct method: Gaussian elimination, Gauss-Jordan methods, LU Decomposition method-Crout's method. Algorithm for tri-diagonal system, Iterative method: Jacobi and Gauss-Seidal's method -Sufficient conditions for convergence - Eigen Value problems- Power method.

Interpolation: Lagrange's method, Newton's divided difference, forward and backward difference interpolation method. Least squares fitting of a curve to data-Polynomial curve fitting, exponential curve ($y = ae^{bx}$) fitting to data.

Numerical Differentiation based on interpolation and finite difference. Numerical Integration-Closed and open type integration rules-Trapezoidal rule, Simpson's1/3ruleand3/8 rule, mid-point and two-point rule. Adaptive integration based on Simpson's Rule. Gauss quadrature methods, Integrals with infinite limits $\int_0^{\infty} e^{-}(x)dx$).

Numerical solution of ordinary differential equations: Taylor's series method, Single step method- Euler's method, Euler's modified method, Fourth order Runge-Kutta method. Fourth order R-K method for simultaneous equations and 2nd order ODE. Multi step methods:Milne's and Adams method.

References

1.	Jain, M.K., Iyengar, S.R. and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, New Age International, 2019.
2.	S.S. Sastry, Introductory methods of numerical Analysis, 4/e, Prentice Hall of India, New Delhi, 5th edition, 2012.
3.	David Kincaid and Ward Cheney, Numerical Analysis, 3rd edition, American Mathematics Society, (Indian edition) –2012.
4.	Gerald, C.F., and Wheatley, P.O., Applied Numerical Analysis, Addison-Wesley Publishing Company, 7th edition, 2007.
5.	G Dahlquist and A Bjorke, Numerical Methods in Scientific Computing, vol. 1 SIAM,2008

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Compute numerical solution of given system by direct and iterative methods.
CO2	Compute largest eigenvalue and its corresponding eigenvector of matrix A.
CO3	Interpolate function and approximate the function by polynomia and compute differentiation and integration
CO4	Compute numerical solution of ordinary differential equations by finite difference method.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE54
Course Title	:	**Analytical Instrumentation**
Type of Course	:	PE
Prerequisites	:	ICPC14, ICPC17
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To teach the students about the analysis of materials which is an important requirement of processcontrol and quality control in industry
CLO2	To expose the students to principles of various analytical methods.
CLO3	To impart knowledge on various spectroscopic instruments used in the analysis of materials
CLO4	To introduce the concept of analytical instruments used in drug and pharmaceutical lab
CLO5	To introduce different analytical instruments used in environmental pollution monitoring

Course Content

Electromagnetic radiation and its interaction with matter – Beer's law – Spectral methods of analysis – Absorption spectroscopy – Radiation sources – Monochromators – Filters – Prisms – Diffraction gratings –Detectors – Choice of solvents. UV-Visible spectrometers – single-beam and double-beam instruments.

Infrared spectrophotometer – IR sources – Cells – detectors – sample preparation. Analysis using Attenuated Total Reflectance (ATR). Atomic absorption spectrometry (AAS) – Wavelength choice – Sources – Cells – Detectors. Flame emission spectrometry. Atomic fluorescence spectrometry.

X-ray spectroscopy – X-ray absorption methods – X-ray fluorescence methods – X-ray diffraction. Radioactive measurement – Units of radioactivity – Application of radio-nuclides in analysis – Radioactivity detectors. Nuclear magnetic Resonance (NMR) spectroscopy – Basic principles – Continuous-wave NMR spectrometer – Pulsed Fourier Transform NMR spectrometer – NMR applications.

Sampling – Sample collection for gas, liquid, and solid analysis. pH measurement – Basic principles –Ion selective electrodes – Glass and reference electrodes – pH meter and its calibration. Electrical conductivity measurement – Measuring circuit – Water and steam purity measurement using electrical conductivity. Oxygen measurement – Paramagnetic oxygen analyzers – Ceramic electrode for high temperature oxygen measurement – Dissolved oxygen measurement.

Flue gas analysis for pollution control – Measurement of CO, carbon di-oxide, NOX and SOX, dust and smoke measurement. Chromatography – Basic principles of liquid and gas chromatography – Column details – Detectors for chromatography – Thermal conductivity detector – Flame ionization detector – Flame photometric detector – Electron capture detector – Effect of temperature programming – High pressure liquid chromatography (HPLC)

References

1.	Braun, Robert D., Introduction to Instrumental Analysis, Pharma Book Syndicate, Hyderabad, 2ndEdition, 2012.
2.	Ewing, G.W., Instrumental Methods of Analysis, McGraw Hill, Singapore, 5th Edition, 1992
3.	Jain, R.K., Mechanical and Industrial Measurements, Khanna Publishers, Delhi, 1999.
4.	Bela G. Liptak, Instrument Engineers' Handbook, Volume One: Process measurement and analysis,CRC Press, 4th Edition, 2003.
5.	Considine, D.M. Process/Industrial Instruments and Controls Handbook, McGraw Hill, Singapore,4th Edition, 1993.
6.	Sherman, R.E. and Rhodes L.J., Analytical Instrumentation, ISA Press, New York, 1996.
7.	Khandpur R.S, Handbook of Analytical Instruments, Tata McGraw Hills, 2nd Edn.2006

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Appreciate the relevance of material sampling and analysis in process control and quality control inindustry.
CO2	Understand the physical principles behind the various widely used analytical methods in theindustry.
CO3	Understand the important components and concepts of various spectroscopic instruments and instruments used in drug and pharmaceutical lab and pollution monitoring.
CO4	Select an appropriate analytical instrument for an industrial requirement.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	-	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	-	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	-	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	-	-	-	-	2	2	2	3	3	3	-

Course Code	**:**	ICPE55
Course Title	**:**	**Data structures and algorithms**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce first level topics covering basics in Algorithms and Data Structures
CLO2	To provide examples for various design paradigms
CLO3	To identify the basic properties of graphs and trees and model simple applications

Course Content

Introduction to problem solving, Mathematical preliminaries, Growth of functions, time complexity and space complexity, worst-case and average-case analyses, use of order notations and related results, recurrence relations: substitution method, recurrence trees, Master's theorem and its applications.

Insertion-Sort, Divide and Conquer Strategy and Merge-Sort, Heap-sort, Quick-sort, Randomized versions ofQuick-sort, sorting in linear time,

Elementary data structures (Arrays, Stacks, Queues, Linked Lists), Hash tables, Binary search trees,Advanced data structures: B-Trees, Fibonacci heaps, Data structures for disjoint sets (for applications in control system design).

Dynamic Programming, Greedy Algorithms, B-Trees, Elementary Graph Algorithms, Arithmetic Circuits, Matrix Operations, Linear Programming, Polynomials and FFT, Number Theoretic Algorithms

Advanced Topics – NP-Completeness, Approximation Algorithms, Randomized Algorithms, Applications in Engineering – Control Systems, VLSI Design, etc.

References

1.	Cormen TH, Leiserson CE, \and Rivest RL, Introduction to Algorithms, 3rd Edition, Prentice Hall ofIndia. (This book is popularly called as C-L-R)
2.	Ellis Horowitz, Sartaj Sahni and Sanguthevar Rajasekaran, —Fundamentals of ComputerAlgorithms‖, Second Edition, Universities Press, 2008.
3.	Kenneth A. Berman and Jerome L. Paul, Algorithms, Cengage Learning India, 2010.
4.	Alfred V Aho, John E Hopcroft and Jeffrey D Ullman, —The Design and Analysis of ComputerAlgorithms‖, First Edition, Pearson Education, 2006.
5.	Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, Introduction toAlgorithms, 4th Edition, MIT Press, PHI, 2021.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Use linear and nonlinear data structures to solve real-time problems
CO2	Apply basic searching and sorting techniques in different application domains
CO3	Apply basic soring techniques in different application domains
CO4	Use design strategies to solve complex problems

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE56
Course Title	**:**	**Nuclear Instrumentation**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14, ICPC17
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic concept of radioactivity, properties of alpha, beta and gamma rays
CLO2	To study various radiation detectors, detector classification
CLO3	To study the electronics and counting systems
CLO4	To study applications of nuclear instrumentation in medicines, Industry and in Agriculture

Course Content

Radioactivity: General properties of Nucleus, Radioactivity, Nature of Nuclear Radiation's, Properties of Alpha, Beta and Gamma rays, Natural and artificial radio-activity. Radioactivity Laws, Half-life period, radioactive series, Isotopes and Isobars, Various effects- photoelectric, Compton scattering and pair production, stopping power and range of charged nuclear particles

Radiation Detectors: Techniques for radiation detection, Detectors for Alpha, beta and gamma rays, Detector classification, Gas filled detectors - volt ampere characteristics, Ionization chamber, Proportional counter, Geiger Muller counter, designing features, Scintillation detectors, Photomultiplier tube, dark currents, pulse resolving power, efficiency of detection, Solid state detectors (Lithium ion drifted – Si-Li, Ge-Li, Diffused junction, surface barrier detectors)

Electronics and Counting systems**:** Pre-amp, shaping amplifiers, Discriminators, Scalars and count rate meters, Pulse shaping, peak stretchers, photon counting system block diagram, single channel analyser SCA (pulse height analyser - PHA), Coincidence detection

Nuclear Spectroscopy systems: Factors influencing resolution of gamma energy spectrum, Energy resolution in radiation detectors, Multichannel analysers (MCA), Role of Nuclear ADC's – performance parameters.

Radiation Monitors and Application in Medicines**:** Radiation uptake studies – block diagram and design features. Gamma camera – design, block diagram, medical usage. Nuclear instrumentation for health care, Radiation Personnel Health Monitors like neutron monitors, Gamma Monitors, Tritium monitors, Iodine monitors and PARA (particulate activity radiation alarms).

Applications in Industry**:** Basic Nuclear Instrumentation system – block diagram, Personal monitors like Thermo Luminescence Detectors (TLD). Dosimeters, Tele-detectors. Nuclear Instrumentation for power reactor. Nuclear Instrumentation for Toxic fluid tank level measurement, weighing, thickness gauges, Agriculture applications like food irradiation, Underground Piping Leak detection, water content measurement etc.

References

1.	G.F. Knoll, Radiation Detection and Measurement, 2nd Edition, John Wiley and Sons,1998.
2.	P.W. Nicholson, Nuclear Electronics, John Wiley, 1998.
3.	S.S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley Easter Limited,1986.
4.	Gaur and Gupta, Engineering Physics, Dhanpat Rai and Sons, 2001.
5.	Irvin Kaplan, Nuclear Physics , Narosa, 1987.
6.	M.N. Avdhamule and P.G. Kshirsagar, Engineering Physics, S. Chand and Co., 2001.
7.	R.M. Singru, Introduction to Experimental Nuclear Physics, Wiley Eastern Pvt. Ltd., 1974.
8.	B.R. Bairi, Balvinder Singh, N.C. Rathod, P.V. Narurkar , Hand Book of Nuclear Medical Instruments, TMH Publishing New Delhi, 1974.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	The students get well versed with construction and working of various radiation detectors.
CO2	Students also get thorough knowledge of electronics and counting systems used in nuclear instrumentation
CO3	Understand the radiation monitors in medical applications
CO4	Students get detailed information about applications of nuclear instrumentation in medicine, industry etc.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	:	ICPE57
Course Title	:	**Condition Monitoring**
Type of Course	:	PE
Prerequisites	:	ICPC14, ICPC17
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the importance of condition monitoring in the automotive, structural and processindustries
CLO2	To make understand the role of different sensors and signal conditioning techniques in the conditionmonitoring
CLO3	To expose to wireless sensor networks and their protocols
CLO4	To provide knowledge of machine learning and its relation with condition monitoring
	To provide real time exposure in continuous condition monitoring

Course Content

Introduction: Motivation for condition monitoring, Historical overview – Reactive Maintenance, Scheduled Maintenance, Condition Based Preventive Maintenance, Predictive Maintenance and Digital Twin. Structural Health Monitoring (SHM) – Advantages and Challenges. Machinery Fault Diagnosis - Principles, Fault diagnostics and Prognostics. Environmental Monitoring – Air, Water, Soil contamination. Local and Global health monitoring.

Sensors and Signal Conditioning Techniques: Vibration Monitoring – Accelerometers, Types. Temperature Monitoring – Thermocouple, RTD (Resistance Temperature Detector), Infrared Thermography. Fiber Optic Sensors, NDT (Non-Destructive Testing) – Eddy Current Testing, Magnetic Particle Inspection (MPI), Dye Penetration, Acoustic Emission and its applications. Smart Sensing for condition monitoring. Data Acquisition Systems, Application of various signal processing methods – Time domain analysis, Frequency domain analysis, Non-stationary signal analysis.

Role of Wireless Sensor Networks in Condition Monitoring: Introduction to WSN – Network Topologies, Advantages and Challenges. IEEE 802.11 Standard. Wireless Network Protocols – Bluetooth, WiFi, Zigbee, 5G, NFC, RFID. RFID Technology - General Block diagram, Applications in Condition Monitoring. Introduction to Energy Harvesting Techniques. Comparison of Wired and Wireless Condition Monitoring.

Machine Learning (ML) for Condition Monitoring :Introduction, Review of Linear Algebra, Logistic Regression, Regularization, Neural Networks – Representation and Learning, Machine Learning System Design, Support Vector Machines, Unsupervised Learning, Dimensionality Reduction, Anomaly Detection. Application to Condition Monitoring.

Applications and Case Studies:Future of Condition based Monitoring – SHM and Rotating Machinery[2], Railway – Noise and Vibration Monitoring, Crack Detection in Composites (Aerospace structures), Condition Monitoring in – Agriculture, Biomedical, Food Processing and Packaging, Pipelines and Piping.
Case study 1 – Machine Fault Diagnosis using Vibration analysis (Wired sensing).
Case study 2 – Crack characterization of metallic structures using RFID Sensor (Wireless sensing).

References

1.	Philip Wild, Industrial Sensors and Applications for Condition Monitoring, Professional Engineering Publishing, April 20, 1994.
2.	Fu Ko Chang, Structural Health Monitoring: Current Status and Perspectives, Stanford University - 1997.
3.	Amiya Ranjan Mohanty, Machinery Condition Monitoring Principles and Practices, CRCpress, Taylor and Francis ,2017.
4.	Andrew Ng, Machine Learning Yearning, 2018.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Familiar with the need of condition monitoring in the automotive, structural and process industries and gain knowledge of sensors and signal conditioning techniques
CO2	Understand the operation of wireless sensor networks and their deployment.
CO3	Gain the knowledge of machine learning and its application in condition monitoring.
CO4	Develop/Design an application specific condition monitoring system for fault diagnosis andPrognosis.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE58
Course Title	:	**Safety Instrumented system**
Type of Course	:	PE
Prerequisites	:	ICPC17
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To make the students aware of basic concepts of safety instrumented system, standards and riskanalysis techniques.
CLO2	To make the students understand different layers of protection.
CLO3	To make student conscious about safety instrumentation applications.
CLO4	To make the students aware of potential events and impact of failures.
CLO5	To make students aware of design, installation and maintenance procedures.

Course Content

INTRODUCTION : Safety Instrumented System (SIS): need, features, components, difference between basic process control system and SIS - Risk: how to measure risk, risk tolerance, Safety integrity level, safety instrumented functions - Standards and Regulation – HSE-PES, AICHE-CCPS, IEC-61508, ANSI/ISA-84.00.01-2004 (IEC 61511 Mod) and ANSI/ISA – 84.01-1996, NFPA 85, API RP 556, API RP 14C, OSHA (29 CFR 1910.119 – Process Safety Management of Highly Hazardous Chemicals – SIS design cycle - Process Control vs. Safety Control.

PROTECTION LAYERS AND SAFETY REQUIREMENT SPECIFICATIONS : Prevention Layers: Process Plant Design, Process Control System, Alarm Systems, Procedures, Shutdown/Interlock/Instrumented Systems (Safety Instrumented Systems – SIS), Physical Protection - Mitigation Layers: Containment Systems, Scrubbers and Flares, Fire and Gas (FandG) Systems, Evacuation Procedures - Safety specification requirements as per standards, causes for deviation from the standards.

SAFETY INTEGRITY LEVEL (SIL) Evaluating Risk, Safety Integrity Levels, SIL Determination Method : As Low As Reasonably Practical (ALARP), Risk matrix, Risk Graph, Layers Of Protection Analysis (LOPA) – Issues related to system size and complexity – Issues related to field device safety – Functional Testing.

SYSTEM EVALUATION :Failure Modes, Safe/Dangerous Failures, Detected/Undetected Failures, Metrics: Failure Rate, MTBF, and Life, Degree of Modeling Accuracy, Modeling Methods: Reliability Block Diagrams, Fault Trees, Markov Models - Consequence analysis: Characterization of potential events, dispersion, impacts, occupancy considerations, consequence analysis tools - Quantitative layer of protection analysis: multiple initiating events, estimating initiating event frequencies and IPL failure probabilities.

CASE STUDY : SIS Design check list - Case Description: Furnace/Fired Heater Safety Shutdown System: Scope of Analysis, Define Target SILs, Develop Safety Requirement Specification (SRS), SIS Conceptual Design, Lifecycle Cost Analysis, Verify that the Conceptual Design Meets the SIL, Detailed Design, Installation, Commissioning and Pre-start-up Tests, Operation and Maintenance Procedures.

