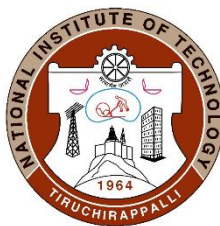


# BTECH\_ICE\_(2024- 2028)\_CURRICULUM

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



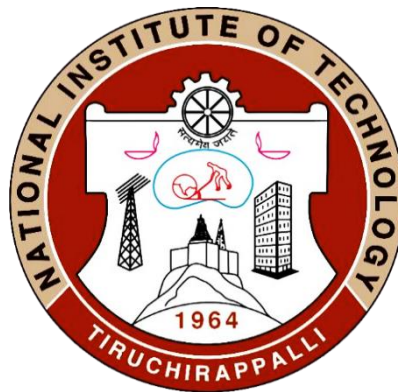
# **Bachelor of Technology (B.Tech.)**

in

## **INSTRUMENTATION AND CONTROL ENGINEERING**

### **Flexible CURRICULUM and SYLLABUS**

*for the students admitted in the academic year 2024 - 2025*



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 in Instrumentation and Control Engineering.
- To enhance knowledge, create passion for learning, foster innovation and nurture talents towards serving the society and the country.
- To encourage faculty and students to keep in pace with the latest technological developments and to pursue research in those areas.
- To enable the students to engage themselves in entrepreneurship and product development for the benefit 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:

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

<b>PO1</b>	<b>Engineering Knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
<b>PO2</b>	<b>Problem Analysis:</b> Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
<b>PO3</b>	<b>Design/Development of Solutions:</b> 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.
<b>PO4</b>	<b>Conduct Investigations of Complex Problems:</b> 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.
<b>PO5</b>	<b>Modern Tool Usage:</b> 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.
<b>PO6</b>	<b>The Engineer and Society:</b> 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.
<b>PO7</b>	<b>Environment and Sustainability:</b> Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.



<b>PO8</b>	<b>Ethics:</b> Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
<b>PO9</b>	<b>Individual and Team Work:</b> Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
<b>PO10</b>	<b>Communication:</b> 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.
<b>PO11</b>	<b>Project Management and Finance:</b> 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.
<b>PO12</b>	<b>Life-long Learning:</b> 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:

<b>PSO1</b>	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
<b>PSO2</b>	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
<b>PSO3</b>	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 3 <sup>rd</sup> to 6 <sup>th</sup> semester	16	10.0
<b>Total</b>	<b>57</b>	<b>160</b>	<b>100</b>
<b>Honours (Optional)</b>	Courses for 15 credits	<b>15</b> <b>Additional credits</b>	-
<b>Minor (Optional)</b>	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 2<sup>nd</sup> to 6<sup>th</sup> 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 8<sup>th</sup> 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 8<sup>th</sup> 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 8<sup>th</sup> 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 LR's 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	
<b>Total</b>	<b>22</b>	<b>56</b>	<b>15</b>	<b>52</b>	<b>8</b>	<b>16</b>	<b>12</b>	<b>36</b>	<b>160</b>	<b>160</b>

**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		
<b>Same as B.Tech.</b>	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>B.Sc. (Engg.) Exit</b>	V	1	3	3	9	2	4	1	3	19	35
	VI	4 <sup>#</sup>	12	-	-	2	4	-	-	16	
<b>After B.Sc. (Engg.) exit and join back for B. Tech.</b>	VII	-	-	1	3	-	-	6	18	21	38
	VIII	1	1	3	10	-	-	2	6	17	
	<b>Total</b>	<b>22</b>	<b>56</b>	<b>15</b>	<b>52</b>	<b>8</b>	<b>16</b>	<b>12</b>	<b>36</b>	<b>160</b>	<b>160</b>

<sup>#</sup>(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 and Foreign Trade	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 6 <sup>th</sup> sem; assessment in the 7 <sup>th</sup> Semester for 4 year B.Tech. Winter – after 5 <sup>th</sup> sem; assessment in the 6 <sup>th</sup> 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
<b>Total</b>		<b>22</b>	<b>56</b>



**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
		<b>Total</b>	<b>19</b>	

**Semester II (January Session)**

S. No.	Course Code	Course	Credits	Category
1.	HSIR11	English for Communication (Theory and Lab)	4	GIR
2.	MAIR22	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/ SWIR12/ SWIR13	NSS/NCC/NSO	0	GIR
8.	ICPC11	Circuit Theory (Programme Core – I)	4	PC
		<b>Total</b>	<b>21</b>	

**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
		<b>Total</b>	<b>25</b>	

**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
<b>Total</b>			<b>22</b>	

**Semester V (July Session)**

S. No.	Course Code	Course	Credits	Category
1.	HSIR13	Industrial Economics and Foreign Trades	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 – V	3	PE
7.	ICPEXX	Programme Elective – VI / 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
<b>Total</b>			<b>25</b>	

**Semester VI (January Session)**

S. No.	Course Code	Course	Credits	Category
1.	ICIR19	Industrial Lecture	1	GIR
2.	HSIR14	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
<b>Total</b>			<b>24</b>	

**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
		<b>Total</b>	<b>15</b>	

**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
		<b>Total</b>	<b>9</b>	

**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
<b>Total</b>	<b>160</b>

**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 and Foreign Trades	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 – V / 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
<b>Total</b>			<b>19</b>	

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

Sl. No.	Course Code	Course	Credits	Category
1.	ICIR19	Industrial Lecture	1	GIR
2.	HSIR14	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
<b>Total</b>			<b>16</b>	