References

1.	Paul Gruhn and Harry L. Cheddie, Safety Instrumented systems: Design, Analysis and Justification,ISA, 2nd edition, 2018.
2.	Eric W. Scharpf, Heidi J. Hartmann, Harlod W. Thomas, Practical SIL target selection: Risk analysis per the IEC 61511 safety Lifecycle, exida2nd Edition 2016.
3.	William M. Goble and Harry Cheddie, Safety Instrumented Systems Verification: Practical Probabilistic Calculations ISA, 2005.
4.	Edward Marszal, Eric W. Scharpf, Safety Integrity Level Selection: Systematic Methods Including Layer of Protection Analysis, ISA, 2002.
5.	Standard - ANSI/ISA-84.00.01-2004 Part 1 (IEC 61511-1 Mod) Functional Safety: Safety Instrumented Systems for the Process Industry Sector - Part 1: Framework, Definitions, System, Hardware and Software Requirements, ISA, 2004.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Analyse the role of safety instrumented system in the industry and identify the hazards.
CO2	Determine the safety integrity level for an application and characterize the safety environment in industry.
CO3	Analyse the failure modes, failure rates and MTBF using various reliability engineeringtools.
CO4	Apply the design, installation and maintenance procedures for SIS applied to industrialprocesses.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO2	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-

Course Code	:	ICPE59
Course Title	:	**Modern Optimization Techniques and Algorithms**
Type of Course	:	PE
Prerequisites	:	MAIR courses
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments (3), End Assessment (1)

Course Learning Objectives (CLO)

CLO1	To introduce and elaborate the field of optimization and applications in dynamical systems and engineering.
CLO2	To gain understanding in the methods, both classical and modern, of obtaining optimal solutions under various conditions.
CLO3	To estimate the size of search space in which solutions are sought and appreciate the fundamentals of complex systems.
CLO4	To devise algorithmic optimal solutions via known methods such as Dynamic Programming, and explore modern paradigms such as reinforcement learning for solving a wider class of large-scale real-world problems

Course Content

Introduction – OR Models, Basic modelling with Linear Programming and its variants, Deterministic Dynamic Programming, Decision Analysis & Games, Markovian Decision Processes, Curse of Dimensionality, Heuristic Methods, e.g., GA, PSO etc.

Online learning – Adaptive learning, spanning lookup tables, parametric and nonparametric models (including neural networks), The Reinforcement Learning Problem.

Derivative-based stochastic optimization – stochastic gradient methods, Step-size policies and *optimal* policies; Derivative-free stochastic optimization – Multi-Armed Bandit Problem and classes of policies applied to this broad problem class.

State-dependent problems – Modelling general dynamic problems, e.g., energy systems, transportation systems, healthcare systems, as sequential decision problems, Designing policies for a given problem.

Approximate Dynamic Programming – Policy function approximations and policy search, Methods for performing search over tunable parameters: numerical derivatives, backpropagation, and the policy-gradient method.

Cost function approximations – Parameterized optimization models widely used in industry on an ad-hoc basis, Applications and Case Studies.

References

1.	Hamdy A Taha, Operations Research: An Introduction, 9/e, Pearson, 2012.
2.	Richard Bellman, Dynamic Programming, Dover Publications, 2003.
3.	Richard Sutton, A.G. Barto, Reinforcement Learning: An Introduction, 2/e, MIT Press, 2018 (available as a free download).
4.	Warren B Powell, Reinforcement Learning & Stochastic Optimization, John Wiley & Sons, 2022.
5.	Resources webpage on sequential decision analytics: https://tinyurl. com/sdalinks/
6.	D. Bertsekas, Dynamic Programming and Optimal Control, vols. 1 & 2, Athena Scientific, 2012

7.	Warren B. Powell, Sequential Decision Analytics and Modelling, NOW Publishing, Boston, MA, 2022, https://tinyurl.com/ sdamodeling/ (available as a free download).
8.	Paul J Nahin, When Least is Best, Princeton Univ. Press, 2004.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Model engineering problems as computational optimization problems.
CO2	Understand the curse of dimensionality and need for heuristics in optimization in terms of Genetic Algorithms and the like.
CO3	Cast engineering design as solution to dynamic optimization problems modelled in learning paradigms.
CO4	Make meaningful objective functions for algorithmically arriving at optimal solutions.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1															
CO2															
CO3															
CO4															

Course Code	**:**	ICPE60
Course Title	**:**	**Robot Dynamics and Control**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18, ICPC21
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the importance of Position and Orientation in specifying the complete description of Robots.
CLO2	To study the Robot Dynamics and its properties.
CLO3	To design various Controllers for the Trajectory Tracking Problem of the Robot.
CLO4	To analyse the Stability of the Robot.

Course Content

Fundamentals of Robotics: Links and Joints, Types of Joints, Wrists Design, End Effectors, Actuators, Mathematical Representation of Robots, Position and Orientation, Homogeneous Transformation, Degrees-of-Freedom, Denavit-Hartenberg (D-H) Parameters, Forward Kinematics, Inverse Kinematics, Linear and Angular Velocities, Manipulator Jacobian, Wrist and Arm Singularity, Static Force Analysis.

Robot Dynamics: Linear Acceleration, Angular Acceleration, Lagrange-Euler Method, Newton-Euler Method, Robotic Manipulator Dynamics in Cartesian Space, State-Space Model, Properties of Robot Dynamic Equations, Illustration on 2-DOF Robotic Manipulator.

Robot Motion Control: Feedback Control System, Stabilization and Trajectory Tracking Problems, Control of Second-Order Systems, Modeling and Control of a single Joint, Manipulator Control Problem, Force Control of Robotic Manipulator, Design of Robust Controllers, Illustrative Examples.

References

1.	A. Ghoshal, “Robotics: Fundamental Concepts and Analysis”, Oxford University Press, 2010
2.	R. K. Mittal and I. J Nagrath, “Robotics and Control”, Tata McGraw Hill, 2003
3.	J. J. Craig, “Introduction to Robotics: Mechanics and Control”, Pearson Education, 2022
4.	J.J. E. Slotine, “Applied Non-Linear Control”, Prentice Hall, 1991
5.	R. M. Murray, Z. Li, and S. S. Sastry, “A Mathematical Introduction to Robotic Manipulation”, CRC Press, 2017
6.	M. W. Spong and M. Vidyasagar, “Robot Dynamics and Control”, John Wiley & Sons, 2008
7.	R. D. Klafter, T. A. Chmielewski and M. Negin, “Robotic Engineering: An Integrated Approach”, Prentice Hall, 1989
8.	H. K. Khalil, “Nonlinear Systems”, Prentice Hall, 1991

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	To explain the basic concepts of Mathematical Representation of Robot.
CO2	Understand the Dynamic Model of the Robot and its properties.
CO3	Design various Controllers for Trajectory Tracking Problem of Robot.
CO4	Analyze the Stability of Robot Motion Control System.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	-	-	-	-	-	-	3	3	3	
CO2	3	3	3	3	2	-	-	-	-	-	-	3	3	3	
CO3	3	3	3	3	2	-	-	-	-	-	-	3	3	3	
CO4	3	3	3	3	2	-	-	-	-	-	-	3	3	3	

Course Code	**:**	ICPE61
Course Title	**:**	**CMOS Analog IC Design**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC12, ICPC20
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop skill for analog circuit design specifically relevant to CMOS IC design.
CLO2	To develop ability for the analysis of CMOS circuit noise and mismatch, and their impact on the circuit design.
CLO3	To develop skills to design and analyze several types of CMOS OpAmp at the transistor level.

Course Content

Introduction to MOSFETs, Simple MOSFET Circuits, MOSFET Current Mirrors, Cascode Amplifiers, MOSFET in Integrated Circuits, MOSFET Capacitances, Noise of Simple Circuits, Systematic Mismatch, Random Mismatch, Differential Amplifiers.

Concept of feedback, stability of negative feedback systems, dominant pole compensation, active load, differential amplifiers - noise and offset, slew rate, OTA, working principles and different types, datasheet, design example, folded-cascode, working principles and different types.

Multi-stage amplifier, step response, sinusoidal steady state response, loop gain and unity loop gain frequency, OpAmp realization using controlled sources; delay in the loop, negative feedback amplifier with ideal delay-small delays and large delays, negative feedback amplifier with parasitic poles and zeros, Nyquist criterion, Phase margin.

Single stage OpAmp, folded cascode opamp, telescopic opamp, Two and three stage miller compensated OpAmp, feedforward compensated OpAmp, two stage OpAmp, three stage and triple cascade OpAmp, common mode rejection ratio, fully differential single stage opamp, common mode feedback, fully differential two stage opamp; fully differential versus pseudo-differential, Introductory concept of PLL and VCO.

References

1.	B.Razavi, Design of Analog CMOS Integrated Circuits, McGraw Hill Edition2002.
2.	Paul. R.Gray, Robert G. Meyer, “Analysis and Design of Analog Integrated Circuits, Wiley, (4/e), 2001.
3.	Analog Integrated Circuit Design" by David A. Johns and Ken Martin
4.	CMOS Analog Circuit Design" by Phillip E. Allen and Douglas R. Holberg
5.	Analog Circuit Design: Discrete and Integrated" by Sergio Franco
6.	R. Jacob Baker, “CMOS Circuit Design, Layout, and Simulation, Wiley, (3/e),2010.
7.	The Art of Electronics by Paul Horowitz and Winfield Hill
8.	Analog Design for CMOS VLSI Systems by Franco Maloberti
9.	CMOS VLSI Design: A Circuits and Systems Perspective by Neil H.E. Weste and David Money Harris

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design CMOS based analog integrated circuits (IC) and analyze their performance.
CO2	Understand the negative feedback control applied in the design of CMOS circuit.
CO3	Examine the noise found in CMOS circuits and frequency response of CMOS circuits and assess its impact on circuit performance.
CO4	Develop and evaluate various CMOS operational amplifier (OpAmp) designs at the transistor level.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-	-	-	-	1	1	2	3	3	-
CO2	3	3	3	3	3	-	-	-	-	1	2	2	3	3	-
CO3	3	3	3	3	3	-	-	-	-	1	1	2	3	3	-
CO4	3	3	3	3	3	-	-	-	-	1	2	2	3	3	-

Course Code	:	ICPE62
Course Title	:	**Sensor Interface Design**
Type of Course	:	PE
Prerequisites	:	ICPC11, ICPC12, ICPC17
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart expertise in designing analog signal conditioning circuits tailored for resistive, capacitive, inductive, and piezoelectric sensors with the aim of enhancing their performance characteristics.
CLO2	To offer knowledge regarding the design of transmitters adhering to industrial standards.
CLO3	To provide understanding of data acquisition system design and tackle associated challenges.
CLO4	To provide knowledge about the modern digital interface, direct microcontroller interface and universal interface for sensors.

Course Content

Design of analog signal conditioning circuits for resistive, capacitive, inductive, and piezoelectric sensors to enhance linearity, sensitivity, resolution, and meet specific performance criteria using a practical hardware-based approach. Advanced electronic instrumentation for temperature compensation, power dissipation, addressing self-heating errors, managing current limits, evaluating circuit range and dynamic response. Noise analysis of interface circuits. Real-world case studies and hands-on experiences in analog interface design for temperature, pressure, and displacement sensors applied in industrial settings.

Review of transmitter technologies: designing two-wire, three-wire, and four-wire transmitters with analog electronic circuits and integrated circuits (ICs). Developing interface circuits for lead resistance compensation and precise 4-terminal low-resistance measurements. Introduction to data acquisition system, A/D conversion, issues related to interfacing of static and dynamic sensors.

Smart sensors and digital sensor system design, Basic of digital interfacing circuits for resistive, capacitive and inductive sensors. Digitizer design based on dual slope integrator for resistance to digital converter (RDC) and capacitance to digital converters (CDC). Addressing power dissipation, mitigating self-heating errors, managing current limits, and dynamic response of circuits. Case studies and hands-on for digital interface for sensors for industrial applications.

Modern digital interfacing circuit based on switched capacitor (SC) and sigma-delta modulators. Case studies and hands-on for designing digital interface for gas sensors and meteorological parameters.

Direct microcontroller interface (DMI) for resistive and capacitive transducers: design and practical implementation. Universal frequency to digital converter, universal sensors and transducer interface- features and performance, Using GPIO pins for digital interface for sensors, future trends in sensor circuit design, Case studies and hands-on for interfacing biomedical sensors with microcontrollers.

References

1.	Ramon Pallas-Areny, John G. Webster, Sensors and Signal Conditioning, 2/e, Wiley India, 2012.
2.	Daniel H. Sheingold, Transducer Interfacing Handbook, Analog Devices, 1980.
3.	Walt Kester, Practical Design Techniques for Sensor Signal Conditioning, Analog Devices, 1999.
4.	Walt Kester, Practical Analog Design Techniques, Analog Devices, 1995.
5.	Daniel H. Sheingold, Analog-Digital Conversion handbook, Analog Devices, 1986.
6.	Ferran Reverter, Ramon Pallas-Areny, Direct Sensor-to-Microcontroller Interface Circuits: Design and Characterization, Marcombo, 2005.
7.	Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 4/e, TMH, 2016.
8.	William D. Stanley, Operational Amplifiers with Linear Integrated Circuits, 6/e, Pearson Education, 2004.
9.	Paul Horowitz and Winfield Hill, The art of electronics. 2/e. Cambridge University Press, 2006.
10.	James W. Dally (Author), William F. Riley (Author), Kenneth G. Mcconnell, Instrumentation for Engineering Measurements, 2/e, Wiley India, 2010
11.	John P Bentley, Principles of Measurement Systems, 4/e Pearson Pentice Hall, 2005
12.	Ernest O. Doebelin (Author), Dhanesh N. Manik, Measurement Systems, 7/e, McGraw-Hill, 2019
13.	William C. Dunn, Introduction to Instrumentation, Sensors, and Process Control, ArtechHouse, 2005.
14.	Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer, 1993.
15.	H.R. Taylor, Data Acquisition for Sensor Systems, Springer, 2010.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design electronic interface circuits for resistive, capacitive, inductive, and piezoelectric sensors.
CO2	Design analog electronic circuits and integrated circuits-based transmitters for specified physical parameters.
CO3	Design digital interface circuits for resistive and capacitive sensors.
CO4	Design direct microcontroller interface for resistive and capacitive transducers.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	1	2	2	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	2	2	3	-
CO3	3	3	3	3	3	-	-	-	1	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICPE63
Course Title	**:**	**Artificial Intelligence in Instrumentation and Measurement**
Type of Course	**:**	PE/OE
Prerequisites	**:**	--
Contact Hours	**:**	3 hours (42 hrs max)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic concepts of neural networks
CLO2	To impart knowledge on the development of classical deep neural networks such as CNN and RNN
CLO3	To make the students aware of graph neural networks and generative AI
CLO4	To demonstrate various applications of AI in instrumentation and measurement

Course Content

History of Deep Learning, Deep Learning Success Stories, McCulloch Pitts Neuron, Thresholding Logic, Perceptrons, Perceptron Learning Algorithm and Convergence, Multilayer Perceptrons (MLPs), Representation Power of MLPs

Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, Representation Power of Feedforward Neural Networks

Feedforward Neural Networks, Backpropagation, Gradient Descent (GD), Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam

Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Better activation functions, Better weight initialization methods, Batch Normalization

Convolutional Neural Networks, Types of CNN, LeNet, AlexNet, ZF-Net, VGGNet, GoogLeNet, ResNet

Auto encoders, Types of auto encoders, Recurrent neural networks, LSTM and Types, Multimodal data and models, Graph neural networks and Generative adversarial networks, Transformers: Multi-headed Self Attention, Cross Attention

Applications: Autonomous driving, fault detection, vision-based measurement, and health along with case studies

References

1.	Ian Goodfellow and Yoshua Bengio and Aaron Courville. Deep Learning. An MIT Press book. 2016.
2.	Charu C. Aggarwal. Neural Networks and Deep Learning: A Textbook. Springer. 2019.
3.	Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media, 2017.
4.	Eren, Halit. Artificial Intelligence in Wireless Sensors and Instruments: Networks and Applications. N.p., Taylor & Francis Limited, 2024.
5.	Neural Networks for Instrumentation, Measurement, and Related Industrial Applications. Japan, IOS Press, 2003.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the basic concepts of artificial neural networks
CO2	Gain the knowledge of classical deep learning algorithms and its variants
CO3	Understand the concepts of graph neural networks and generative AI along with its importance
CO4	Design and develop deep learning architectures for real-world applications

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	-	-	-	-	-	2	3	3	
CO2	3	3	3	3	3	2	-	-	-	-	-	2	3	3	
CO3	3	3	3	3	3	2	-	-	-	-	-	2	3	3	
CO4	3	3	3	3	3	2	-	-	-	-	-	2	3	3	

Course Code	**:**	ICPE64
Course Title	**:**	**Thermodynamics and Fluid Mechanics**
Type of Course	**:**	PE
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge about the fundamentals of thermodynamic laws, concepts and principles.
CLO2	To introduce the principles of various cycles and to apply the thermodynamic concepts in variousapplications.
CLO3	To introduce the fundamental concepts of fluid mechanics, pressure distribution and dimensionalanalysis.
CLO4	To comprehend the metering and transportation of fluids and fluid moving machinery performance.

Course Content

Basic concepts of thermodynamics: Thermodynamic equilibrium, quasi-static process, zeroth law, work and heat interactions, first law for a cycle and a process, steady flow processes, second law statements, reversibility, Carnot theorem, Clausius inequality, entropy principle. Available energy: Availability and irreversibility, properties of pure substances, phase equilibrium diagrams, Rankine cycle, reheat and regenerative cycle, properties of ideal gas, Stirling and Ericson cycles.

Heat engines: Otto, diesel and dual cycles, Brayton cycle with regeneration, inter cooling and reheat, Joule- Thompson effect.

Fundamentals of Fluid mechanics: Classification of fluids and their physical properties, Fluid statics, manometers, pressure on submerged bodies**.** Ideal fluid - velocity field - stream line, streak line and path line, continuity equation - Rotational and irrotational flow, stream function and potential function, Euler's equations of motion, Bernoulli's equation and its application. Classification of open channel flows - measurement of discharge using rectangular and V-notches. Dimensional analysis – Rayleigh's method - Buckinghan Theorem and its applications. Laminar flow – Losses – Hagen-Poiseuille equation – Turbulent pipe flow – Friction.

Darcy Weisbach equation – Moody's diagram, minor losses – Boundary layer and its basic concepts.

Fluid machinery: Centrifugal pumps, Reciprocating pumps, Hydraulic ram, Impulse turbine, Reaction turbine.

References

1.	Zemansky, Heat and Thermodynamics, McGraw Hill, New York, 7th Edition, 1997.
2.	Ojha C.S.P., Berndtsson R., Chandramouli P.N., Fluid Mechanics and Machinery, OxfordUniversity Press, 2010.
3.	Streeter V.L. and Wylie E.B., Fluid Mechanics, McGraw Hill, New York, 9th Edition, 1997.
4.	Van Wylen G.A., Fundamentals of classical Thermodynamics, John Wiley and Sons, 4th Edition,1994.
5.	Cengal Y.A., Bogles M.A., Micheal Boles, Thermodynamics, McGraw Hill Book Company, 2ndEdition, 1994.

6.	Nag P.K., Engineering Thermodynamics, Tata McGraw Hill, 2nd Edition, 1995.
7.	Crowe C.T., Elger D.F., Williams B.C., Roberson J.A., Engineering Fluid Mechanics John Wiley andSons, 9th Edition, 2009.
8.	S. K. Som, Gautam Biswas, Suman Chakraborty, Introduction to Fluid Mechanics and FluidMachines, 3rd Edition. Tata McGraw-Hill Education. (2013)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Apply the fundamentals of thermodynamics to various process.
CO2	Understand various thermodynamic cycles and their applications to heat engines.
CO3	Apply the knowledge of fundamental concepts in fluids mechanics and usage of dimensionalanalysis for scaling experimental results.
CO4	Select the metering equipment and fluid moving machinery for an appropriate process engineering operation.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	1	1	1	3	1	-	1	2	2	3	2	1
CO2	3	1	3	1	1	2	3	1	-	1	3	3	3	3	2
CO3	3	-	3	2	2	1	2	1	1	1	2	2	3	2	1
CO4	3	-	3	2	2	2	2	1	1	2	2	3	3	3	2

Course Code	:	ICPE65
Course Title	:	**Design and Applications of Sensors and Transducers**
Type of Course	:	PE
Prerequisites	:	ICPC14
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide fundamentals of various types of diaphragm design.
CLO2	To familiarize with design of strain gauge, capacitive and inductive based transducers and its applications.
CLO3	To furnish the knowledge on design of accelerometer and gyroscope.
CLO4	To provide the basics of various chemical sensors and its design criterion.

Course Content

Introduction to diaphragm; Diaphragm performance and materials, Design of flatdiaphragms, flat diaphragms with rigid centre convex diaphragms, rectangular diaphragms corrugated diaphragms and semiconductor diaphragms through analytical and numerical simulation.

Design of strain gauge-based load cells, torque sensors, force sensors and pressure sensors (Theory and experimentation)

Design of capacitance-based displacement, pressure and level sensors; Design of mutual inductance transducers for measurement of displacement and experimentation. Design of proximity sensors and practical demonstration.

Accelerometer and Gyroscopic design and its applications. Design of Hall Effectsensors, and practical demonstration of few applications.

Introduction to chemical Sensors, characteristics. Design of DO2 sensor, ChemFETs, PEMFCs.

References

1.	Karl Hoffmann, An introduction to stress analysis and transducer design using strain gauges, HBM, 2012.
2.	James W. Dally, William F. Riley, Kenneth G. McConnell, Instrumentation for Engineering Measurements, Wiley, 2010.
3.	Di Giovanni, Flat and Corrugated Diaphragm Design Handbook, CRC Press, 1982.
4.	Fraden, Jacob, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer, 3rd Editions, 1993.
5.	Richard S. Figliola, Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley and Sons, Inc, 6th Edition,1991.
6.	Authors: Fraden, Jacob, Handbook of Modern Sensors: Physics, Designs, and Applications, Springe, 3rd Editions, 2010.
7.	Alexander D. Khazan, Transducers and Their Elements: Design and Application, PTR Prentice Hall,1994
8.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition, 1995.
9.	Peter H. Sydenham, Richard Thorn, Handbook of Measuring System Design, Wiley,2005

10.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2nd Edition,2008
11.	Patranabis, Sensors and Transducers, Prentice Hall, 2nd Edition,2003.
12.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd
13.	Kirianaki N.V., Yurish S.Y., ShpakN.O., Deynega V.P., Data Acquisition and Signal Processing for Smart Sensors, John Wiley and Sons, Chichester, UK, 2002

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Select and design diaphragm for different practical applications.
CO2	Design strain gauge-based torque, force, load and pressure measurement systems.
CO3	Design capacitance/ inductance transducers for the measurement of displacement, pressure and level.
CO4	Acquire knowledge in design of accelerometer and gyroscope.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	-	2	3	3	2	-	2	-	3	3	3	2
CO2	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
CO3	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
CO4	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-

Course Code	**:**	ICPE66
Course Title	**:**	**Design of Instrumentation Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17, ICPC20
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart the design knowledge of flow measurement and temperature measurementdevices.
CLO2	To introduce about control valve sizing and section of pumps for practical applications.
CLO3	To introduce the process of Electronic product design
CLO4	To familiarize with the Control Panel design and Control room design details.

Course Content

Flow measurement: Design of Orifice meter, Rotameter, Electromagnetic flow meter, Ultrasonic flow meter, Coriolis flow meter. Temperature measurement: RTD measuring circuit, cold junction compensation circuit for thermocouple, linearization of thermistor characteristics and design of temperature transmitter.

Review of flow equations. Valve selection and sizing for liquid service, gas or vapor service, flashing liquids, mixed phase flow. Control valve noise. Control valve cavitations. Actuator sizing. Design of safety relief valves and rupture discs.

Valves: Control valves - design of actuators and positioners - types of valve bodies - valve characteristics- materials for body and trim - sizing of control valves - selection of body materials and characteristics of control valves for typical applications.

Electronic product design: System Engineering, ergonomics, phases involved in electronic product design. Enclosure Design: Packing and enclosures design guidelines, Grounding and shielding, front panel and cabinet design of an electronic product

Control Panel Design: Panel selection-size, type, construction and IP classification. GA Diagrams, Power wiring and distribution, Typical wiring diagrams for AI, DI, AO,DO, RTD, and T/C modules. Earthing scheme. Panel ventilation, cooling and illumination. Operating consoles- ergonomics. Wiring accessories- ferules, lugs, PVC ducts, spiral etc. Wire sizes and color coding. Packing, Pressurized panels- X, Y, and Z Purging for installation in hazardous areas. Ex-proof panels. Control Room Design: Layout and environment.

References

1.	Bela G. Liptak, Instrument Engineer’s Hand Book – Process Control, Chilton Company, 3rd Edition, 1995.
2.	Andrew Williams, Applied instrumentation in the process industries, 2nd Edition, Vol. 1 and 3, Gulf publishing company (1993)
3.	Anderson N.A., Instrumentation for Process Measurement and Control, Routledge, 3rd Edition, 1997.
4.	Considine D.M., Process Instruments and Controls Handbook, McGraw-Hill., 5th Edition2009.
5.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd (2011)
6.	R. W. Zape, Valve selection handbook third edition, Jaico publishing house, Les Driskell, Control valve sizing, ISA.

7.	Curtis Johnson, Process Control Instrumentation Technology, PHI/Pearson Education 2002.
8.	Kim R Fowler, Electronic Instrument Design, Oxford University- 1996.
9.	Manual on product design: IISc C.E.D.T.
10.	Harshvardhan, Measurement Principles and Practices, Macmillan India Ltd-1993.
11.	Mourad Samiha and Zorian Yervant, Principles of Testing Electronic Systems, New York. John Wiley and Sons, 2000.
12.	Anand M S, Electronic Instruments and Instrumentation Technology, New Delhi. Prentice Hall of India, 2004.
13.	Ott H W, Noise Reduction Techniques in Electronic System., (2) John Wiley and Sons New York, 1988.
14.	Johnson C.D., Process Control Instrumentation Technology, Prentice Hall of India, 8th Edition, 2009.
15.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition 1995.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design temperature and flow measurement system for process application.
CO2	Design and Analyze CV Sizing
CO3	Identify various Control panels and Control Room details
CO4	Design an electronic product.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	2	3	2	2	-	2	-	3	3	3	2
CO2	2	-	3	-	3	3	2	2	-	2	-	3	3	3	2
CO3	2	3	3	3	3	3	3	3	-	3	-	3	3	3	2
CO4	3	3	3	3	3	3	3	3	-	3	-	3	3	3	2

Course Code	**:**	ICPE67
Course Title	**:**	**Design of Micro Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC14
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide knowledge on MEMS design and various fabrication processes.
CLO2	To impart knowledge on mechanics of membranes and beams in micro scale.
CLO3	To convey the design principles of electrostatic actuation and sensing.
CLO4	To impart design knowledge on micro pressure sensor and micro accelerometer.
CLO5	To provide knowledge on MEMS sensor integration and packaging.

Course Content

Introduction, An approach to MEMS design, Basic introduction to fabrication, process integration.

Energy conserving transducer, Mechanics of membranes and beams

Electrostatic Actuation and Sensing, Effects of electrical excitation

Design of Micro pressure sensor and Micro accelerometer Electronic Integration and Packaging

References

1.	Stephen D. Senturia, Microsystem Design, Kluwer Academic Publishers, Boston,1st Edition, 2001.
2.	Minhang Bao., Analysis and Design Principles of MEMS Devices, Elsevier, 1st Edition, 2005.
3.	M. Elwenspoek, R. Wiegerink, Mechanical Microsensors, Springer, Berlin, 1st Edition, 2010.
4.	Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, McGraw-Hill, Boston, 2017.
5.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre., Micro and Smart Systems by, Wiley-India, 2019

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design and fabricate simple micro devices.
CO2	Design and analyze simple mechanical structures used in sensor actuators.
CO3	Design electrostatic based actuation and sensing devices, micro pressure sensor and micro accelerometer.
CO4	Understand sensor integration and packaging techniques

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	2	2	2	-	-	-	3	3	3	2
CO2	3	3	3	3	3	2	2	3	-	-	-	3	3	3	2
CO3	2	3	3	-	3	3	2	3	-	-	-	3	3	3	2
CO4	2	3	3	-	3	3	3	3	-	-	-	3	3	3	2

Course Code	:	ICPE68
Course Title	:	**Design of Control Systems**
Type of Course	:	PE
Prerequisites	:	ICPC18, ICPC21
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge in the concepts and techniques of linear and nonlinear control system analysis and synthesis in the modern control (state space) framework.
CLO2	To teach the control design using the classical design principles
CLO3	To teach the controller and observer designs

Course Content

Design of Feedback Control Systems: Introduction; Approaches to System Design; Cascade Compensation Networks; Phase-Lead Design Using the Bode Diagram; Phase-Lead Design Using the Root Locus; System Design Using Integration Networks; Phase-Lag Design Using the Root Locus; Phase-Lag Design Using the Bode Diagram; Design on the Bode Diagram Using Analytical Methods; Systems with a Pre-filter; Design for Deadbeat Response; Design Examples.

Design of State Variable Feedback Systems Introduction, State space representation of physical systems, State space models of some common systems like R-L-C networks, DC motor, inverted pendulum etc., Controllable Canonical Form, Observable Canonical Form, Diagonal Canonical Form, State transition matrix, Solution of state equations, Controllability and Observability, Full-State Feedback Control Design; Observer Design; Integrated Full-State Feedback and Observer; Tracking Reference Inputs; Internal Model Design; Design Examples.

Lyapunov's stability and optimal control positive/negative definite, positive/negative semi-definite functions, Lyapunov stability criteria, introduction to optimal control, Riccatti Equation, Linear Quadratic Regulator, Design Examples.

References

1.	Bernard Friedland, Control System Design: An Introduction to State-Space Methods (Dover Books on Electrical Engineering), Dover Publications Inc., 2005.
2.	Gene F. Franklin, J. Da Powell, Abbas Emami-Naeini, Feedback Control of Dynamic Systems, Pearson Prentice Hall, 7th Edition, 2022.
3.	Richard C Dorf, Robert H Bishop, Modern Control Systems, Pearson Education India, 12th Edition, 2016.
4.	Albertos, P., and Mareels, I., Feedback Control for Everyone, Springer Verlag, 2010. Available for free download.
5.	Brogan, W.L., Modern Control Theory, Prentice Hall, 1993. Cheaper Indian Edition is available
6.	Strogatz, S.H., Nonlinear Dynamics and Chaos: with Applications to Physics, Biology, Chemistry, and Engineering, 2nd Edition, Westview Press (USA), Basic Books (India) 2014
7.	Liu, Y-Y., and Barabási, A-L., Control Principles of Complex Systems, Reviews of Modern Physics, Vol. 88, pp. 1-58, 2016
8.	Corke, P., Robotics, Vision and Control, 2nd Edition, Springer International, 2017.
9.	Katsuhiko Ogata, Modern Control Engineering, Pearson, 5th Edition, 2015.
10.	Madan Gopal, Modern Control System Theory, New Age International Private Limited, 2014.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Develop mathematical models for various physical systems.
CO2	Design state feedback controllers and observers.
CO3	Design nonlinear controllers using Lyapunov theory.
CO4	Analyze the stability of nonlinear system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	2	-	-	-	3	3	3	2
CO2	3	3	3	3	3	2	2	3	-	-	-	3	3	3	2
CO3	2	3	3	-	3	3	2	3	-	-	-	3	3	3	2
CO4	2	3	3	-	3	3	3	3	-	-	-	3	3	3	2

Course Code	:	ICPE69
Course Title	:	**Advanced Process Control Methods**
Type of Course	:	PE
Prerequisites	:	ICPC18, ICPC21
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose students to the advanced control methods used in industries and research.
CLO2	To teach various system identification and parameter estimation techniques.
CLO3	To prepare the student to take up such challenges in his profession.

Course Content

Review of System Identification, Parametric and non-parametric methods of system identification, Different family of BJ model; Choice of Input Signals; Least square (LS), Recursive LS, Weighted LS method of system identification.

Introduction to optimal filtering – need for filtering – Noise characteristics- Development of different state estimation techniques such as Kalman filter, Extended Kalman filter, Uncentered Kalman filter and particle Kalman filter. Development and validation of the state estimation/filtering concept with simulated non-linear systems using simulation software.

Development of SDCS system – Review of conventional Digital Control system – Development of SMPC, IMC and Performance enhancement of digital PID controller algorithm - Multivariable control strategies; Model Predictive Control, Model forms for Model Predictive Control. Dynamix matrix controller (DMC)

Development of augmented state space model – GPC – Controller Tuning and Robustness Issues; Extensions to Constrained and Multivariable Cases. Introduction to next generation controller – RTDA controller – Objective function – Derivation of control law – Implementation of above Digital control system using simulation software with case studies. Case studies of APC estimation/filtering and controller concept with industrial process control applications.

References

1.	B.W. Bequette, Process Control Modeling, Design and Simulation, Prentice Hall of India, New Delhi,2015.
2.	D.E. Seborg, T.E. Edgar, D.A. Mellichamp. Process Dynamics and Control, WileyIndia Pvt. Ltd., Fourth Edition.2016.
3.	Ceil L. Smith., Advanced Process Control: Beyond Single Loop Control, 1st Edition,Wiley-AIChE .
4.	B.A. Ogunnaikeand, W.H. Ray, Process Dynamics, Modelling and Control, OxfordPress, 1997.
5.	W.L. Luyben, Process Modelling Simulation and Control for Chemical Engineers, McGraw Hill, 2nd Edition, 1990.
6.	S. Bhanot, Process Control: Principles and Applications, Oxford UniversityPress, 2008.
7.	Les Kane., Advanced Process Control and Information Systems for the Process Industries, Gulf Professional Publishing. (1999)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design an appropriate advanced controller for specific problems in process industries.
CO2	Develop suitable filters for linear/non-linear system
CO3	Design of SDCS for multivariable systems.
CO4	Develop the MPC and next generation controller for multivariate system

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	-	3	2	3	3	2	3	-	-	-	3	3	3	2
CO2	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
CO3	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
CO4	3	-	3	3	3	3	2	3	-	-	-	3	3	3	2

Course Code	**:**	ICPE70
Course Title	**:**	**Robust and Optimal Control Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC18, ICPC22
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce analysis and design techniques for multivariable control systems toundergraduate students

Course Content

Introduction, Linear Algebra, Linear Dynamical Systems (Review of state-space theory)

Performance Specifications, Stability and Performance of Feedback Systems.

Model Uncertainty and Robustness – Structured Singular Values, Parameterization of Stabilizing Controllers, Algebraic Riccati Equations.

H-infinity optimal control, linear quadratic optimization, H-infinity loop shaping, Controller order reduction, Fixed order controllers.

Discrete-time Control – Discrete Lyapunov equations, Discrete Riccati equations, Bounded Real Functions, Discrete-time H2 control, Controller order reduction using co-prime factorization.