\*Project work is mandatory in the 6<sup>th</sup> 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 6<sup>th</sup> 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 6<sup>th</sup> 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 4<sup>th</sup> 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 – VI	3	PE
3.	ICPEXX	Programme Elective – VII	3	PE
4.	ICPEXX	Programme Elective – VIII	3	PE
5.	ICPEXX	Programme Elective – IX / Open Elective – III	3	PE/OE
6.	ICPEXX	Programme Elective – X / Open Elective - IV	3	PE/OE
7.	ICPEXX	Programme Elective – XI / Open Elective - V	3	PE/OE
<b>Total</b>			<b>21</b>	

### 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
<b>Total</b>			<b>17</b>	

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

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

**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 3<sup>rd</sup> 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)	2 <sup>nd</sup>	-	4
2.	ICPC12	Electronic Circuits (Programme Core – II)	3 <sup>rd</sup>	ICPC11	4
3.	ICPC13	Signals and Systems (Programme Core – III)	3 <sup>rd</sup>	-	4
4.	ICPC14	Sensors and Transducers (Programme Core – IV)	3 <sup>rd</sup>	-	3
5.	ICPC15	Digital Electronics (Programme Core – V)	3 <sup>rd</sup>	-	3
6.	ICPC16	Microprocessors and Microcontrollers (Programme Core – VI)	4 <sup>th</sup>	ICPC15	3
7.	ICPC17	Industrial Instrumentation (Programme Core-VII)	4 <sup>th</sup>	ICPC14	3
8.	ICPC18	Control Systems - I (Programme Core – VIII)	4 <sup>th</sup>	ICPC13	4
9.	ICPC19-A	Product Design and Development – 1 (Theory) Programme Core – IX Part A	4 <sup>th</sup>	-	2
	ICPC19-B	Product Design and Development – 2 (Practice) Programme Core – IX Part B	5 <sup>th</sup>	-	2
10.	ICPC20	Analog Signal Processing (Programme Core – X)	5 <sup>th</sup>	ICPC12, ICPC13	4
11.	ICPC21	Process Control (Programme Core – XI)	5 <sup>th</sup>	ICPC18	3
12.	ICPC22	Control Systems - II (Programme Core – XII)	5 <sup>th</sup>	ICPC18	3
13.	ICPC23	Electrical and Electronic Measurements (Programme Core – XIII)	6 <sup>th</sup>	ICPC11, ICPC12	3
14.	ICPC24	Digital Signal Processing (Programme Core – XIV)	6 <sup>th</sup>	ICPC13	3
15.	ICPC25	Logic and Distributed Systems (Programme Core – XV)	6 <sup>th</sup>	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)	3 <sup>rd</sup>	ICPC11	2
2.	ICLR12	Electronic Circuits Laboratory (Laboratory – II)	3 <sup>rd</sup>	-	2
3.	ICLR13	Sensors and Transducers Laboratory (Laboratory – III)	4 <sup>th</sup>	ICPC14	2
4.	ICLR14	Microprocessors and Microcontrollers Laboratory (Laboratory – IV)	4 <sup>th</sup>	-	2
5.	ICLR15	Control Engineering Laboratory (Laboratory – V)	5 <sup>th</sup>	ICPC18	2
6.	ICLR16	Analog Signal Processing Laboratory (Laboratory – VI)	5 <sup>th</sup>	-	2
7.	ICLR17	Instrumentation Laboratory (Laboratory – VII)	6 <sup>th</sup>	ICPC17	2
8.	ICLR18	Industrial Automation and Process Control Laboratory (Laboratory – VIII)	6 <sup>th</sup>	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

**(IV) 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 <i>Selected</i> 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.

#### (V) 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.

#### (VI) **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 5<sup>th</sup> to 8<sup>th</sup> 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

#### (VII) **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





**(VIII) 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<sup>th</sup> to 8<sup>th</sup> 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)



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the students the role and values of Instrumentation Engineering in the society.
<b>CLO2</b>	To emphasize the importance of codes and standards in Instrumentation and Control Engineering relevant to industry
<b>CLO3</b>	To make the student appreciate the relation between the building blocks of instrumentation and control engineering in a device or a plant
<b>CLO4</b>	To make the student sketch the basic building blocks of instrumentation and control engineering for various industrial and scientific applications
<b>CLO5</b>	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 <a href="https://www.isa.org/standards-and-publications/isa-standards/find-isa-standards-by-topic">https://www.isa.org/standards-and-publications/isa-standards/find-isa-standards-by-topic</a>
5.	Bureau of Indian Standards



### Course Outcomes (CO)

At the end of the course student will be able to

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

### Mapping of Course Outcomes and Programme Outcomes

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PSO1</b>	<b>PSO2</b>	<b>PSO3</b>
<b>CO1</b>	2	2	2	2	2	2	2	2	3	3	3	2	2	2	2
<b>CO2</b>	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
<b>CO3</b>	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
<b>CO4</b>	3	3	3	3	3	1	1	1	2	2	2	3	3	3	1
<b>CO5</b>	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)



<b>Course Code</b>	:	MAIR34
<b>Course Title</b>	:	<b>Probability and Distribution theory</b>
<b>Type of Course</b>	:	IR
<b>Prerequisites</b>	:	-
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	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

<b>CLO1</b>	Familiarize basic concepts of probability and random variables
<b>CLO2</b>	Identifying and analyzing random variables in practical problems
<b>CLO3</b>	Introduce important probability distributions for analyzing the data
<b>CLO4</b>	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, 7 <sup>th</sup> 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, 5 <sup>th</sup> 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, 2 <sup>nd</sup> 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

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

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	HSIR13
<b>Course Title</b>	:	<b>Industrial Economics and Foreign Trade</b>
<b>Type of Course</b>	:	IR
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, End Assessment

### Course Learning Objectives (CLO)

The course intends

<b>CLO1</b>	To provide knowledge on demand analysis and forecasting of consumer behaviour
<b>CLO2</b>	To provide knowledge to the students on the basic issues such as productivity, efficiency, capacity utilization and debates involved in industrial development
<b>CLO3</b>	To provide knowledge on inter-regional and international trade
<b>CLO4</b>	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, 5 <sup>th</sup> Edition, 2017
4.	Paul, Krugman. International Economics. Pearson, 10 <sup>th</sup> Edition, 2017
5.	Kenneth D. George. Industrial Organization, Routledge, 2009



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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





<b>Course Code</b>	:	HSIR14
<b>Course Title</b>	:	<b>Professional Ethics</b>
<b>Type of Course</b>	:	IR
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, End Assessment

### Course Learning Objectives (CLO)

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

<b>CO1</b>	Understand the basic perception of profession, professional ethics, and various moral and social issues.
<b>CO2</b>	Demonstrate awareness of their rights and responsibility as engineers.
<b>CO3</b>	Acquire knowledge about various roles of engineers in a variety of global issues.
<b>CO4</b>	Thrive in competitive professional spaces with integrity and responsibility.
<b>CO5</b>	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
<b>CO1</b>	1	1	1	2	1	3	2	3	3	2	3	3	1	2	3
<b>CO2</b>	1	1	1	1	1	3	2	3	3	2	2	3	1	2	3
<b>CO3</b>	2	1	1	1	1	3	3	3	3	3	3	3	2	3	3
<b>CO4</b>	1	1	2	2	2	3	3	3	3	3	3	3	1	3	3
<b>CO5</b>	1	1	2	2	1	3	2	3	3	3	3	3	1	2	3



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide the student an opportunity to engage in a short-term project at an industry, research organization or in an academic laboratory.
<b>CLO2</b>	To make the student interact with industry personnel/ academic researchers and learn about relevant standards, advanced tools and techniques.
<b>CLO3</b>	To inculcate in the student the values of professionalism, workplace ethics and socially and environmentally conscious behaviour.
<b>CLO4</b>	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

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide the student an opportunity to formulate and work on a research problem in a preferred domain of specialization.
<b>CLO2</b>	To make the student aware of existing literature relevant to the research problem, frame the research hypothesis and perform the research design.
<b>CLO3</b>	To expose the student to standard techniques in data acquisition, interpretation and analysis in the preferred domain of specialization.
<b>CLO4</b>	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

<b>CO1</b>	Formulate and state a research problem clearly.
<b>CO2</b>	Compile relevant literature, frame research hypotheses and perform the research design.
<b>CO3</b>	Describe standard techniques in the specialization domain to acquire and compile relevant data, interpret & analyze it and test the research hypotheses.
<b>CO4</b>	Arrive at logical conclusions and propose suitable recommendations on the research problem.
<b>CO5</b>	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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To make the student recall fundamental concepts in Instrumentation and Control Engineering.
<b>CLO2</b>	To enable a holistic integration of learnings from different courses in the programme relevant to problem solving in Instrumentation and Control Engineering.
<b>CLO3</b>	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.
<b>CLO4</b>	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

<b>CO1</b>	Recall and apply fundamental concepts in science and engineering to model practical scenarios.
<b>CO2</b>	Integrate learnings from different courses in Instrumentation and Control Engineering and apply them for technical problem solving.
<b>CO3</b>	Develop and Apply skills related to communication and problem solving while attending technical interviews
<b>CO4</b>	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





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To make the student relate theoretical knowledge and concepts in Instrumentation and Control Engineering to practical relevance and applications in the industry.
<b>CLO2</b>	To enable the student, learn about contemporary problems faced by the industry and systematic approaches in solving them.
<b>CLO3</b>	To provide a platform for the student to interact with experts from industries and research and development organizations.
<b>CLO4</b>	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

<b>CO1</b>	Connect theoretical concepts in Instrumentation and Control Engineering to practical relevance and applications in the industry.
<b>CO2</b>	Get exposure on various challenges faced by the modern industry and the systematic approaches to tackle them.
<b>CO3</b>	Enhance comprehension and communication skills during interactions with experts from the industry.
<b>CO4</b>	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	PS01	PS02	PS03
<b>CO1</b>	3	3	3	2	2	-	-	-	-	-	-	3	3	3	1
<b>CO2</b>	3	3	3	3	2	3	2	3	2	2	2	3	3	3	2
<b>CO3</b>	-	-	-	-	-	2	2	3	3	3	-	2	-	2	3
<b>CO4</b>	2	-	2	3	3	2	-	2	2	3	3	2	2	2	3



## **PROGRAMME CORE (PC) COURSES**



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To teach the electrical circuit laws and theorems to aid in circuit analysis
<b>CLO2</b>	To impart problem solving technique of linear passive electrical circuits.
<b>CLO3</b>	To expose the students to the transient behaviour of different R-L-C circuits.
<b>CLO4</b>	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, Circuit 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- $\phi$  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, 8 <sup>th</sup> Edition, 2013
2.	Franklin F. Kuo, Network Analysis and Synthesis, Wiley International, 5 <sup>th</sup> Edition, 2012
3.	Van Valkenburg, Network Analysis, Prentice Hall, Revised 3 <sup>rd</sup> Edition, 2019.
4.	Charles K. Alexander, Mathew N.O Sadiku, Fundamentals of Electric Circuits TMH Education Pvt. Ltd, 5 <sup>th</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

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

<b>CLO1</b>	Understand the applications of diode and biasing techniques for BJTs and MOSFETs
<b>CLO2</b>	Design different types of amplifiers using active loads.
<b>CLO3</b>	Analyze the high-frequency response of various amplifier circuits.
<b>CLO4</b>	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,