References

1.	D.E. Kirk, Optimal Control Theory: An Introduction, Dover Publications, 2004
2.	J. C. Doyle, B. Francis and A. Tannenbaum, Feedback Control Theory, Macmillan, 1990.
3.	A. E. Bryson Jr. and Y. C. Ho, Applied Optimal Control, Taylor and Francis, 2018.
4.	P J Nahin, When Least is Best, Princeton Univ. Press, 2004, D Bertsimas and J N Tsitsiklis, Introduction to Linear Optimization, Athena Scientific,1997.
5.	H A Taha, Operations Research: An Introduction, 9/e, Pearson Education, 2014.
6.	D Bauso, Game Theory with Engineering Applications, SIAM, 2016.
7.	K Morris, Introduction to Feedback Control, Academic Press, 2001.
8.	H P Geering, Optimal Control with Engineering Applications, Springer Verlag, 2007.
9.	K. Zhou, J. C. Doyle and K. Glover, Robust and Optimal Control, Prentice-Hall, NJ07458, 1996.
10.	A. A. Stoorvogel, H-infinity Control Problem: A State-space Approach, Prentice Hall, 1992

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Apply Optimization tools to multivariable feedback systems.
CO2	Use computer software to design MIMO robust controllers.
CO3	Perform a full design cycle on MIMO models of systems.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
CO2	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
CO3	3	2	3	3	3	2	3	-	2	3	-	3	3	3	-
CO4	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-

Course Code	**:**	ICPE71
Course Title	**:**	**Design of Sensors Systems**
Type of Course	**:**	PE
Prerequisites	**:**	ICPC17
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide knowledge on the design of signal conditioning circuits for resistive, capacitive and thermal transducers to improve the sensor characteristics.
CLO2	To provide knowledge on the design of transmitters with industrial standard.
CLO3	To impart the knowledge of data acquisition system design, sensor networks andbuses
CLO4	To provide knowledge about the smart sensor design, direct sensor microcontrollerinterface and universal interfacing circuit.

Course Content

Design of signal conditioning circuits for resistive, capacitive, thermal transducers for improving linearity, sensitivity and other required specifications and performance through hardware and software methods through theory and practical approach. Linearization, A/D conversion, temperature compensation. Noise analysis of interface circuits. Current, frequency, period or pulse-width modulation conversion

Review of transmitters – design of two wire and four wire transmitters using analog electronic circuits and IC's. EMI and EMC design consideration for sensor interfacing circuit design.

Introduction to data acquisition system, issues related to interfacing of static and dynamic sensors. Design of data acquisition for a given measurement application through theory and practical approach. Introduction to Sensor buses and sensor network protocols.

Smart sensors and digital sensor system design: Technologies and design methodology, IEEE 1451 standard and frequency sensors.

Direct sensor-microcontroller interface for resistive and capacitive transducers: design and practical implementation. Universal frequency to digital converter, universal sensors and transducer interface- features and performance, future trends in sensor circuit design.

References

1.	Ramon Pallas Areny, John G. Webster, Sensors and Signal Conditioning, 2nd Edition, John Wiley and Sons, 2000.
2.	Kirianaki N.V., Yurish S.Y., ShpakN.O., Deynega V.P., Data Acquisition andSignal Processing for Smart Sensors, John Wiley and Sons, Chichester, UK, 2002
3.	Ferran Reverter, Ramon Pallas Areny, Direct Sensor-to Microcontroller Interface Circuits: Design and Characterization, Marcombo S.A., 2005
4.	Smart Sensors and MEMS, ed. by S.Y. Yurish and M.T. Gomes, Springer Verlag, 2005
5.	A. Custodio, R. Bragos, R. Pallas-Areny, A Novel Sensor-Bridge-to- Microcontroller Interface, in Proceedings of IEEE Instrumentation and Measurement Technology Conference, Budapest, Hungary, 21-23 May, 2001
6.	Thomas L. Floyd, David Buchla, Fundamentals of analog circuits, 2002-Prentice Hall.
7.	Ernest O. Doebelin; Measurement System Application and Design; Mc-Graw Hill; 5th Edition, 2019.
8.	S. Y. Yurish, F. Reverter, R. Pallas-Areny, Measurement error analysis and uncertainty reduction for period-and time interval-to-digital converters based on microcontrollers, Measurement Science and Technology, Vol.16, No.8, 2005, pp.1660-1666.
9.	William C. Dunn, Introduction to Instrumentation, Sensors, and Process Control, Artech House, 2005.
10.	Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, andApplications, Springer, 2014.
11.	H.R. Taylor, Data Acquisition for Sensor Systems, Springer, 2010.
12.	Manabendra Bhuyan, Intelligent Instrumentation: Principles and Applications, CRC Press Taylor and Francis Group, 2010.
13.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition 1995.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design signal conditioning circuits for resistive, capacitive and thermal transducers
CO2	Design transmitters for the required physical parameters using analog circuitsand IC.
CO3	Interface sensors signal with DAQ, Microcontroller and will be familiar withsensor buses and protocols.
CO4	Design smart sensors systems with standard interfacing circuits.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
CO2	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
CO3	3	3	3	3	-	-	-	-	-	2	-	-	3	3	-
CO4	2	3	3	3	-	3	3	2	-	2	-	-	3	3	2

OPEN ELECTIVES (**OE**)

Course Code	:	ICOE11
Course Title	:	**Biomedical Signal Processing**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of biomedical signals and analysis
CLO2	To introduce different types of bio signals and their characteristics
CLO3	To study different noise removal mechanisms for biomedical signals
CLO4	To analyze the signals using time and frequency domain measures

Course Content

Introduction to signals, Continuous time and discrete time signals and LTI systems, Introductionand properties of Fourier transform, Laplace transform and Z-transform

Nature of biomedical signals; origin and dynamics of electroneurogram (ENG), electromyogram (EMG), electrocardiogram (ECG), electroencephalogram (EEG), event related potentials (ERP), electrogastrogram (EGG), phonocardiogram (PCG), vibromyogram (VMG) and vibroarthogram (VAG), Objectives of biomedical signal analysis and difficulties in biomedical signal analysis

Random, structured and physiological noise, noises and artefacts in ECG, EMG and EEG signals, Filtering for removal of artefacts; Introduction to filter design; Time domain filters, Frequency domain filters, and optimal filters and selection of appropriate filters

Event detections in ECG, EEG and heart sounds, Analysis of wave shape and waveform complexity, QRS complex, analysis of ERPs and analysis of electrical activity using time and frequency domain measures

Analysis of nonstationary and multicomponent signals, heart sound and murmurs, EEG rhythmsand waves and case studies

References

1.	Rangayyan, R. M. (2015). Biomedical signal analysis (2nd Edition). Wiley-IEEE Press. ISBN: 0470911396 (Online ISBN 1119068129).
2.	Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, AWiley-Interscience Publication JOHN WILEY and SONS, INC. ISBN0-471-34540-7. (2001)
3.	B.P. Lathi, Principles of Linear Systems and Signals, Oxford University Press, 2ndEdition,2009
4.	Le Cerutti, S., and Marchesi, C. (Eds.). (2011). Advanced methods of biomedical signal processing (Vol. 27). John Wiley andSons.
5.	Webster, J. G. (2009). Medical instrumentation application and design. John Wiley andSons.
6.	Mitra, S.K., Digital Signal Processing: A Computer-Based Approach, McGraw Hill, NY, 4th Edition, 2013

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the issues associated with the interpretation of biomedical signals
CO2	Have familiarity with different signals such as ECG, EMG and EEG
CO3	Remove the noises in bio signals by selecting appropriate filters
CO4	Implement appropriate signal processing methods to extract reliable information

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	2	3	3	2	2	-	-	-	3	3	3	-
CO2	2	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO3	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
CO4	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-

Course Code	:	ICOE12
Course Title	:	**Micro Electro Mechanical Systems**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamental concepts of MEMS and Micro systems and their relevance tocurrent scientific needs.
CLO2	To introduce the state-of-art micromachining techniques including surface micromachining,bulk micromachining, and related methods.
CLO3	To make the students knowledgeable in the design concepts of micro sensors and microactuators.
CLO4	To introduce the challenges and limitations in the design of MEMS devices
	To make the students knowledgeable in computer aided design tools for modeling MEMSdevice.

Course Content

Introduction, emergence, MEMS application, scaling issues, materials for MEMS, Thin film deposition,lithography and etching.

Bulk micro machining, surface micro machining and LIGA process.

MEMS devices, Engineering Mechanics for Micro System Design – static bending of thin plates, Mechanical vibrational analysis, Thermomechanical analysis, fracture mechanics analysis, Thin film mechanics.

Theory and design: Micro Pressure Sensor, micro accelerometer – capacitive and piezoresistive, micro actuator.

Electronic interfaces, design, simulation and layout of MEMS devices using CAD tools.

References

1.	Tai Ran Hsu, MEMS and Microsystem Design and Manufacture, TataMcGrawHill, New Delhi2017.
2.	Marc Madou, Fundamentals of Micro fabrication, CRC Press, 2nd Edition, 2002.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS, and Smart Devices, JohnWiley and Sons Ltd, 1st Edition, reprinted,2013.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1st Edition,2012.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1st Edition,2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2nd Edition,2011.
7.	Stephen D. Senturia., Microsystem Design, Kluwer Academic Publishers, 2001.
8.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre., Micro and SmartSystems, Wiley-India, 2019.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the fundamental principles behind the working of micro devices/ systemsand their applications.
CO2	Have knowledge in the standard micro fabrication techniques.
CO3	Identify micro sensors and actuators for a specific application.
CO4	Acquire skills in computer aided design tools for modeling and simulating MEMS devices.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	-	-	-	-	3	3	3	2
CO2	3	2	3	2	2	3	2	-	2	-	-	3	3	3	-
CO3	3	3	3	3	2	2	3	-	2	2	2	3	3	3	2
CO4	3	2	3	3	3	2	3	-	2	2	2	3	3	3	2

Course Code	**:**	ICOE13
Course Title	**:**	**Measurement and Control**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge in the basics of measurement system.
CLO2	To expose the students to various measurement techniques used for the measurementof important process variables.
CLO3	To expose the students to the basics of control systems.

Course Content

Fundamental and Importance of Instrumentation, types of instruments, selection of instruments, performance of instruments, error in measurement, calibration and standard, Calibration of instruments: Methods and analysis, Introduction to Transducer and types, Process Instrumentation, recording instruments, indicating and recording Instruments.

Strain and Displacement Measurement:

Factors affecting strain measurements, Types of strain gauges, theory of operation, strain gauge materials, gauging techniques and other factors, strain gauge circuits and applications of strain gauges. Resistive potentiometer (Linear, circular and helical), L.V.D.T., R.V.D.T. and their characteristics, variable inductance and capacitance transducers, Piezo electrical transducers, Hall Effect devices and Proximity sensors.

Pressure and Temperature Measurement:

Mechanical devices like Diaphragm, Bellows, and Bourdon tube for pressure measurement, Variable inductance and capacitance transducers, Piezo electric transducers, L.V.D.T. for measurement of pressure.

Resistance type temperature sensors – RTD and Thermistor, Thermocouples and Thermopiles, Laws of thermocouple, Fabrication of industrial thermocouples, Radiation methods of temperature measurement.

Flow and Level Measurement:

Differential pressure meters like Orifice plate, Venturi tube, flow nozzle, Pitot tube, Rotameter,Turbine flow meter, Electromagnetic flow meter, Ultrasonic flowmeter.

Resistive, inductive and capacitive techniques for level measurement, Ultrasonic methods, Airpurge system (Bubbler method).

Elements of control systems, concept of open loop and closed loop systems, Examples and application of open loop and closed loop systems, brief idea of multivariable control systems. Brief idea of proportional, derivative and integral controllers.

References

1.	D Patranabis, Principles of Industrial Instrumentation, Mc Graw hill, 3rdedition. 2017
2.	A. K. Ghosh, Introduction to Instrumentation and Control, PHI publications, 4thedition. 2012
3.	Nakra Chaudhari, Instrumentation measurement and analysis, Mc Graw hill, 3rdedition.2017
4.	S. K. Bhattacharya, Control Systems Theory and Applications,Pearson.2013
5.	N. C. Jagan, Control Systems, BSPublications.2016
6.	S. K. Singh, Industrial Instrumentation andControl, TMH Publication.2010.
7.	Thomos G. Beckwith and Lewis Back N. Adison Wesely Longman, Mechanical Measurements, Harlow.1993
8.	E. D. Doeblin, Measurement Systems: Application and Design, McGraw – Hill Publication2019.
9.	I. J. Nagrath and M. Gopal, Control Systems Engineering, New Age International (P) Limited, Publishers.2025
10.	N. K. Sinha, Control Systems, New Age International (P) LimitedPublishers.2013.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Familiar with the basics of measurement system, its characteristics and principles offew transducers.
CO2	Familiar with the different temperature, pressure, flow and level measurement techniques used in process industries.
CO3	Able to select and make measurements of temperature, flow, pressure and level in anyprocess industry.
CO4	Familiar with the concept of closed loop control system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
CO2	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO3	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO4	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-

Course Code	**:**	ICOE14
Course Title	**:**	**Industrial Measurements**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of process variable measurements.
CLO2	To expose the students to various measurement techniques used for the measurement oftemperature, flow, pressure and level in process industries.
CLO3	To make the students knowledgeable in the design, installation and troubleshooting of processinstruments.

Course Content

Temperature measurement: Introduction to temperature measurements, Thermocouple, Resistance Temperature Detector, Thermistor and its measuring circuits, Radiation pyrometers and thermal imaging.

Pressure measurement: Introduction, definition and units, Mechanical, Electro-mechanical pressure measuring instruments. Low pressure measurement, Transmitter definition types, I/P and P/I Converters.

Level measurement: Introduction, Mechanical and electrical methods of level measurement.

Flow measurement: Introduction, definition and units, classification of flow meters, differential pressure and variable area flow meters, Positive displacement flow meters, Electro Magnetic flow meters, Hot wire anemometer and ultrasonic flow meters. Calibration and selection of Flow meters

References

1.	Ernest.O. Doebelin and Dhanesh.N. Manik, Doebelin's Measurement Systems, McGraw HillEducation, 7th Edition, 2019.	
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4th Edition, 2003.	
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3rd Edition, 2010.	
4.	B.E. Noltingk, Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition,1995.	
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill,Singapore, 5th Edition, 2009.	
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I andVol II, GulfPublishing Company, Houston,2001	
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3rd Edition, 2005.	
8.	Tony.R. Kuphaldt, Lessons in Industrial Instrumentation, Version 2.02, April 2017	

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Familiar with the different temperature, pressure, flow and level measurement techniquesused in process industries.
CO2	Able to select and make measurements of temperature, flow, pressure and level in any processindustry.
CO3	Able to identify or choose temperature, flow, pressure and level measuring device for specificprocess.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO2	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO3	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
CO4	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-

Course Code	**:**	ICOE15
Course Title	**:**	**Virtual Instrument Design**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce to the students about the interfacing techniques of various transducers.
CLO2	To expose the students to different signal conditioning circuits.
CLO3	To impart knowledge on the hardware required to build Virtual Instrument.
CLO4	To impart knowledge to build GUI for Virtual Instrument.

Course Content

Transducer Interfacing: Interfacing techniques for the following transducers: Potentiometers - Temperature sensors – Thermocouple, RTD, Thermistors – Load cells – High and low range tension, Low and mid-range precision – Torque Sensors –Pressure sensors – Vibration Sensors – Acoustic Sensors – Automotive Sensors – Displacement sensors – Biomedical transducers.

Signal Conditioning: Filtering, Cold Junction Compensation, Amplification, Instrumentation Amplifier Linearization–Circuit Protection-Ground loops, CMRR, Noise Reduction and Isolation, Attenuation Multiplexing–Digital signal conditioning–IEEE1451standards Transducer Electronic Data Sheet (TEDS)

Data Acquisition and Hardware Selection: Overview of DAQ architecture – Analog IO and DigitalIO - Finite and continuous buffered acquisition – Data acquisition with C language - Industrial Communication buses – Wireless network standards - Micro-controller selection parameters for a virtual instrument – CPU, code space (ROM), data space (RAM) requirements.

Real-Time OS for Small Devices: Small device real-time concepts – Resources - Sequential programming - Multitasking - RTOS – Kernels – Timing loops – Synchronization and scheduling –Fixed point analysis – Building embedded real-time application for small devices.

Graphical User Interface for Virtual Instrument: Building an embedded Virtual Instrument GUI – Text and Number display – GUI Windows management. – Simulation – Display drivers – Creating and distributing applications – Examples of Virtual Instrument design using GUI in any of the applications like consumer goods, robotics, machine vision, and process control automation.

References

1.	Daniel H. Sheingold, Transducer Interfacing Handbook – A Guide to Analog Signal Conditioning, Analog Devices Inc.1980.
2.	Kevin James, PC Interfacing and Data Acquisition- Techniques for Measurement, Instrumentation and Control, Newnes, 2011.
3.	Timothy Wilmshurst, Designing Embedded Systems with PIC Microcontrollers- Principles and Applications, Elsevier, 2010.
4.	Jean Labrosse, Embedded System Building Blocks, 2nd Edition. RandD Books, 2020
5.	Jean Labrosse, MicroC/OS-II – The Real-Time Kernel, 2nd Edition. CMP Books, 2002

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Interface the target transducer to the signal conditioning board.
CO2	Condition the acquired signal from the transducer to standard data formats.
CO3	Select the most appropriate hardware for the virtual instrument to be built.
CO4	Implement the real-time OS for the selected micro-controller and the GUI interface for the virtual instrument.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
CO2	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
CO3	2	3	3	3	3	3	2	2	-	-	-	3	3	3	-
CO4	3	2	2	3	2	3	3	2	-	-	-	3	3	3	-

Course Code	**:**	ICOE16
Course Title	**:**	**Neural Networks and Fuzzy Logic**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To provide an overview of intelligent techniques.
CLO2	Develop skills to gain a basic understanding of neural network and fuzzy logic theory.
CLO3	To introduce different architectures and algorithms of Neural Networks.
CLO4	To impart knowledge on Fuzzy set theory and Fuzzy rules.