<b>CO1</b>	Apply knowledge of diodes, transistors (BJTs and FETs), and their biasing circuits to understand amplifier operation
<b>CO2</b>	Analyze the performance of small signal BJT and FET amplifiers - single stage and multi stage amplifiers
<b>CO3</b>	Design and analyze the characteristics of MOSFET and BJT amplifiers
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the student to identify and represent the type of signals and systems.
<b>CLO2</b>	To introduce the mathematical tools available to analyze continuous time signals and systems.
<b>CLO3</b>	To introduce the mathematical tools available to analyze discrete time signals and systems.
<b>CLO4</b>	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, 3 <sup>rd</sup> Edition, 1987
2.	Oppenheim A.V., Wilsky and Nawab, Signals and Systems, Pearson India Education Services Private limited India, 2 <sup>nd</sup> Edition, 2016
3.	Chen C.T., Systems and Signal Analysis - A Fresh Look, Oxford University Press India, 3 <sup>rd</sup> Edition, 2004
4.	B.P. Lathi, Principles of Linear Systems and Signals, Oxford University Press, 2 <sup>nd</sup> Edition, 2009
5.	Cooper G.R and Mc Gillem C.D, Probabilistic Methods of Signals and System Analysis, Oxford University Press, 3 <sup>rd</sup> Edition, 1999
6.	Chesmond, Wilson and Lepla, Advanced Control System Technology, Viva Books, 1 <sup>st</sup> Edition, 1998
7.	Ziemer R.E., Tranter W.H., and Fannin D.R., Signals and Systems: Continuous and Discrete, Prentice Hall, 4 <sup>th</sup> 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,

<b>CO1</b>	Classify the signals and systems based on their properties and determine the response of LTI system using convolution
<b>CO2</b>	Analyze the spectral characteristics of continuous and discrete time signals and systems using Fourier transforms.
<b>CO3</b>	Apply Laplace and Z transform to analyze continuous and discrete time systems
<b>CO4</b>	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
<b>CO1</b>	3	3	3	2	3	2	-	-	-	-	-	2	3	3	-
<b>CO2</b>	3	3	2	2	3	2	-	-	-	-	-	3	3	3	-
<b>CO3</b>	3	3	3	3	3	1	1	-	-	-	-	3	3	3	-
<b>CO4</b>	3	1	2	1	1	2	-	-	-	-	-	2	2	2	-





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to various sensors and transducers for measuring mechanical quantities.
<b>CLO2</b>	To make the students familiar with the specifications of sensors and transducers.
<b>CLO3</b>	To teach the basic conditioning circuits for various sensors and transducers.
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2005.
2.	Doebelin E.O, Measurement Systems - Application and Design, McGraw-Hill, 4 <sup>th</sup> Edition, 2004.
3.	S.M. Sze, Semiconductor sensors, John Wiley and Sons Inc., 3 <sup>rd</sup> edition, 2006.
4.	James W. Dally, Instrumentation for Engineering Measurements, Wiley, 2 <sup>nd</sup> Edition, 1993
5.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2 <sup>nd</sup> edition, 2008
6.	Patranabis, Sensors and Transducers, Prentice Hall, 2 <sup>nd</sup> edition, 2003.
7.	Alok Baura, Fundamentals of Industrial Instrumentation, Wiley India Pvt. Ltd, 2011.
8.	Murthy D. V. S, Transducers and Instrumentation, Prentice Hall, 2 <sup>nd</sup> Edition, 2011
9.	Neubert H.K.P, Instrument Transducers - An Introduction to their Performance and Design, Oxford University Press, 2 <sup>nd</sup> Edition, 1999.
10.	Waldemar Nawrocki, Measurement Systems and Sensors, Artech House, 2005
11.	B.E. Nolingk, Instrumentation Reference Book, Butterworth- Heinemann, 2 <sup>nd</sup> Edition 1995.



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|-----|---|
| 12. | Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal Processing for Smart Sensors, John Wiley and Sons, Chichester, UK, 2002. |
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**Course Outcomes (CO)**

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

<b>CO1</b>	Understand the basics of measurement system- its input, output configuration and its static and dynamic characteristics.
<b>CO2</b>	Explain the principle and working of various sensors and transducers.
<b>CO3</b>	Design signal conditioning circuit for various transducers.
<b>CO4</b>	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
<b>CO1</b>	3	2	3	2	3	-	1	-	2	-	-	-	2	-	-
<b>CO2</b>	2	3	3	-	-	-	-	-	2	-	-	2	2	3	-
<b>CO3</b>	2	3	3	-	-	-	-	-	2	-	-	2	2	3	-
<b>CO4</b>	-	2	3	-	-	-	-	-	2	-	-	2	2	3	-



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

### Course Learning Objectives (CLO)

The subject aims to provide the student with

<b>CLO1</b>	An understanding of number systems, codes and their conversions.
<b>CLO2</b>	The capability to reduce Boolean expression using K-map and tabular methods.
<b>CLO3</b>	The ability to design and analyze combinational and sequential logic circuits for a given problem statement.
<b>CLO4</b>	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, 5 <sup>th</sup> 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, 2 <sup>nd</sup> Edition, 2000
4.	J.M. Rabaey, Digital Integrated Circuits: A Design Perspective, Prentice Hall of India, 2 <sup>nd</sup> Edition, 2003
5.	N.H.E. Weste, and K. Eshraghian, Principles of CMOS VLSI Design: A Systems Perspective, Pearson Education Inc., (Asia), 3 <sup>rd</sup> 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. Carroll and J.D. Irwin, Digital Logic Circuit Analysis and Design, 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, 12 <sup>th</sup> Edition, Prentice Hall, 2010

### Course Outcomes (CO)

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

<b>CO1</b>	Understand various number systems, conversions and simplify the logical expressions using Boolean functions.
<b>CO2</b>	Design and develop arithmetic and other special functions using combinational logic circuits and PLDs.
<b>CO3</b>	Design and develop synchronous and asynchronous for the given problem statement.
<b>CO4</b>	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