Course Content

Introduction to fuzzy logic and neural networks, Classification, Merits and demerits of intelligent techniques compared to conventional techniques. Need of an intelligent technique for real world Engineering applications.

Supervised and Unsupervised Neural networks: Perceptron, Standard backpropagation Neural network: Architecture, Algorithm and other issues. Discrete Hopfield's networks, Kohnen's self- organizing maps, adaptive resonance theory (ART1).

Neural networks for control systems: Schemes of Neuro-control, identification and control of dynamical systems, case studies.

Fuzzy set and operations, Fuzzy relations, Fuzzifications, Fuzzy rule-based systems, defuzzification fuzzy learning algorithms.

Fuzzy logic for control system with case studies. Introduction to neuro-fuzzy system and genetic algorithm.

References

1.	Timothy J. Ross, Fuzzy Logic with Engineering Applications, John Wiley and Sons Ltd Publications, 4th edition,2016.
2.	Laurene Fausett, Fundamentals of Neural networks, Pearson education, Eight Impression, 2012.
3.	S. Haykin, Neural Networks: A comprehensive Foundation, Prentice Hall Inc., New Jersey, 2nd Edition, 2009.
4.	Klir G.J and Folger T.A, Fuzzy sets, Uncertainty and Information, Prentice Hall, New Delhi, 2015.
5.	Zdenko Kovacic, Stjepan Bogdan, Fuzzy Controller Design Theory and Applications, CRC Press, 1st edition, 2006.
6.	Satish Kumar, Neural Networks – A classroom approach, Tata McGraw-Hill Publishing Company Limited, 2017.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Have familiarity with the basic concepts of Neural Network and Fuzzy logic.
CO2	Develop Neural Network based modelling and control for different process applications
CO3	Design Fuzzy logic-based control system for process applications.
CO4	Design hybrid neuro-fuzzy architecture for engineering optimization problems.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	3	3	2	2	-	-	-	-	3	3	3	-
CO2	3	2	3	3	3	3	2	2	2	2	2	3	3	3	2
CO3	3	2	3	3	3	3	2	2	2	2	2	3	3	3	2
CO4	3	3	3	3	3	3	3	2	2	2	2	3	3	3	2

Course Code	**:**	ICOE17
Course Title	**:**	**Network Control Systems**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the emerging field of multi-agent and network control systems
CLO2	To expand the scope of traditional control systems to include large-scale interconnected systems
CLO3	To demonstrate consensus and leader-follower paradigms in a distributed environment
CLO4	To introduce different applications that fall in the gamut of network control systems.

Course Content

Introduction to multi-agent systems, Information exchange via local interactions, Basics of graph theory

Reaching agreement in undirected and directed networks, Agreement via Lyapunov functions,Agreement over random networks

Formation control, Shape based control, Dynamic formation selection, Assigning roles, Cooperative robotics, Wireless sensor networks

Graph theoretic controllability, Network formation, Optimizing the weighted agreement, Planningover proximity graphs, Higher order networks

Introduction to social networks, opinion dynamics, epidemics, games etc.

References

1.	Mehran Mesbahi and Magnus Egerstedt, Graph Theoretic Methods in Multiagent Networks, Princeton University Press, 2010.
2.	F. Bullo, J. Cortes, and S. Martinez, Princeton, Distributed Control of Robotic Networks, University Press, 2009.
3.	P. J. Antsaklis and P. Tabuada, Networked Embedded Sensing and Control, Springer, 2006.
4.	A.L. Barabasi, Network Science, Cambridge University Press, 2016

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design control system in the presence of quantization, network delay or packet loss.
CO2	Understand distributed estimation and control suited for network control system.
CO3	Develop simple application suited for network control systems.
CO4	Technically understand larger-scale techno-socio-economic networks and models prevalent in today's society.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1															
CO2															
CO3															
CO4															

Course Code	:	ICOE18
Course Title	:	**Control Systems**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the concept of feedback control system.
CLO2	To impart knowledge in mathematical modeling of physical systems.
CLO3	To impart knowledge in characteristics and performance of feedback control system.
CLO4	To teach a variety of classical methods and techniques for analysis and design ofcontrol systems.

Course Content

Review of Systems, Mathematical Models – Differential Equations, Linear Approximations andTransfer Functions, Block Diagrams and Signal Flow Graphs

Feedback Control System Characteristics, and Performance Specifications on transients and steady-state, Stability of Linear Feedback Systems – Routh-Hurwitz criterion.

The Root Locus Method, Feedback Control System Analysis and Performance Specifications inTime- Domain, Design of Lead, Lag, and PID Controller using Root Locus.

Frequency Response methods, Nyquist Stability Criterion, Bode Plots, performance specifications in Frequency Domain, stability Margins.

Design of Lead, Lag and PID controller in Frequency Domain.

References

1.	Dorf, R.C., Bishop, R.H., Modern Control Systems, Prentice Hall, 14th edition,2022.
2.	Katsuhiko Ogata, Modern Control Engineering, PHI LearningPrivateLtd, 5thEdition, 2010.
3.	Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control of Dynamic Systems, Prentice Hall, 8th Edition, 2020
4.	Nise, N.S., Control Systems Engineering, Wiley, 8th Edition, 2019.
5.	John J.D., Azzo Constantine, H. and Houpis Stuart, N Sheldon, “Linear Control System Analysis and Design with MATLAB”, 6th Edition 2013
6.	Dutton, K., Thompson, S., Barraclough, B., The Art of Control Engineering, PrenticeHall,1997.
7.	M. Gopal., Control Systems: Principles and Design, 4th Edition, 2012, Mc Graw Hill Publication
8.	Anish Deb, Srimanti Roychoudhury, Control System Analysis and Identification with MATLAB, Block Pulse and Related Orthogonal Functions, published 2020

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Generate mathematical models of dynamic control system by applying differential equations.
CO2	Analyze and characterize the behavior of a control system in terms of different system, performance parameters and assess system stability.
CO3	Evaluate and analyses system performance using frequency and transient response analysis.
CO4	Design and simulate control systems (linear feedback control systems, PID controller, and multivariable control systems), using control software, to achieve required stability, performance and robustness.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO2	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO3	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO4	2	-	-	3	3	3	2	2	-	-	-	3	3	3	-

Course Code	:	ICOE19
Course Title	:	**Energy Harvesting Techniques**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce basic energy harvesting techniques using smart materials and structuresand combining with mechanisms.
CLO2	To impart knowledge in the design of power converter circuits for ambient energy harvesters.
CLO3	To introduce mathematical modelling of piezoelectric based energy harvesters.
CLO4	To introduce on certain case studies.

Course Content

Energy Harvesting Basics, Analysis of ambient energy- Vibration, shock, wind, Thermal, RF, energy transducers- electromagnet, photovoltaic, piezoelectric and other smart materials- working principle, equivalent circuit models.

Vibrational energy harvesting- Electromechanical Modelling of Cantilevered Piezoelectric Energy Harvester for Persistent Base Motion-lumped parameter model, correction factors, coupled distributed parameter model, modelling assumptions, closed form solution for unimorph and bimorph configuration, harvesting techniques for broadband excitation

Piezoelectric energy harvesting circuits-low power rectifier circuits with resistive, linear and nonlinear reactive input impedance, piezoelectric pre-biasing, self-tuning, DC-DC switch mode converters, impedance matching circuits for maximum output power.

Electromagnetic energy harvesting- Wire wound coil properties, micro fabricated coils, magnetic materials, scaling of electromagnetic vibration generators and damping, maximizing power from anEM generator, micro and macro scale implementation.

Thermoelectric Energy harvesting- Harvesting Heat, thermoelectric theory, thermoelectric generators and its efficiency, matched thermal resistance, heat flux, design consideration, optimization for maximum output, matching thermoelectric to heat exchangers- thin film devices.

Case study- harvester driven by muscle power, knee joint movement harvesting, etc. strategies to improve energy conversion efficiency for different ambient sources.

References

1.	Shashank Priya and Daniel J. Inman, Energy Harvesting Technologies, Springer-Verlag New York, Inc., 1st Edition,2010.
2.	Danick Briand, EricYeatman, and Shad Roundy, Micro energy harvesting, Wiley-VCHVerlag GmbH and Co,2015.
3.	Stephen Beeby, Neil white, Energy Harvesting for Autonomous Systems, Artechhouse,Norwwood,1st Edition ,2010.

4.	Alper Erturk and Daniel J Inman, Piezoelectric Energy Harvesting, John Wiley and Sons.Ltd.1st Edition ,2011.
5.	Tom J. Kazmiershi, Steve Beeby, Energy Harvesting System, Principles, Modelling andApplication, springer, Newyork,2011.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Comprehend in the concept of various ambient energy harvesting techniques.
CO2	Design optimal power converting circuits for different harvesters.
CO3	Design electromagnetic and thermoelectric based energy harvesters.
CO4	Apply the energy harvesting concepts to common engineering problems.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO2	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO3	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
CO4	2	-	-	3	3	3	2	2	-	-	-	3	3	3	-

Course Code	:	ICOE20
Course Title	:	**Smart Materials and Systems**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To expose to the basics of sensors used in industries.
CLO2	To provide adequate knowledge on smart instrumentation and wireless sensor networks.
CLO3	To impart knowledge on various standard protocols used in wireless instrumentation.
CLO4	To apply the knowledge of sensors, transceivers, controllers and power supplies toimplement a WSN for a required application.

Course Content

Sensor Classification-Thermal sensors -Humidity sensors -Capacitive Sensors-Planar Inter digital Sensors-Planar Electromagnetic Sensors-Light Sensing Technology-Moisture Sensing Technology-Carbon Dioxide (CO_2) sensing technology-Sensors Parameters

Frequency of Wireless communication -Development of Wireless Sensor Network based Project- Wireless sensor based on microcontroller and communication device-Zigbee Communication device.

Power sources- Energy Harvesting –Solar and Lead acid batteries-RF Energy /Harvesting-Energy Harvesting from Vibration-Thermal Energy Harvesting-Energy Management Techniques- Calculation for Battery Selection

Brief description of API mode data Transmission-Testing the communication between coordinator and remote XBee-Design and development of graphical user interface for receiving sensor data using C++; Abrief review of signal processing techniques for structural health monitoring.

WSN based physiological parameters monitoring system- Intelligent sensing system for emotion recognition-WSN based smart power monitoring system. Digital light processor (DLP)

References

1.	Subhas Chandra Mukhopadhyay, Smart Sensors, Measurement and Instrumentation,Springer Heidelberg, New York, Dordrecht London, 2013.
2.	Halit Eren, Wireless Sensors and Instruments: Networks, Design and Applications ebook published in 2018
3.	Uvais Qidwai, Smart Instrumentation: A data flow approach to Interfacing, Chapman and Hall, CRC 1ST Edition 2019

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand about smart instrumentation system.
CO2	Design self-diagnosing instrumentation system..
CO3	Identify the issues in power efficient systems and implement energy managementtechniques in WSN
CO4	Design wireless instrumentation systems for the given requirement.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	2	2	2	1	2	1	3	3	3	2
CO2	2	3	2	2	3	1	1	1	1	2	1	3	3	3	1
CO3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2
CO4	3	3	2	3	3	2	3	2	2	2	3	3	3	3	2

Course Code	**:**	ICOE21
Course Title	**:**	**Product Design and Development (Theory and Practice)**
Type of Course	**:**	Open Elective (OE)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	The aim of this course is to inculcate into the student the spirit of innovation and entrepreneurship. This is achieved in this course by making the students to develop a marketable product on their own as a group. At the end of this semester course, the students will learn how to know the needs of the society and solve the musing the technical knowledge at their disposal.
CLO2	The students will learn some of the general concepts needed for new product development and simultaneously learn how to interact with society outside the campus to learn about its needs. They also learn about how to get prototypes fabricated outside the campus.
CLO3	The students will fabricate an alpha prototype and test it for its conformity to the design specifications at the beginning of the next academic session
CLO4	After demonstration of the alpha prototype, they proceed to fabricate a beta prototype that is acceptable in the market-place

Course Content

Introduction to product design – Product planning – Identifying customer needs – Project selection

– Concept generation–Concept testing–Concept selection . Product specification–Product architecture

– Industrial design – Robust design. Product development economics – Design for manufacturing – Supply chain design – Intellectual property – Design for environment.

PRACTICAL WORK

Interaction with public outside the campus- identifying customer needs- product selection based on customer needs- concept generation- concept testing.

Identifying fabrication requirements- Identifying fabricators for the project- costing- financial model for the product development-finding outside finance for product development if possible andrequired -patent search for the product.

Alpha prototype fabrication and testing-to be submitted at the end of the semester with customeracceptance survey

Course Evaluation

Theoretical and Practical part will be evaluated separately and grades will be awarded. Theoretical component will be evaluated during the semester (50%) and the practical component (50%) will be evaluated at the end of the semester.

References

1.	Karl T. Ulrich and Steven D. Eppinger, Product Design and Development, 7th Edition, Tata McGraw-Hill. (2020)
2.	Kevin Otto and Kristin Wood, Product Design, Published 2013 by Prentice Hall
3.	Journals related to Engineering design.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Make market surveys for new product development
CO2	Select an appropriate product design and development process for a given application
CO3	Plan the entire cycle of new product design and development and fabricate prototypes of new products and test them.
CO4	Choose an appropriate agronomy for the product and adopt methods to minimize the cost.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	3	2	3	3	3	3	3	3	3	3	3	2
CO2	3	2	2	3	3	3	3	2	3	3	3	3	3	3	2
CO3	3	2	3	3	2	3	3	2	3	3	3	3	2	3	2
CO4	3	3	3	3	2	3	3	3	3	3	3	3	2	3	3

Course Code	:	ICOE22
Course Title	:	**Medical Imaging Systems**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the methods of medical imaging.
CLO2	To impart knowledge in the physics behind the various imaging techniques.
CLO3	To teach the construction and working of various imaging techniques.
CLO4	To study the methods of image reconstruction

Course Content

Introduction to image processing in medical applications, X-Ray tubes, cooling systems, removal of scatters, Fluoroscopy- construction of image Intensifier tubes, angiographic setup, mammography, digital radiology, DSA.

Need for sectional images, Principles of sectional scanning, CT detectors, Methods of reconstruction, Iterative, Back projection, convolution and Back-Projection. Artifacts, Principle of 3D imaging

Alpha, Beta and Gamma radiation, Radiation detectors, Radio isotopic imaging equipments, Radio nuclides for imaging, Gamma ray camera, scanners, Positron Emission tomography, SPECT, PET/CT.

Wave propagation and interaction in Biological tissues, Acoustic radiation fields, continuous and pulsed excitation, Transducers and imaging systems, Scanning methods, Imaging Modes, Principles and theory of image generation.

NMR, Principles of MRI, Relaxation processes and their measurements, Pulse sequencing and MR image acquisition, MRI Instrumentation, Functional MRI.

References

1.	D.N. Chesney and M.O. Chesney, Radio graphic imaging, CBS Publications, New Delhi, 4th Edition, 2005.
2.	Dwight G. Nishimura, Lulu, Principles of Magnetic Resonance Imaging, StanfordUniv,2010
3.	Flower M.A., Webb’s Physics of Medical Imaging, Taylor and Francis, New York, 2nd Edition, 2012.
4.	Prince and Links, Medical Imaging Signals and Systems, 2nd Edition, Pearson,2015
5.	Rangaraj M. Rangayyan, Biomedical Image Analysis, CRC Press, Boca Raton, FL,2005.
6.	Donald W. McRobbice, Elizabeth A. Moore, Martin J. Grave and Martin R. Prince, MRI from picture to proton, Cambridge University press, New York, 2nd Edition,2007.
7.	Kavyan Najarian and Robert Splinter, Biomedical signals and Image processing, CRC press, New York, 2nd Edition, 2012.
8.	Jerry L. Prince and Jonathan M. Links, Medical Imaging Signals and Systems- Pearson Education Inc., 2nd Edition, republished 2022

9.	Rangaraj M. Rangayyan, Biomedical Image Analysis, CRC Press, Boca Raton, FL,2024 ebook wiley online books

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Acquire basic domain knowledge about the various medical imaging techniques.
CO2	Understand the construction and working of various medical imaging equipments.
CO3	Provide a foundational understanding of algorithms used in medical imaging
CO4	Analyze the medical images for diagnosis

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	2	1	1	2	1	1	2	1	3	3	3	1
CO2	3	2	3	3	2	2	1	1	1	2	2	3	3	3	1
CO3	3	2	3	3	3	-	1	2	1	2	2	3	3	3	2
CO4	2	1	3	3	3	1	1	2	2	1	2	3	3	3	2

Course Code	:	ICOE23
Course Title	:	**Building Automation**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic blocks of Building Management System.
CLO2	To impart knowledge in the design of various sub systems (or modular system) of building automation..
CLO3	To provide insight into some of the advanced principles for safety in automation.
CLO4	To Design energy management system

Course Content

Introduction:

Concept and application of Building Management System (BMS) and Automation, requirements and design considerations and its effect on functional efficiency of building automation system, architecture and components of BMS.

HVAC system:

Different components of HVAC system like heating, cooling system, chillers, AHUs, compressors and filter units and their types. Design issues in consideration with respect to efficiency and economics, concept of district cooling and heating.