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the architecture of 8, 16 and 32-bit microprocessor and microcontroller.
<b>CLO2</b>	To impart microcontroller programming skills in students.
<b>CLO3</b>	To familiarize the students with data transfer and interrupt services.
<b>CLO4</b>	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 6 <sup>th</sup> Edition, Penram International Publishing (India) pvt. Ltd. 2013
2.	Douglas V. Hall, Microprocessors and Interfacing-Programming and Hardware, McGraw Hill Education, 3 <sup>rd</sup> Edition, 1 July 2017
3.	Kenneth J. Ayala, The 8051 Micro controller, Thomson Delmar Learning, 3 <sup>rd</sup> Edition, 2004
4.	John H Davies, MSP430 Microcontroller Basics, Newnes, 1 <sup>st</sup> Edition, 2010
5.	Jonathan W Valvano, Embedded Microcomputer Systems: Real Time Interfacing, CENGAGE Learning Custom Publishing, 3 <sup>rd</sup> Edition, 2010

### Course Outcomes (CO)

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

<b>CO1</b>	Understand the various functional blocks of microprocessor and microcontrollers.
<b>CO2</b>	Understand and write the assembly and C language programs.
<b>CO3</b>	Interface the peripherals with microprocessors and microcontrollers.
<b>CO4</b>	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



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

### Course Learning Objectives (CLO)

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

### 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, 6 <sup>th</sup> Edition, 2011
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4 <sup>th</sup> Edition, 2003
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3 <sup>rd</sup> Edition, 2010
4.	B.E. Noltingk, Instrumentation Reference Book, Butterworth Heinemann, 2 <sup>nd</sup> Edition, 1995
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill, Singapore, 5 <sup>th</sup> Edition, 1999
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I and Vol II, Gulf Publishing Company, Houston, 2001
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3 <sup>rd</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the concept of feedback control system.
<b>CLO2</b>	To impart knowledge in mathematical modeling of physical systems.
<b>CLO3</b>	To impart knowledge in characteristics and performance of feedback control system.
<b>CLO4</b>	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, 5 <sup>th</sup> 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 1 <sup>st</sup> 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,

<b>CO1</b>	Generate mathematical models of dynamic control system by applying differential equations.
<b>CO2</b>	Analyze and characterize the behavior of a control system in terms of different system, performance parameters and assess system stability.
<b>CO3</b>	Evaluate and analyze system performance using frequency and transient response analysis.
<b>CO4</b>	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
<b>CO1</b>	3	2	3	3	3	-	-	-	-	-	-	2	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	1	1	-	2	3	3	-
<b>CO3</b>	2	2	2	3	3	-	-	-	1	1	-	-	2	3	-
<b>CO4</b>	3	2	3	3	3	-	2	1	1	1	-	2	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To inculcate into the student the spirit of innovation and entrepreneurship.
<b>CLO2</b>	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.
<b>CLO3</b>	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.
<b>CLO4</b>	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)

#### CONCEPTUAL TOPICS COVERED BY LECTURES (Semester-IV)

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

#### PRACTICAL WORK (Semester-IV)

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.

#### SUMMER VACATION WORK (between Semester-IV and Semester-V)

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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To inculcate into the student the spirit of innovation and entrepreneurship.
<b>CLO2</b>	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.
<b>CLO3</b>	To make the students fabricate an alpha prototype and test it for its conformity to the design specifications.
<b>CLO4</b>	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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To teach the properties of analog signals and systems and random signal analysis
<b>CLO2</b>	To familiarize the students to DC and AC characteristics of operational amplifiers and its influence on output and their compensation techniques
<b>CLO3</b>	To impart the students to design signal conditioning circuits using Op-Amp
<b>CLO4</b>	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, 4 <sup>th</sup> edition Mc-Graw Hill Inc. 2014.
2.	A.P. Malvino, Electronic Principles, Tata McGraw Hill Publications, 8 <sup>th</sup> Edition, 2016
3.	Wai-Kai-Chen, The circuits and filters Handbook, CRC press, 2 <sup>nd</sup> Edition, 2003.
4.	Gabel R.A. and Robert R.A., Signals and Linear Systems, John Wiley and Sons, 3 <sup>rd</sup> Edition, 2009
5.	James M. Fiore, Op Amps and Linear Integrated Circuits – Concepts and Applications, Cengage Learning Pvt, Ltd, 3 <sup>rd</sup> 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,

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





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the terminology and concepts associated with Process control domain.
<b>CLO2</b>	To impart knowledge in the design of control systems and PID controller tuning for processes.
<b>CLO3</b>	To familiarize the students with characteristics, selection, sizing of control valves.
<b>CLO4</b>	To elaborate different types of control schemes such as cascade control, feed forward control and Model 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 Hall of India, New Delhi, 3 <sup>rd</sup> Edition, 2008
2.	D.R. Coughanowr, Steven E LeBlanc, Process Systems Analysis and Control, McGraw Hill, Singapore, 3 <sup>rd</sup> Edition, 2009
3.	B.W. Bequette, Process Control Modeling, Design and Simulation. Prentice Hall of India, New Delhi, 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, 3 <sup>rd</sup> Edition2005
6.	Bela G. Liptak, Instrument Engineers' Handbook, Volume II: Process Control and Optimization, CRCPress, 4 <sup>th</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce about the system states and state-space modeling of dynamical systems.
<b>CLO2</b>	To teach the advanced methods and techniques of linear system analysis and stability using Lyapunov theory.
<b>CLO3</b>	To demonstrate how algebraic methods can be deployed in developing feedback controllers for a larger scale of systems.
<b>CLO4</b>	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 ,5 <sup>th</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	2	3	3	3	1	1	-	1	1	2	3	3	3	-
<b>CO2</b>	3	2	3	3	3	1	1	-	1	2	3	3	3	3	-
<b>CO3</b>	3	1	3	3	3	-	1	-	1	1	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	2	2	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To give an overview of current, voltage and power measuring electrical, electronics and digital instruments.
<b>CLO2</b>	To expose the students to the design of bridges for the measurement of resistance, capacitance and inductance.
<b>CLO3</b>	To give an overview of test and measuring instruments.
<b>CLO4</b>	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: Electrodynamometer 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,

<b>CO1</b>	Demonstrate familiarity with various measuring instruments (ammeters, voltmeters, wattmeters, energy meters, extension of meters, current and voltage transformers) used to measure electrical quantities.
<b>CO2</b>	Design suitable DC and AC bridges for the measurement of R, L, C and Frequency measurement.
<b>CO3</b>	Suggest the kind of instrument suitable for typical measurements.
<b>CO4</b>	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
<b>CO1</b>	3	2	1	1	2	2	1	1	1	1	1	2	2	2	1
<b>CO2</b>	3	2	2	2	2	2	1	1	1	1	1	2	2	1	1
<b>CO3</b>	2	3	1	1	3	2	2	1	1	1	1	2	1	2	1
<b>CO4</b>	2	3	1	2	2	2	1	1	1	1	1	2	1	2	1



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide higher level of understanding of discrete-time and digital signal in time and frequency domains.
<b>CLO2</b>	To provide knowledge to analyze linear systems with difference equations
<b>CLO3</b>	design and implement different structures of FIR and IIR filters.
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2007
3.	Ifeachor, E.C., and Jervis, B.W., Digital Signal Processing: A Practical Approach, Pearson Education Asia, 2 <sup>nd</sup> Edition, 2009



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

**Course Outcomes (CO)**

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

<b>CO1</b>	Analyze the signals in both time and frequency domain
<b>CO2</b>	Design FIR and IIR filters for signal pre-processing
<b>CO3</b>	Implement and realize the filters using different structures.
<b>CO4</b>	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
<b>CO1</b>	3	2	3	3	3	1	2	-	2	1	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	1	3	-	2	2	3	3	3	3	-
<b>CO3</b>	3	3	3	3	3	2	3	-	2	2	3	3	3	3	-
<b>CO4</b>	3	3	3	3	3	2	3	1	3	3	3	3	3	3	1





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the importance of process automation techniques.
<b>CLO2</b>	To impart knowledge in PLC based programming.
<b>CLO3</b>	To introduce distributed control system and different communication protocols.
<b>CLO4</b>	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 and Applications, Prentice Hall Inc., New Jersey, 5 <sup>th</sup> 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, 6 <sup>th</sup> Edition, 2023
4.	Deshpande P. Band Ash R.H., Elements of Process Control Applications, ISA Press, New York 1995
5.	Curtis D. Johnson, Process Control Instrumentation Technology, Pearson New International, 8 <sup>th</sup> Edition, 2013



6.	Krishna Kant, Computer-based Industrial Control, Prentice Hall, New Delhi, 2 <sup>nd</sup> Edition, 2011
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### Course Outcomes (CO)

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

<b>CO1</b>	Understand various process automation technologies.
<b>CO2</b>	Design and develop a PLC ladder programming for simple process applications.
<b>CO3</b>	Apply different security design approaches, engineering and operator interface issues for designing of Distributed Control System.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	2	2	3	2	1	3	1	1	3	3	3	1
<b>CO2</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
<b>CO3</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
<b>CO4</b>	3	2	2	2	2	1	1	1	2	1	1	3	3	2	1



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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To understand and analyze the basic theorems of Circuit theory
<b>CLO2</b>	To analyze the transient and frequency response of the circuit
<b>CLO3</b>	To realize and verify the AC circuits
<b>CLO4</b>	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, 6 <sup>th</sup> Edition, 2006

### Course Outcomes (CO)

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

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



### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To understand characteristics of diodes and transistors
<b>CLO2</b>	To design the amplifier circuits and analyze its frequency response
<b>CLO3</b>	Understand and analyze different applications of combinational circuits.
<b>CLO4</b>	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 <sup>rd</sup> 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 <sup>rd</sup> Edition New York, NY, USA, McGraw-Hill, 2003

### Course Outcomes (CO)

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

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



### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To familiarize the students to the basic principles of various transducers.
<b>CLO2</b>	To impart knowledge in static and dynamic characteristics of sensors.
<b>CLO3</b>	To impart knowledge in the design of signal conditioning circuits for transducers.
<b>CLO4</b>	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,

<b>CO1</b>	Analyze the static characteristics of different measurement systems
<b>CO2</b>	Design the signal conditioning circuits for transducers
<b>CO3</b>	Choose the appropriate measuring meter to avoid loading
<b>CO4</b>	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	-



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

### Course Learning Objectives (CLO)

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

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



### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge on analysis and design of control system in time and frequency domain.
<b>CLO2</b>	To impart knowledge in classical control and state space-based control system design.
<b>CLO3</b>	To study the characteristics of compensating networks
<b>CLO4</b>	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,

<b>CO1</b>	Design control systems in both classical and modern techniques.
<b>CO2</b>	Design and implement controllers to regulate and control various systems.
<b>CO3</b>	Design full order and reduced order state observer.
<b>CO4</b>	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	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge on design and test the Op-amp and other ICs based circuits.
<b>CLO2</b>	To impart knowledge on the design of filters
<b>CLO3</b>	To understand the working of data converters
<b>CLO4</b>	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,