Access control and security systems:

Concept of automation in access control system for safety, Physical security system with components, Access control components, Computer system access control – DAC, MAC, and RBAC.

Fire and alarm system:

Different fire sensors, smoke detectors and their types and CO2 sensors, Fire control panels, design considerations for the FA system, concept of IP enabled fire and alarm system, design aspects and components of PA system.

CCTV system and energy management system:

Components of CCTV system like cameras, types of lenses, typical types of cables, controlling system, concept of energy management system, occupancy sensors, fans and lighting controller. Introduction to structural health monitoring and methods employed.

References

1.	Jim Sinopoli, Smart Buildings, Butterworth-Heinemann imprint of Elsevier, 2nd Edition.,2010.
2.	Albert Ting Pat So, WaiLok Chan, Intelligent Building Systems, Kluwer Academic publisher, 3rd Edition, 2012.
3.	Reinhold A. Carlson, Robert A. Di Giandomenico, Understanding Building Automation Systems, published by R.S. Means Company,1991.
4.	Morawski, E, Fire Alarm Guide for Property Managers, Publisher: KessingerPublishing, 2007.
5.	Building Automation: Control Devices and Applications by In Partnership with NJATC (2008).
6.	Building Control Systems, Applications Guide (CIBSE Guide) by The CIBSE (2000).
7.	Phil Zito., Building Automation Systems a to Z: How to Survive in a World Full of Bas, CreateSpace Independent Pub." 2016.
8.	James Backer, Viktoriya, Leena Greefe., Building Automation: Communication systems with EIB/KNX, LON and BACnet (Signals and Communication Technology), Springer publication. (2018)

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the concept behind building automation.
CO2	Plan for building automation.
CO3	Design sub systems for building automation and integrate those systems.
CO4	Learn to design energy efficient system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	2	2	1	3	2	1	3	3	3	2
CO2	2	2	3	3	2	2	2	1	2	2	2	3	3	3	1
CO3	3	3	3	3	3	2	2	1	3	2	2	3	3	3	2
CO4	3	3	3	3	3	1	2	2	2	1	3	3	3	3	1

Course Code	:	ICOE24
Course Title	:	**Biomedical Instrumentation**
Type of Course	:	Open Elective (OE)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessments, Assignments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To educate the students on the different medical instruments.
CLO2	To familiarize the students with the analysis and design of instruments to measurebio-signals like ECG, EEG, EMG, etc.
CLO3	To have a basic knowledge in therapeutic devices
CLO4	To introduce about the clinical laboratory instruments and familiar about electrical safety.

Course Content

Electro physiology**:** Review of physiology and anatomy, resting potential, action potential, bioelectric potentials, electrode theory, bipolar and uni-polar electrodes, surface electrodes, needle electrode and microelectrode, physiological transducers-selection criteria and its application.

Bioelectric potential and cardiovascular measurement**s**: ECG recording system, Heart sound measurement-stethoscope, phonocardiograph (PCG), Foetalmonitor-ECG-phonocardiography, vector cardiograph, cardiac arrhythmia's monitoring system. EMG, EEG - Evoked potential response, ERG and EOG recording system. Measurement of blood pressure using sphygmomanometer instrument based on Korotkoff sound, indirect measurement of blood pressure,automated indirect measurement, and direct measurement techniques.

Clinical Laboratory Equipment**:** Chemical tests in clinical laboratory, Automated Biochemical Analysis System. Blood gas analyzer, Acid –base balance, Blood PH measurement, blood PCO2, blood PO2, Intra –arterial blood gas analyzers, Blood cell counters- types of blood cells, - methods of cell counting -coulter counter- Automatic recognition and differential blood cell counting.

Respiratory and pulmonary measurements: Physiology of respiratory system, respiratory rate measurement- artificial respirator- oximeter, pulmonary function measurements–spirometer–photo plethysmography and body plethysmography. Principal and techniques of impedance pneumography, Apnea monitor.

Electrical safety: Sources of electrical hazards in medical environment and safety techniques for checking safety parameters of biomedical equipment.

References

1.	John G. Webster, John W Clark, jr, MedicalInstrumentationApplicationandDesign,4th Edition, John Wiley and sons, New York, 2010
2.	Arthur Guyton, John E. Hall, Text Book of Medical Physiology, 13th Edition, Elsevier Saunders, 2016 pdf
3.	Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Prentice Hall of India, New Delhi,2014.
4.	Jerry. L.Prince, Jonathan M. Links, Medical Imaging Signals and Systems, 2ndEdition, Pearson Prentice Hall, published by Pearson in 2022.
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6.	R.S. Khandpur, Hand Book of Biomedical Instrumentation, 3rd edition, McGraw Hill Education (India) Private Limited,2014.
7.	Andrew G. Webb, Principles of Biomedical Instrumentation, Cambridge University Press, 2018;
8.	Cromwell ,Biomedical Instrumentation and Measurement, 2nd Edition, Pearson India 2015
9.	JosephJ .Carr and John M.Brown, Introduction to Biomedical Equipment Technology, 4thEdition, Pearson publishing, 2013.
10.	Onkar N. Pandey, Rakesh Kumar, Bio Medical Electronics and Instrumentation, Katson Books, 5th Edition 2019 reprint 2024
11.	M Arumugam, Biomedical Instrumentation Anuradha Publications, 2017

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the concept behind building automation.
CO2	Plan for building automation.
CO3	Design sub systems for building automation and integrate those systems.
CO4	Learn to design energy efficient system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	2	2	1	3	2	1	3	3	3	2
CO2	2	2	3	3	2	2	2	1	2	2	2	3	3	3	1
CO3	3	3	3	3	3	2	2	1	3	2	2	3	3	3	2
CO4	3	3	3	3	3	1	2	2	2	1	3	3	3	3	1

HONOURS **(HO)** COURSES

Course Code	:	ICHO11
Course Title	:	**Design of sensors and Transducer**
Type of Course	:	HO
Prerequisites	:	ICPC14
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide fundamentals of various types of diaphragm design.
CLO2	To familiarize with design of strain gauge, capacitive and inductive based transducers and its applications.
CLO3	To furnish the knowledge on design of accelerometer and gyroscope.
CLO4	To provide the basics of various chemical sensors and its design criterion.

Course Content

Introduction to diaphragm; Diaphragm performance and materials, Design of flatdiaphragms, flat diaphragms with rigid centre convex diaphragms, rectangular diaphragms corrugated diaphragms and semiconductor diaphragms through analytical and numerical simulation.

Design of strain gauge-based load cells, torque sensors, force sensors and pressure sensors (Theory and experimentation)

Design of capacitance-based displacement, pressure and level sensors; Design of mutual inductance transducers for measurement of displacement and experimentation. Design of proximity sensors and practical demonstration.

Accelerometer and Gyroscopic design and its applications. Design of Hall Effectsensors, and practical demonstration of few applications.

Introduction to chemical Sensors, characteristics. Design of DO2 sensor, ChemFETs, PEMFCs.

References

1.	Karl Hoffmann, An introduction to stress analysis and transducer design using strain gauges, HBM, 2012 pdf
2.	James W. Dally, William F. Riley, Kenneth G. McConnell, Instrumentation for Engineering Measurements, Wiley, 1993.
3.	Di Giovanni, Flat and Corrugated Diaphragm Design Handbook, CRC Press, 1982.
4.	Fraden, Jacob, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer, 4th Editions, 2010.
5.	Richard S. Figliola, Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley and Sons, Inc, 6th Edition, 2015 .
6.	Fraden, Jacob, Handbook of Modern Sensors: Physics, Designs, and Applications, Springe, 4th Editions, 2010.
7.	Alexander D. Khazan, Transducers and Their Elements: Design and Application, PTR Prentice Hall,1994
8.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition 1995.
9.	Peter H. Sydenham, Richard Thorn, Handbook of Measuring System Design, Wiley,2005

10.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2nd Edition,2008
11.	Patranabis, Sensors and Transducers, Prentice Hall, 2nd Edition,2003.
12.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd kindle 2011.
13.	Kirianaki N.V., Yurish S.Y., ShpakN.O., Deynega V.P., Data Acquisition and Signal Processing for Smart Sensors, John Wiley and Sons, Chichester, UK, 2002

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Select and design diaphragm for different practical applications.
CO2	Design strain gauge-based torque, force, load and pressure measurement systems.
CO3	Design capacitance/ inductance transducers for the measurement of displacement, pressure and level.
CO4	Acquire knowledge in design of accelerometer and gyroscope.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	3	-	2	3	3	2	-	2	-	3	3	3	2
CO2	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
CO3	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
CO4	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-

Course Code	**:**	ICHO12
Course Title	**:**	**Instrumentation System Design**
Type of Course	**:**	HO
Prerequisites	**:**	ICPC17, ICPC20
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart the design knowledge of flow measurement and temperature measurementdevices.
CLO2	To introduce about control valve sizing and section of pumps for practical applications.
CLO3	To introduce the process of Electronic product design
CLO4	To familiarize with the Control Panel design and Control room design details.

Course Content

Flow measurement: Design of Orifice meter, Rotameter, Electromagnetic flow meter, Ultrasonic flow meter, Coriolis flow meter. Temperature measurement: RTD measuring circuit, cold junction compensation circuit for thermocouple, linearization of thermistor characteristics and design of temperature transmitter.

Review of flow equations. Valve selection and sizing for liquid service, gas or vapor service, flashing liquids, mixed phase flow. Control valve noise. Control valve cavitations. Actuator sizing. Design of safety relief valves and rupture discs.

Valves: Control valves - design of actuators and positioners - types of valve bodies - valve characteristics- materials for body and trim - sizing of control valves - selection of body materials and characteristics of control valves for typical applications.

Electronic product design: System Engineering, ergonomics, phases involved in electronic product design. Enclosure Design: Packing and enclosures design guidelines, Grounding and shielding, front panel and cabinet design of an electronic product

Control Panel Design: Panel selection-size, type, construction and IP classification. GA Diagrams, Power wiring and distribution, Typical wiring diagrams for AI, DI, AO,DO, RTD, and T/C modules. Earthing scheme. Panel ventilation, cooling and illumination. Operating consoles- ergonomics. Wiring accessories- ferules, lugs, PVC ducts, spiral etc. Wire sizes and color coding. Packing, Pressurized panels- X, Y, and Z Purging for installation in hazardous areas. Ex-proof panels. Control Room Design: Layout and environment

References

1.	Bela G. Liptak, Instrument Engineer's Hand Book – Process Control, Chilton Company, 3rd Edition, 2013
2.	Andrew Williams, Applied instrumentation in the process industries, 2nd Edition, Vol. 1 and 3, Gulf publishing company (1993)
3.	Anderson N.A., Instrumentation for Process Measurement and Control, Routledge, 3rd Edition, 1997.
4.	Considine D.M., Process Instruments and Controls Handbook, McGraw-Hill., 5th Edition2009.
5.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd (2011)
6.	R. W. Zape, Valve selection handbook third edition, Jaico publishing house, Les Driskell, Control valve sizing, ISA.

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9.	Manual on product design: IISc C.E.D.T.
10.	Harshvardhan, Measurement Principles and Practices, Macmillan India Ltd-2000
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12.	Anand M S, Electronic Instruments and Instrumentation Technology, New Delhi. Prentice Hall of India, 2009.
13.	Ott H W, Noise Reduction Techniques in Electronic System., (2) John Wiley and Sons New York, 1988.
14.	Johnson C.D., Process Control Instrumentation Technology, Prentice Hall of India, 8th Edition, 2009.
15.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2nd Edition 1995.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design temperature and flow measurement system for process application.
CO2	Design and Analyze CV Sizing
CO3	Identify various Control panels and Control Room details
CO4	Design an electronic product.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	2	3	2	2	-	2	-	3	3	3	2
CO2	2	-	3	-	3	3	2	2	-	2	-	3	3	3	2
CO3	2	3	3	3	3	3	3	3	-	3	-	3	3	3	2
CO4	3	3	3	3	3	3	3	3	-	3	-	3	3	3	2

Course Code	**:**	ICHO13
Course Title	**:**	**Micro System Design**
Type of Course	**:**	HO
Prerequisites	**:**	ICPC14
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide knowledge on MEMS design and various fabrication processes.
CLO2	To impart knowledge on mechanics of membranes and beams in micro scale.
CLO3	To convey the design principles of electrostatic actuation and sensing.
CLO4	To impart design knowledge on micro pressure sensor and micro accelerometer.
CLO5	To provide knowledge on MEMS sensor integration and packaging.

Course Content

Introduction, An approach to MEMS design, Basic introduction to fabrication, process integration.

Energy conserving transducer, Mechanics of membranes and beams

Electrostatic Actuation and Sensing, Effects of electrical excitation

Design of Micro pressure sensor and Micro accelerometer Electronic Integration and Packaging

References

1.	Stephen D. Senturia, Microsystem Design, Kluwer Academic Publishers, Boston,1st Edition, 2001.
2.	Minhang Bao., Analysis and Design Principles of MEMS Devices, Elsevier, 1st Edition, 2005.
3.	M. Elwenspoek, R. Wiegerink, Mechanical Microsensors, Springer, Berlin, 1st Edition, 2010.
4.	Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, Paperback, Boston, 2017.
5.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K. Aatre., Micro and Smart Systems by, Wiley-India, 2010

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design and fabricate simple micro devices.
CO2	Design and analyze simple mechanical structures used in sensor actuators.
CO3	Design electrostatic based actuation and sensing devices, micro pressure sensor and micro accelerometer.
CO4	Understand sensor integration and packaging techniques

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	2	2	2	-	-	-	3	3	3	2
CO2	3	3	3	3	3	2	2	3	-	-	-	3	3	3	2
CO3	2	3	3	-	3	3	2	3	-	-	-	3	3	3	2
CO4	2	3	3	-	3	3	3	3	-	-	-	3	3	3	2

Course Code	:	ICHO14
Course Title	:	**Control System Design**
Type of Course	:	HO
Prerequisites	:	ICPC18, ICPC21
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart knowledge in the concepts and techniques of linear and nonlinear control system analysis and synthesis in the modern control (state space) framework.
CLO2	To teach the control design using the classical design principles
CLO3	To teach the controller and observer designs

Course Content

Design of Feedback Control Systems: Introduction; Approaches to System Design; Cascade Compensation Networks; Phase-Lead Design Using the Bode Diagram; Phase-Lead Design Using the Root Locus; System Design Using Integration Networks; Phase-Lag Design Using the Root Locus; Phase-Lag Design Using the Bode Diagram; Design on the Bode Diagram Using Analytical Methods; Systems with a Pre-filter; Design for Deadbeat Response; Design Examples.

Design of State Variable Feedback Systems Introduction, State space representation of physical systems, State space models of some common systems like R-L-C networks, DC motor, inverted pendulum etc., Controllable Canonical Form, Observable Canonical Form, Diagonal Canonical Form, State transition matrix, Solution of state equations, Controllability and Observability, Full-State Feedback Control Design; Observer Design; Integrated Full-State Feedback and Observer; Tracking Reference Inputs; Internal Model Design; Design Examples.

Lyapunov's stability and optimal control positive/negative definite, positive/negative semi-definite functions, Lyapunov stability criteria, introduction to optimal control, Riccatti Equation, Linear Quadratic Regulator, Design Examples.

References

1.	Bernard Friedland, Control System Design: An Introduction to State-Space Methods (Dover Books on Electrical Engineering), Dover Publications Inc., 2005.
2.	Gene F. Franklin, J. Da Powell, Abbas Emami-Naeini, Feedback Control of Dynamic Systems, Pearson Prentice Hall, 7th Edition, 2014.
3.	Richard C Dorf, Robert H Bishop, Modern Control Systems, Pearson Education India, 13th Edition, 2013.
4.	Albertos, P., and Mareels, I., Feedback Control for Everyone, Springer Verlag, 2010. Available for free download.
5.	Brogan, W.L., Modern Control Theory, Prentice Hall, 1993. Cheaper Indian Edition is available. 3rd Edition.
6.	Strogatz, S.H., Nonlinear Dynamics and Chaos: with Applications to Physics, Biology, Chemistry, and Engineering, 2nd Edition, Westview Press (USA), Basic Books (India) 2014
7.	Liu, Y-Y., and Barabási, A-L., Control Principles of Complex Systems, Reviews of Modern Physics, Vol. 88, pp. 1-58, 2016
8.	Corke, P., Robotics, Vision and Control, 2nd Edition, Springer International, 2017.
9.	Katsuhiko Ogata, Modern Control Engineering, Pearson, 5th Edition, 2010
10.	Madan Gopal, Modern Control System Theory, New Age International Private Limited, 2014.

Course Outcomes (CO)

At the end of the course student will be able

CO1	Develop mathematical models for various physical systems.
CO2	Design state feedback controllers and observers.
CO3	Design nonlinear controllers using Lyapunov theory.
CO4	Analyze the stability of nonlinear system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	2	-	-	-	3	3	3	2
CO2	3	3	3	3	3	2	2	3	-	-	-	3	3	3	2
CO3	2	3	3	-	3	3	2	3	-	-	-	3	3	3	2
CO4	2	3	3	-	3	3	3	3	-	-	-	3	3	3	2

Course Code	**:**	ICHO15
Course Title	**:**	**Advanced Process Control**
Type of Course	**:**	HO
Prerequisites	**:**	ICPC18, ICPC21
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose students to the advanced control methods used in industries and research.
CLO2	To teach various system identification and parameter estimation techniques.
CLO3	To prepare the student to take up such challenges in his profession.

Course Content

Review of System Identification, Parametric and non-parametric methods of system identification, Different family of BJ model; Choice of Input Signals; Least square (LS), Recursive LS, Weighted LS method of system identification.