<b>CO1</b>	Design analog and digital system level circuit.
<b>CO2</b>	Simulate and validate analog circuits using simulation software
<b>CO3</b>	Implement various signal processing functions using analog electronic components
<b>CO4</b>	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
<b>CO1</b>	2	3	2	3	3	2	3	2	2	3	2	3	3	3	3
<b>CO2</b>	3	3	3	3	3	3	3	3	2	3	2	3	3	3	2
<b>CO3</b>	3	3	3	2	2	3	2	2	2	2	2	3	3	3	3
<b>CO4</b>	2	3	3	2	2	3	2	2	2	2	2	3	3	3	3



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To familiarize the students with different signal conditioning circuits for temperature and pressure measurement system.
<b>CLO2</b>	To familiarize the students to the calibration practices used in industries.
<b>CLO3</b>	To impart knowledge in the transmitter design.
<b>CLO4</b>	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, 6 <sup>th</sup> Edition, 2021

### Course Outcomes (CO)

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

<b>CO1</b>	Suggest a suitable temperature sensor for an application.
<b>CO2</b>	Evaluate various temperature and pressure measuring sensors.
<b>CO3</b>	Design and implement signal conversion and manipulation circuits for temperature and pressure measurement systems.
<b>CO4</b>	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





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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge on the time and frequency analysis of first order and second order system
<b>CLO2</b>	To impart practical knowledge in PC based data acquisition, analysis and control of different process trainers.
<b>CLO3</b>	To teach the industrial automation concept and programming techniques.
<b>CLO4</b>	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 Converter 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, 3 <sup>rd</sup> Edition, 2009
3.	B.W. Bequette, Process Control Modeling, Design and Simulation, Pearson, 2 <sup>nd</sup> Edition 2023

### Course Outcomes (CO)

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

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



### Course Outcome and Programme Outcome Mapping

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



## **PROGRAMME ELECTIVE (PE) COURSES**



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To educate the students on the different medical instruments
<b>CLO2</b>	To familiarize the students with the analysis and design of instruments to measure bio-signals like ECG, EEG, EMG, etc.
<b>CLO3</b>	To have a basic knowledge in therapeutic devices
<b>CLO4</b>	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 measurements: 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 pCO<sub>2</sub>, blood pO<sub>2</sub>, 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, 4 <sup>th</sup> Edition, John Wiley and sons, New York, 2010.
2.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 5 <sup>th</sup> Edition, Wiley, 2020. (e book).
3.	Arthur Guyton, John E. Hall, Text Book of Medical Physiology, 14 <sup>th</sup> Edition, Elsevier Saunders, 2020.



4.	Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Prentice Hall of India, New Delhi, 2 <sup>nd</sup> Edition, 1990.
5.	Jerry. L.Prince, Jonathan M. Links, Medical Imaging Signals and Systems, 2 <sup>nd</sup> Edition, 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,3 <sup>rd</sup> edition, 2007.
8.	Joseph J. Carr and John M. Brown, Introduction to Biomedical Equipment Technology ,4 <sup>th</sup> Edition,Pearson publishing, 2000.
9.	R.S. Khandpur, Hand Book of Biomedical Instrumentation, 3 <sup>rd</sup> 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,

<b>CO1</b>	To understand, design and evaluate systems and devices that can measure, test and/or acquire bio-signal information from the human body.
<b>CO2</b>	Familiar with patient monitoring equipment used in hospitals.
<b>CO3</b>	Ability to explain the medical diagnostic and therapeutic techniques
<b>CO4</b>	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
<b>CO1</b>	3	3	2	3	3	3	3	2	1	2	2	3	3	3	1
<b>CO2</b>	3	3	3	2	3	3	3	2	2	2	2	3	3	3	2
<b>CO3</b>	3	2	3	-	-	-	-	-	-	-	-	2	3	3	-
<b>CO4</b>	3	2	3	2	3	2	2	1	1	2	2	3	3	3	1



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the importance of biomedical signals and analysis
<b>CLO2</b>	To introduce different types of bio signals and their characteristics
<b>CLO3</b>	To study different noise removal mechanisms for biomedical signals
<b>CLO4</b>	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 vibroarthrogram (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, 3 <sup>rd</sup> 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, 5 <sup>th</sup> Edition, Wiley, 2020. (e book).
7.	Mitra, S.K., Digital Signal Processing: A Computer-Based Approach, McGraw Hill, NY, 4 <sup>th</sup> Edition, 2010.



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamentals of image processing
<b>CLO2</b>	To introduce to the concept of image restoration and reconstructions
<b>CLO3</b>	To introduce the concepts of image segmentation and compressions
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2017.
2.	Jain Anil K., Fundamentals of Digital Image Processing, Prentice Hall India, 4 <sup>th</sup> Edition, 1989.
3.	Milan Sonka, Vaclav Hlavav, Roger Boyle, Image Processing, Analysis and Machine Vision, Cengage Learning, 4 <sup>th</sup> Edition, 2014.
4.	Rangaraj M. Rangayyan, Biomedical Image Analysis, CRC Press, 2005.
5.	Pratt W.K, Digital Image Processing, Wiley-Interscience, 4 <sup>th</sup> Edition, 2007.