Introduction to optimal filtering – need for filtering – Noise characteristics- Development of different state estimation techniques such as Kalman filter, Extended Kalman filter, Uncentered Kalman filter and particle Kalman filter. Development and validation of the state estimation/filtering concept with simulated non-linear systems using simulation software.

Development of SDCS system – Review of conventional Digital Control system – Development of SMPC, IMC and Performance enhancement of digital PID controller algorithm - Multivariable control strategies; Model Predictive Control, Model forms for Model Predictive Control. Dynamix matrix controller (DMC)

Development of augmented state space model – GPC – Controller Tuning and Robustness Issues; Extensions to Constrained and Multivariable Cases. Introduction to next generation controller – RTDA controller – Objective function – Derivation of control law – Implementation of above Digital control system using simulation software with case studies. Case studies of APC estimation/filtering and controller concept with industrial process control applications.

References

1.	B.W. Bequette, Process Control Modeling, Design and Simulation, Prentice Hall of India, New Delhi,2004.
2.	D.E. Seborg, T.E. Edgar, D.A. Mellichamp. Process Dynamics and Control, WileyIndia Pvt. Ltd., Fourth Edition.2017.
3.	Ceil L. Smith., Advanced Process Control: Beyond Single Loop Control, 1st Edition,Wiley-AIChE .
4.	B.A. Ogunnaikeand, W.H. Ray, Process Dynamics, Modelling and Control, OxfordPress, 1997.
5.	W.L. Luyben, Process Modelling Simulation and Control for Chemical Engineers, McGraw Hill, 2nd Edition, 1999.
6.	S. Bhanot, Process Control: Principles and Applications, Oxford UniversityPress, 2008.
7.	Les Kane., Advanced Process Control and Information Systems for the Process Industries, Gulf Professional Publishing. (1999)

Course Outcomes (CO)

At the end of the course student will be able

CO1	Design an appropriate advanced controller for specific problems in process industries.
CO2	Develop suitable filters for linear/non-linear system
CO3	Design of SDCS for multivariable systems.
CO4	Develop the MPC and next generation controller for multivariate system

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	-	3	2	3	3	2	3	-	-	-	3	3	3	2
CO2	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
CO3	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
CO4	3	-	3	3	3	3	2	3	-	-	-	3	3	3	2

Course Code	:	ICHO16
Course Title	:	**Optimal and Robust Control**
Type of Course	:	HO
Prerequisites	:	ICPC18, ICPC22
Contact Hours	:	56 (4 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Introduce analysis and design techniques for multivariable control systems toundergraduate students

Course Content

Introduction, Linear Algebra, Linear Dynamical Systems (Review of state-space theory)

Performance Specifications, Stability and Performance of Feedback Systems.

Model Uncertainty and Robustness – Structured Singular Values, Parameterization of Stabilizing Controllers, Algebraic Riccati Equations.

H-infinity optimal control, linear quadratic optimization, H-infinity loop shaping, Controller order reduction, Fixed order controllers.

Discrete-time Control – Discrete Lyapunov equations, Discrete Riccati equations, Bounded Real Functions, Discrete-time H2 control, Controller order reduction using co-prime factorization.

References

1.	D.E. Kirk, Optimal Control Theory: An Introduction, Dover Publications, 2004
2.	J. C. Doyle, B. Francis and A. Tannenbaum, Feedback Control Theory, Macmillan, 1990.
3.	A. E. Bryson Jr. and Y. C. Ho, Applied Optimal Control, Taylor and Francis, 1975.
4.	P J Nahin, When Least is Best, Princeton Univ. Press, 2004, D Bertsimas and J N Tsitsiklis, Introduction to Linear Optimization, Athena Scientific,1997.
5.	H A Taha, Operations Research: An Introduction, 9/e, Pearson Education, 2014.
6.	D Bauso, Game Theory with Engineering Applications, SIAM, 2016.
7.	K Morris, Introduction to Feedback Control, Academic Press, 2001.
8.	H P Geering, Optimal Control with Engineering Applications, Springer Verlag, 2007.
9.	K. Zhou, J. C. Doyle and K. Glover, Robust and Optimal Control, Prentice-Hall, NJ07458, 1996.
10.	A. A. Stoorvogel, H-infinity Control Problem: A State-space Approach, Prentice Hall, 1992

Course Outcomes (CO)

At the end of the course student will be able

CO1	Apply Optimization tools to multivariable feedback systems.
CO2	Use computer software to design MIMO robust controllers.
CO3	Perform a full design cycle on MIMO models of systems.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
CO2	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
CO3	3	2	3	3	3	2	3	-	2	3	-	3	3	3	-
CO4	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-

Course Code	**:**	ICHO17
Course Title	**:**	**Sensors System Design**
Type of Course	**:**	HO
Prerequisites	**:**	ICPC17
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide knowledge on the design of signal conditioning circuits for resistive, capacitive and thermal transducers to improve the sensor characteristics.
CLO2	To provide knowledge on the design of transmitters with industrial standard.
CLO3	To impart the knowledge of data acquisition system design, sensor networks andbuses
CLO4	To provide knowledge about the smart sensor design, direct sensor microcontrollerinterface and universal interfacing circuit.

Course Content

Design of signal conditioning circuits for resistive, capacitive, thermal transducers for improving linearity, sensitivity and other required specifications and performance through hardware and software methods through theory and practical approach. Linearization, A/D conversion, temperature compensation. Noise analysis of interface circuits. Current, frequency, period or pulse-width modulation conversion

Review of transmitters – design of two wire and four wire transmitters using analog electronic circuits and IC's. EMI and EMC design consideration for sensor interfacing circuit design.

Introduction to data acquisition system, issues related to interfacing of static and dynamic sensors. Design of data acquisition for a given measurement application through theory and practical approach. Introduction to Sensor buses and sensor network protocols.

Smart sensors and digital sensor system design: Technologies and design methodology, IEEE 1451 standard and frequency sensors.

Direct sensor-microcontroller interface for resistive and capacitive transducers: design and practical implementation. Universal frequency to digital converter, universal sensors and transducer interface- features and performance, future trends in sensor circuit design.

References

1.	Ramon Pallas Areny, John G. Webster, Sensors and Signal Conditioning, 2nd Edition, John Wiley and Sons, 2000.
2.	Kirianaki N.V., Yurish S.Y., ShpakN.O., Deynega V.P., Data Acquisition andSignal Processing for Smart Sensors, John Wiley and Sons, Chichester, UK, 2002
3.	Ferran Reverter, Ramon Pallas Areny, Direct Sensor-to Microcontroller Interface Circuits: Design and Characterization, Marcombo S.A., 2005
4.	Smart Sensors and MEMS, ed. by S.Y. Yurish and M.T. Gomes, Springer Verlag, 2005

5.	A. Custodio, R. Bragos, R. Pallas-Areny, A Novel Sensor-Bridge-to- Microcontroller Interface, in Proceedings of IEEE Instrumentation and Measurement Technology Conference, Budapest, Hungary, 21-23 May, 2001
6.	Thomas L. Floyd, David Buchla, Fundamentals of analog circuits, 2002-Prentice Hall.
7.	Ernest O. Doebelin; Measurement System Application and Design; Mc-Graw Hill; 5thEdition, 2003.
8.	S. Y. Yurish, F. Reverter, R. Pallas-Areny, Measurement error analysis and uncertainty reduction for period-and time interval-to-digital converters based on microcontrollers, Measurement Science and Technology, Vol.16, No.8, 2005, pp.1660-1666.
9.	William C. Dunn, Introduction to Instrumentation, Sensors, and Process Control, Artech House, 2005.
10.	Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer, 1993.
11.	H.R. Taylor, Data Acquisition for Sensor Systems, Springer, 2010.
12.	Manabendra Bhuyan, Intelligent Instrumentation: Principles and Applications, CRC Press Taylor and Francis Group, 2010.
13.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, 2ndEdition 1995.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Design signal conditioning circuits for resistive, capacitive and thermal transducers
CO2	Design transmitters for the required physical parameters using analog circuitsand IC.
CO3	Interface sensors signal with DAQ, Microcontroller and will be familiar withsensor buses and protocols.
CO4	Design smart sensors systems with standard interfacing circuits.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
CO2	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
CO3	3	3	3	3	-	-	-	-	-	2	-	-	3	3	-
CO4	2	3	3	3	-	3	3	2	-	2	-	-	3	3	2

Course Code	**:**	ICHO18
Course Title	**:**	**Project-based Learning**
Type of Course	**:**	HO
Prerequisites	**:**	-
Contact Hours	**:**	56 (4 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To enable the student to design, develop and construct hands-on solution to a problem.
CLO2	To build student's creative capacity to work through problems that may or may not be well-defined.
CLO3	To provide students opportunities to work across disciplines, on real-world problems of technical interest
CLO4	To foster student independence, ownership of his/her work and the development of practical skills that are valued at the workplace.

Course Content

The course provides an opportunity to the students to carry out semester-long research and development project in an identified area of research, with the guidance of a faculty supervisor. The activities are designed in an engaging experience, in such a way that the academic skills, capabilities and logical thinking converge towards solving of open ended problems.

The typical phases of the work done by the student could be:

- Problem identification: Defining a problem in terms of given constraints or challenges
- Devising solutions: Listing down possible multiple ideas to solve a problem, and choosing the potential solution path to the problem (i.e., how to achieve the solution)
- Prototyping: Designing and developing a prototype of the solution
- Testing the developed solution products or services, Refining the solution based on feedback from experts,instructors, and/or peers.

The evaluation will be based on weekly productivity and punctuality of the student, who will be applying knowledge and skills towards solving the problem. The student would submit two intermediate progress reports through the semester and a final report at the end. The reports should be of high academic quality so that they can culminate in a research publication in a well-reputed journal or conference in the chosen field of study.

The learning from the course would be student-centric, and could be tied to his/her readiness for a career in the industry or higher academic research.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Identify a problem of significance to the industry and the academic community, with the help of mentor
CO2	Design the most effective solution to the problem, given the constraints and challenges
CO3	Develop a prototype, that would be an embodiment of the proposed solution.
CO4	Present a technical report on the overall project.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	_	2	2	_	_	2	2	2	2	3	_	1
CO2	3	2	3	2	2	2	3	2	2	2	3	2	3	3	2
CO3	3	3	3	3	3	2	2	3	2	2	3	2	3	3	2
CO4	2	2	_	3	3	2	3	3	3	3	3	2	3	3	3

MINOR (MI) COURSES

Course Code	:	ICMI11
Course Title	:	**Transducer Engineering**
Type of Course	:	PE
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to various sensors and transducers for measuring mechanical quantities.
CLO2	To make the students familiar with the specifications of sensors and transducers.
CLO3	To teach the basic conditioning circuits for various sensors and transducers.
CLO4	To introduce advances in sensor technology

Course Content

General concepts and terminology of measurement systems, transducer classification, general input-output configuration, static and dynamic characteristics of a measurement system, Statistical analysis of measurement data.

Resistive transducers: Potentiometers, metal and semiconductor strain gauges and signal conditioning circuits, strain gauge applications: Load and torque measurement, Digital displacement transducer.

Self and mutual inductive transducers- capacitive transducers, eddy current transducers, proximity sensors, tacho-generators and stroboscope.

Piezoelectric transducers and their signal conditioning, Seismic transducer and its dynamic response, photoelectric transducers, Hall effect sensors, Magneto strictive transducers, Basics of Gyroscope.

Introduction to semiconductor sensor, materials, scaling issues and basics of micro fabrication. Smart sensors

References

1.	John P. Bentley, Principles of Measurement Systems, Pearson Education, 4th Edition, 2005.
2.	Doebelin E.0, Measurement Systems - Application and Design, McGraw-Hill, 4th Edition, 2004.
3.	S.M. Sze, Semiconductor sensors, John Wiley and Sons Inc., 1994.
4.	Pallas-Areny Ramon, John G. Webster. Sensors and signal conditioning. New York: Wiley, 2001.
5.	Baura, Fundamentals of Industrial Instrumentation, Wiley India, New Delhi 2011
6.	De Silva, Clarence W. Sensors and actuators: Engineering system instrumentation. CRC Press, 2015.
7.	Ripka, Pavel, Alois Tipek, eds. Modern sensors handbook. John Wiley and Sons, 2013.
8.	Khazan, Alexander D. Transducers and their elements: design and application. Prentice Hall, 1994.
9.	Fraden, Jacob. Handbook of modern sensors: physics, designs, and applications. Springer Scienceand Business Media, 2004.
10.	Tumanski, Slawomir. Handbook of magnetic measurements. CRC Press, 2016.
11.	Murthy D. V. S, Transducers and Instrumentation, Prentice Hall, 2nd Edition,2011.

12.	James W. Dally, Instrumentation for Engineering Measurements, Wiley, 2nd Edition,1993.
13.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2nd Edition,2008.
14.	B.E. Noltingk, Instrumentation Reference Book, Butterworth- Heinemann, Second edition 1995
15.	Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal Processingfor Smart Sensors, John Wiley and Sons, Chichester, UK, 2002

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Have familiarity with the basics of measurement system and its input, output configuration.
CO2	Have familiarity with both static and dynamic characteristics of measurement system.
CO3	Have familiarity with the principle and working of various sensors and transducers.
CO4	Select proper transducer / sensor for a specific measurement application.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	2	3	3	2	3	2	2	2	2	3	1	2	3	3	1
CO2	3	3	3	3	3	1	2	2	2	2	1	2	3	3	1
CO3	3	2	3	2	3	2	2	1	2	2	2	3	3	3	1
CO4	3	3	3	3	2	2	3	1	2	2	3	3	3	3	1

Course Code	:	ICMI12
Course Title	:	**Test and Measuring Instruments**
Type of Course	:	Minor(MI)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To give an overview of current, voltage and power measuring electrical, electronics and digitalinstruments.
CLO2	To expose the students to the design of bridges for the measurement of resistance, capacitance andinductance.
CLO3	To give an overview of test and measuring instruments.

Course Content

Electrical measurements: General features and Classification of electromechanical instruments. Principles of Moving coil, moving iron instruments. Extension of instrument range: shunt and multipliers, CT and PT.

Measurement of Power: Electrodynamic wattmeter's, Low Power Factor (LPF) wattmeter, errors, calibration of wattmeter. Single and three phase power measurement, Hall effect wattmeter, thermal type wattmeter.

Different methods of measuring low, medium and high resistances, measurement of inductance and capacitance with the help of AC Bridges, Q Meter.

Digital Measurement of Electrical Quantities: Concept of digital measurement, block diagram Study of digital voltmeter, Digital multimeter, Digital LCR meter, Digital wattmeter and energy meters.

DSO, Function generator, Audio frequency signal generation, Waveform analyzers, Spectrum analyzers

References

1.	Golding, E.W. and Widdis, F.C., Electrical Measurements and Measuring Instruments, A.H.Wheeler and Co, 5th Edition, 2011.
2.	David A. Bell, Electronic Instrumentation and Measurements, Oxford University Press, 3rd Edition,2013.
3.	Shawney A K, A course in Electrical and Electronic Measurements and Instrumentation, DhanpatRai and Sons. 19th revised edition, 2013.
4.	Cooper, W.D. and Helfric, A.D., Electronic Instrumentation and Measurement Techniques, PrenticeHall, 1st Edition, 2009.
5.	Kalsi.H. S, Electronic Instrumentation, Tata McGraw Hill Education Private Limited, 3rd Edition,2012.

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Have familiarity with various measuring instruments (ammeters, voltmeters, watt meters, energy meters,extension of meters, current and voltage transformers) used to measure electrical quantities.
CO2	Design suitable DC and AC bridges for the measurement of R, L, C and Frequencymeasurement.
CO3	Suggest the kind of instrument suitable for typical measurements.
CO4	Use the test and measuring instruments effectively.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	1	3	2	1	1	1	1	2	2	3	2	2
CO2	3	3	3	2	3	1	2	1	1	2	1	2	3	2	1
CO3	2	3	3	2	2	2	2	2	2	3	3	3	3	3	2
CO4	2	3	3	2	2	2	2	2	2	3	2	3	3	3	2

Course Code	:	ICMI13
Course Title	:	**Measurements In Process Industries**
Type of Course	:	Minor (MI)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the importance of process variable measurements.
CLO2	To expose the students to various measurement techniques used for the measurement oftemperature, flow, pressure and level in process industries.
CLO3	To make the students knowledgeable in the design, installation and troubleshooting of processinstruments.

Course Content

Temperature measurement: Introduction to temperature measurements, Thermocouple, ResistanceTemperature Detector, Thermistor and its measuring circuits, Radiation pyrometers and thermal imaging.

Pressure measurement: Introduction, definition and units, Mechanical, Electro-mechanical pressuremeasuring instruments. Low pressure measurement, Transmitter definition types, I/P and P/I Converters.

Level measurement: Introduction, Capacitance pickup, Ultrasonic pickup.

Flow measurement: Introduction, definition and units, classification of flow meters, differential pressureand variable area flow meters, Positive displacement flow meters, Electro Magnetic flow meters.

Hot wire anemometer and ultrasonic flow meters. Calibration and selection of Flow meters

References

1.	Ernest.O. Doebelin and Dhanesh.N. Manik, Doebelin's Measurement Systems, McGraw HillEducation, 6th Edition, 2011.
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4th Edition, 2003.
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3rd Edition, 2010.
4.	B.E. Noltingk, Instrumentation Reference Book, Butterworth Heinemann, 2nd Edition, 1995.
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill,Singapore, 5th Edition, 1999.
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I andVol II, Gulf Publishing Company, Houston, 2001
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3rd Edition, 2005.
8.	Tony.R. Kuphaldt, Lessons in Industrial Instrumentation, Version 2.02, April 2014.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Have familiarity with different temperature, pressure, flow and level measurement techniques used inprocess industries.
CO2	Select and make measurements of temperature, flow, pressure and level in any processindustry.
CO3	Understand and calibrate the flow meter
CO4	Identify or choose temperature, flow, pressure and level measuring device for specific process.

Course Outcome and Programme Outcome Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	2	2	2	2	1	2	3	3	3	1
CO2	3	2	3	2	2	2	3	2	2	2	2	3	3	3	2
CO3	3	2	3	2	2	2	2	2	1	3	2	3	3	3	2
CO4	3	2	3	2	2	2	2	2	1	3	2	3	3	3	2

Course Code	**:**	ICMI14
Course Title	**:**	**Essentials Of Control Engineering**
Type of Course	**:**	Minor (MI)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To expose the students to the fundamentals of feedback control system.
CLO2	To impart the knowledge on different types of control systems representation in pictorial andmathematical forms.
CLO3	To teach the performance characteristics and analysis of control systems in time and frequencydomain.

Course Content

Introduction to control system – Open loop and Closed loop system – Feedback system characteristics – Block diagram reduction techniques – Signal flow graph.

Order and type of system – time domain and frequency domain response of different system characteristics using simulation software – Introduction of stability – Routh Hurwitz stability criteria.

Introduction to root locus – plotting of root locus and stability analysis using simulation software. Introduction to bode and Nyquist plot – Plotting of bode and Nyquist plot using simulation software - Gain Margin and Phase margin calculation.

Introduction to different compensator design – the design of different compensator design using simulation software. PID controller design using simulation software.

Application of control system for different domain with case studies.

References

1.	Dorf, R.C., and Bishop, R.H., Modern Control Systems, Prentice Hall, 13th Edition, 2016.
2.	Katsuhiko Ogata Modern Control Engineering, Pearson, 5th Edition, 2009.
3.	Franklin G.F., Powell J.D., Emami-Naeini A., Feedback Control of Dynamic Systems, Pearson, 7thEdition, 2015.
4.	B. C. Kuo, F. Golnaraghi, Automatic Control Systems, Wiley Publishers, India, 8th Edition, 2003.
5.	Ramakalyan A., Control Engineering- A comprehensive foundation, Vikas Publication, New Delhi,2004.
6.	Norman S. Nise, Control Systems Engineering, Wiley India publications, 4th Edition, 2003

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Appreciate the importance of feedback control system.
CO2	Analyze and design the system performance using time domain and frequency domain techniques.
CO3	Perform the stability analysis of control systems
CO4	Use simulation software for classical control system design and analysis.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	2	2	2	2	3	1	1	2	2	2	3	3	2	2
CO2	3	2	3	3	3	3	3	2	3	2	3	3	3	3	2
CO3	3	2	3	3	3	3	3	2	3	2	3	3	3	3	2
CO4	3	2	3	3	3	2	2	2	2	2	2	3	3	3	1

Course Code	**:**	ICMI15
Course Title	**:**	**Industrial Automation and Control**
Type of Course	**:**	Minor (MI)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the importance of process automation techniques.
CLO2	To impart required knowledge in PLC based programming.
CLO3	To introduce to the students to the distributed control system and different communicationprotocols.

Course Content

Introduction and overview of Industrial automation – Block diagram of PLC – different types of PLC – Type of input and output – Introduction to relay logic- Application of PLC.

Introduction to Ladder logic programming – Basic instructions – Timer and Counter instruction- Arithmetic and logical instruction – MCR, PID controller and other essential instruction sets - Case studies and examples for each instruction set.

Introduction to high level PLC language – Programming of PLC using simulation software – Real time interface and control of process rig/switches using PLC.

Introduction to DCS and SCADA - Block diagram – function of each component – Security objective – Operation and engineering station interface – Communication requirements.

Development of different control block using DCS simulation software – Real time control of test rigsusing DCS. Introduction to HART, Fieldbus and PROFIBUS – Application and case studies of large-scale process control using DCS.

References

1.	John W. Webb and Ronald A. Reis, Programmable Logic Controllers - Principles and Applications,Prentice Hall Inc., New Jersey, 5th Edition, 2002.
2.	Lukcas M.P, Distributed Control Systems, Van Nostrand Reinhold Co., New York, 1986.
3.	Frank D. Petruzella, Programmable Logic Controllers, McGraw Hill, New York, 4th Edition, 2010.
4.	Dr. R. Manikandan, Dr. R. Senthil., Logic and Distributed Control System Sai Publishers
5.	John. W. Webb, Ronald A Reis, Programmable Logic Controllers - Principles and Applications,5th Edition, Prentice Hall Inc., New Jersey, 2003.
6.	R.G. Jamkar., Industrial Automation Using PLC SCADA and DCS (PLC and SCADA Book),Global Education Limited; second edition. 2018.
7.	Deshpande P.B and Ash R.H, Elements of Process Control Applications, ISA Press, New York,1995.
8.	Curtis D. Johnson, Process Control Instrumentation Technology, Prentice Hall, New Delhi, 8thEdition, 2005.
9.	Krishna Kant, Computer-based Industrial Control, Prentice Hall, New Delhi, 2nd Edition, 2011.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand process automation technologies.
CO2	Design and develop PLC ladder programming for simple process applications.
CO3	Identify different security design approaches, engineering and operator interface issues for designing distributed control systems.
CO4	Explain latest communication technologies like HART and Field bus protocol.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	3	2	1	3	1	1	3	3	3	1
CO2	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
CO3	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
CO4	3	2	2	2	2	1	1	1	2	1	1	3	3	2	1

Course Code	:	ICMI16
Course Title	:	**Digital Electronics**
Type of Course	:	Minor (MI)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	An understanding of number systems, codes and their conversions.
CLO2	The capability to reduce Boolean expression using K-map and tabular methods.
CLO3	The ability to design and analyze combinational and sequential logic circuits for a given problemstatement.
CLO4	An understanding of digital hardware, different types of logic families and their characteristics

Course Content

Review of number systems and logic gates, Algebraic reductions, Binary codes **-**Weighted and non- weighted, number complements, Binary arithmetic, Error detecting and error correcting codes, SOP, POS Canonical logic forms, Karnaugh maps and Quine-McClusky methods, Don’t care conditions, minimization of multiple output functions.

Synthesis of combinational functions: Arithmetic Circuits-Adder/ Subtractor, carry look-ahead adder, signed number addition and subtraction, BCD adders. IC adders. Multiplexers, implementation of combinational functions using multiplexers, de-multiplexers, decoders, code converters, Digital ICs for combinational logic circuits.

Sequential Logic: Basic latch circuit, Debouncing of a switch, Flip-Flops: truth table and excitation table, conversion of Flip-flops, integrated circuit flip-flops. Race in sequential circuits, Shift Registers, Counters - Synchronous, Asynchronous, Up-Down, Design of counters.

Analysis of clocked sequential circuits, Design with state equations, Moore and Mealy graphs, State reduction and assignment, Sequence detection, Hazards. Complexity and propagation delay analysis of circuits. Programmable logic devices, Design using Programmable Logic Devices (PLA, PAL, CPLD and FPGA).

Digital Hardware: Logic levels, Realization of logic gates, different logic families (TTL, ECL, CMOS, HC,HCT, ACT and HSCMOS), Logic levels, voltages and currents, fan-in, fan-out, speed, power dissipation. Comparison of logic families, interfacing between different families.

References

1.	M. Morris Mano, Charles Kime, Tom Martin, Logic and Computer Design Fundamentals, Pearson,5th Edition, 2016.
2.	J.P. Uyemura, A First Course in Digital Systems Design: An Integrated Approach, NelsonEngineering, 1999.
3.	W. H. Gothmann, Digital Electronics - An Introduction to Theory and Practice, Prentice Hall of India,2nd Edition, 2000
4.	J.M. Rabaey, Digital Integrated Circuits: A Design Perspective, Prentice Hall of India, 2nd Edition,2003.

5.	N.H.E. Weste, and K. Eshraghian, Principles of CMOS VLSI Design: A Systems Perspective,Pearson Education Inc., (Asia), 3rd Edition, 2005.
6.	S. Brown and Z Vranesic, Fundamentals of Logic Design with VHDL Design, Tata McGraw- Hill ,2002
7.	V. P. Nelson, H.T. Nagle, E.D. Caroll and J.D. Irwin, Digital Logic Circuit Analysis andDesign, Prentice Hall International, 1995
8.	Anil K Maini, Digital Electronics: Principles and Integrated Circuits , Wiley, 2019
9.	Thomas L. Floyd, Digital Fundamentals , 11th Edition, Pearson, 2015
10.	Ronald J. Tocci, Widmer Neal, Moss Greg, Digital Systems- Principles and Applications,12th Edition, Prentice Hall, 2010

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand various number systems, conversions and simplify the logical expressions usingBoolean functions.
CO2	Design and develop arithmetic and other special functions using combinational logic circuits andPLDs.
CO3	Design and develop synchronous and asynchronous for the given problem statement.
CO4	Understand how logic gates are built from the fundamental semiconductor electronics and be able to select logic ICs from different families based on requirement.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICMI17
Course Title	**:**	**Microprocessor and Microcontroller**
Type of Course	**:**	Minor (MI)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the architecture of 8, 16 and 32-bit microprocessor and microcontroller.
CLO2	To impart microcontroller programming skills in students.
CLO3	To familiarize the students with data transfer and interrupt services.
CLO4	To Familiarize the students with communication protocols for peripheral interfacing.

Course Content

Introduction to computer architecture and organization, Architecture of 8-bit, 16-bit, 32-bit and 64-bit microprocessors, CISC/RISC design philosophy, bus configurations, CPU module. Embedded system overview.

Introduction to embedded C and assembly language, instruction set of a typical 8-bit and 16-bit microprocessor, subroutines and stacks, energy efficient ultra-low power modes, programming exercises.

Timing diagrams, Memory families, Flash Vs FRAM, on-chip peripherals- working with IO ports, ADC, comparators, timers, PWM, Watchdog, Low power modes.

Architectures of 8 and 16-bit Microcontrollers, comparison, programming exercises, applications of energy efficient systems.

Serial and parallel data transfer schemes, interrupts and interrupt service procedure. Internal peripherals of microcontrollers – SPI, I2C UART, USB and DNA. Interfacing with RTC, EEPROM and DAC.

References

1.	Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications with the 8085 6th Edition, Penram international publishing (India) pvt.Ltd.2013.
2.	Douglas V. Hall, Microprocessors and Interfacing-Programming and Hardware, McGraw-Hill, 2nd Edition, 1999.
3.	Kenneth J. Ayala, The8051Microcontroller, Thomson Delmar Learning, 3rdEdition, 2004.
4.	John H Davies, MSP430 Microcontroller Basics, Newnes, 1st Edition, 2010.
5.	Jonathan W Valvano, Embedded Microcomputer Systems: Real Time Interfacing, CENGAGE Learning Custom Publishing, 3rd Edition, 2010.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the various functional blocks of microprocessors and microcontrollers.
CO2	Understand and write the assembly and C language programs.
CO3	Interface the peripherals with microprocessors and microcontrollers.
CO4	Design and develop microcontroller-based applications.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	1	1	1	1	-	1	2	3	3	1
CO2	3	3	3	3	3	1	2	1	2	-	2	2	3	3	1
CO3	3	3	3	3	2	2	2	2	1	2	1	2	3	3	1
CO4	3	3	3	3	3	2	2	1	2	2	2	2	3	3	2

Course Code	:	ICMI18
Course Title	:	**Micro Electro Mechanical Systems**
Type of Course	:	Minor (MI)
Prerequisites	:	--
Contact Hours	:	42 (3 credits)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the fundamental concepts of MEMS and Micro systems andtheir relevance to current scientific needs.
CLO2	To introduce the state-of-art micromachining techniques including surface micromachining, bulk micromachining, and related methods.
CLO3	To make the students knowledgeable in the design concepts of micro sensorsand micro actuators.
CLO4	To introduce the challenges and limitations in the design of MEMS devices
CLO5	To make the students knowledgeable in computer aided design tools for modeling MEMS device.

Course Content

Introduction, emergence, MEMS application, scaling issues, materials for MEMS, Thin film deposition, lithography and etching.

Bulk micro machining, surface micro machining and LIGA process.

MEMS devices, Engineering Mechanics for Micro System Design – static bendingof thin plates, Mechanical vibrational analysis, Thermomechanical analysis, fracture mechanics analysis, Thin film mechanics.

Theory and design: Micro Pressure Sensor, micro accelerometer – capacitive and piezoresistive, micro actuator.

Electronic interfaces, design, simulation and layout of MEMS devices using CAD tools.

References

1.	Tai Ran Hsu, MEMS and Microsystem Design and Manufacture,TataMcGraw Hill, New Delhi2002.
2.	Marc Madou, Fundamentals of Micro fabrication, CRC Press, 2nd Edition,2002.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS,Smart Devices, John Wiley and Sons Ltd, 1st Edition, reprinted2007.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1st Edition,2001.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1stEdition,2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2nd Edition,2011.
7.	Stephen D. Senturia., Microsystem Design, Kluwer Academic Publishers, 2001.
8.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, and V. K.Aatre., Micro and Smart Systems, Wiley-India, 2010.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the fundamental principles behind the working of micro devices/ systems and their applications.
CO2	Have knowledge in the standard micro fabrication techniques.
CO3	Identify micro sensors and actuators for a specific application.
CO4	Acquire skills in computer aided design tools for modeling and simulating MEMS devices.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO2	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO3	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
CO4	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1

Course Code	**:**	ICMI19
Course Title	**:**	**Medical Instrumentation**
Type of Course	**:**	Minor (MI)
Prerequisites	**:**	--
Contact Hours	**:**	42 (3 credits)
Course Assessment Methods	**:**	Continuous Assessments, Final Assessment

Course Learning Objectives (CLO)

CLO1	To educate the students on the different medical instruments.
CLO2	To familiarize the students with the analysis and design of instruments to measurebio-signals like ECG, EEG, EMG, etc.
CLO3	To have a basic knowledge in therapeutic devices
CLO4	To introduce about the clinical laboratory instruments and familiar about electrical safety.

Course Content

Electro physiology**:** Review of physiology and anatomy, resting potential, action potential, bioelectric potentials, electrode theory, bipolar and uni-polar electrodes, surface electrodes, needle electrode and microelectrode, physiological transducers-selection criteria and its application.

Bioelectric potential and cardiovascular measurement**s**: ECG recording system, Heart sound measurement-stethoscope, phonocardiograph (PCG), Foetalmonitor-ECG-phonocardiography, vector cardiograph, cardiac arrhythmia's monitoring system. EMG, EEG - Evoked potential response, ERG and EOG recording system. Measurement of blood pressure using sphygmomanometer instrument based on Korotkoff sound, indirect measurement of blood pressure,automated indirect measurement, and direct measurement techniques.

Clinical Laboratory Equipment**:** Chemical tests in clinical laboratory, Automated Biochemical Analysis System. Blood gas analyzer, Acid –base balance, Blood PH measurement, blood PCO2, blood PO2, Intra –arterial blood gas analyzers, Blood cell counters- types of blood cells, - methods of cell counting -coulter counter- Automatic recognition and differential blood cell counting.

Respiratory and pulmonary measurements: Physiology of respiratory system, respiratory rate measurement- artificial respirator- oximeter, pulmonary function measurements–spirometer–photo plethysmography and body plethysmography. Principal and techniques of impedance pneumography, Apnea monitor.

Electrical safety: Sources of electrical hazards in medical environment and safety techniques for checking safety parameters of biomedical equipment.

References

1.	John G. Webster, John W Clark, jr, MedicalInstrumentationApplicationandDesign,4th Edition, John Wiley and sons, New York, 2010
2.	Arthur Guyton, John E. Hall, Text Book of Medical Physiology, 12th Edition, Elsevier Saunders, 2011.
3.	Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Prentice Hall of India, New Delhi,2014.
4.	Jerry. L.Prince, Jonathan M. Links, Medical Imaging Signals and Systems, 2ndEdition, Pearson Prentice Hall, 2015..
5.	Shakti Chatterjee and Aubert Miller, Biomedical Instrumentation Systems, CENGAGE Learning publishing, 2016.
6.	R.S. Khandpur, Hand Book of Biomedical Instrumentation, 3rd edition, McGraw Hill Education (India) Private Limited,2014.
7.	Andrew G. Webb, Principles of Biomedical Instrumentation, Cambridge University Press, 2018;
8.	Cromwell ,Biomedical Instrumentation and Measurement, 2nd Edition, Pearson India 2015
9.	JosephJ .Carr and John M.Brown, Introduction to Biomedical Equipment Technology, 4thEdition, Pearson publishing, 2013.
10.	Onkar N. Pandey, Rakesh Kumar, Bio Medical Electronics and Instrumentation, Katson Books, 2011.
11.	M Arumugam, Biomedical Instrumentation Anuradha Publications,2015

Course Outcomes (CO)

On completion of this course, the students will be able to,

CO1	Understand the concept behind building automation.
CO2	Plan for building automation.
CO3	Design sub systems for building automation and integrate those systems.
CO4	Learn to design energy efficient system.

Course Outcome and Programme Outcome Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	3	2	2	2	2	1	3	2	1	3	3	3	2
CO2	2	2	3	3	2	2	2	1	2	2	2	3	3	3	1
CO3	3	3	3	3	3	2	2	1	3	2	2	3	3	3	2
CO4	3	3	3	3	3	1	2	2	2	1	3	3	3	3	1

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