## Course Outcomes (CO)

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

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

## Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the methods of medical imaging.
<b>CLO2</b>	To impart knowledge in the physics behind the various imaging techniques.
<b>CLO3</b>	To teach the construction and working of various imaging techniques.
<b>CLO4</b>	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,4 <sup>th</sup> 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, 2 <sup>nd</sup> Edition, 2012.
4.	Prince and Links, Medical Imaging Signals and Systems, 2 <sup>nd</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To familiarise on patient monitoring systems and telemedicine
<b>CLO2</b>	To understand medical imaging systems
<b>CLO3</b>	To explain extracorporeal devices used in critical care
<b>CLO4</b>	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, Oscopes, 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 , 2 <sup>nd</sup> Edition ,2014, CRC Press.
2.	John G. Webster, Medical Instrumentation Application and Designll , 5 <sup>th</sup> edition, Wiley India PvtLtd, New Delhi,2020.
3.	John G. Webster, John W Clark, jr, Medical Instrumentation Application and Design, 5 <sup>th</sup> Edition,Wiley, 2020. (e book).
4.	Robert B. Northrop, Non-Invasive Instrumentation and Measurement in Medical Diagnosis , 2 <sup>nd</sup> edition, CRC Press,. 2019.
5.	Joseph J.Carrand ,John M. Brown, —Introduction to Biomedical Equipment Technology,4 <sup>th</sup> Edition,Pearson education,2000.
6.	Raghubir Singh Khandpur., Compendium of Biomedical Instrumentation, 3 Volume Set, 3 <sup>rd</sup> Edition,Wiley IndiaPvt. Ltd, 2020
7.	Leslie Cromwell, Biomedical Instrumentation and Measurementll, 2 <sup>nd</sup> Edition, Prentice hall of India,New Delhi, 2015.
8.	L.A. Geddes and L.E. Baker, Principles of Applied Biomedical Instrumentation, John Wiley, NewYork, 3 <sup>rd</sup> Edition, 1991.
9.	Khandpur R.S, Handbook of Biomedical Instrumentationll, 3 <sup>rd</sup> Edition, Tata McGraw-Hill, New Delhi,2014.



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To understand the concepts of various rehabilitation equipments for human movements and applications
<b>CLO2</b>	To understand and gain knowledge about different hearing aids
<b>CLO3</b>	To study various assist devices for visually and auditory impaired
<b>CLO4</b>	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, 5 <sup>th</sup> Edition, mosby, 2020.
2.	Cooper Rory A, An Introduction to Rehabilitation, Taylor and Francis, London, 2012
3.	Joseph D. Bronzino, Handbook of Biomedical Engineering, 2 <sup>nd</sup> 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, CRC Press, 2001.
7.	Warren E. Finn, Peter G. LoPresti, Handbook of Neuroprosthetic Methods, CRC; 1 <sup>st</sup> 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, 1 <sup>st</sup> 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, 1 <sup>st</sup> Edition, CRC Press, 2017.

### Course Outcomes (CO)

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

<b>CO1</b>	Gain adequate fundamental knowledge about the needs of rehabilitations and its future development.
<b>CO2</b>	Gain in-depth knowledge about various assistive technologies for vision and hearing
<b>CO3</b>	Select the appropriate rehabilitation concept for various disabilities.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	2	-	3	3	3	1	1	1	-	-	-	3
<b>CO2</b>	3	3	3	2	-	3	3	3	1	1	1	-	-	-	3
<b>CO3</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO4</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to requirement of standards and calibration techniques, safety mechanisms in instruments used in process industries.
<b>CLO2</b>	To impart knowledge about EMI and EMC problems in industrial measurements.
<b>CLO3</b>	To make the students to draw the specification of the industrial instruments and prepare the instrumentation 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, 2 <sup>nd</sup> Edition, 1995.
2.	Liptak B.G, Process Measurement and Analysis, CRC Press, 5 <sup>th</sup> Edition, 2016.
3.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I and Vol II, Gulf Publishing Company, Houston, 2001
4.	Spitzer D. W., Industrial Flow measurement, ISA press, 3 <sup>rd</sup> Edition, 2005
5.	Patranabis D., Principles of Industrial Instrumentation, Tata McGraw Hill Publishing Company Ltd, 3 <sup>rd</sup> Edition, 2010.
6.	Lawrence D. Goettsche, Maintenance of Instruments and Systems, International society of automation, 2 <sup>nd</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	-	3	3	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	-	2	2	-	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the digital implementation of control systems
<b>CLO2</b>	To review the classical techniques and highlight the practical difficulties
<b>CLO3</b>	To emphasize on the time-domain and state-space implementation using digital processors, and expose the students to industrial practice using PLCs.
<b>CLO4</b>	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, 4 <sup>th</sup> edition., 2014.
2.	M.S. Santina, A.R. Stubberud, and G.H. Hostetter, Digital Control System Design, 2 <sup>nd</sup> Edition, Oxford Univ. Press,
3.	B. C. Kuo, Digital Control System, Oxford University Press, 2 <sup>nd</sup> Edition., 2007.
4.	G. F. Franklin, J. D. Powell and M. L. Workman, Digital Control of Dynamic Systems, Pearson Education, 3 <sup>rd</sup> Edition, 2000.

### Course Outcomes (CO)

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

<b>CO1</b>	Analyze the performance and stability of a discrete-time control system.
<b>CO2</b>	Design state-space digital controllers and implement using processors and PLCs.
<b>CO3</b>	Learn about event driven and hybrid systems.
<b>CO4</b>	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	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide an overview of intelligent techniques.
<b>CLO2</b>	To develop skills to gain a basic understanding of neural network and fuzzy logic theory.
<b>CLO3</b>	To introduce different architectures and algorithms of Neural Networks.
<b>CLO4</b>	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, 4 <sup>th</sup> 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, 3 <sup>rd</sup> 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, 1 <sup>st</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

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

### 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, 4 <sup>th</sup> Edition, John Hopkins University Press, 2007
3.	A. Quarteroni, F. Saleri, Scientific Computing with MATLAB, Springer Verlag, 2003.
4.	<a href="http://www.scilab.org">www.scilab.org</a>
5.	Strang, Linear Algebra and Learning from Data, Wellesley-Cambridge Press, 2019
6.	N. Higham, Accuracy and Stability of Numerical Algorithms, 2 <sup>nd</sup> Edition, SIAM, 2002



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the emerging field of multi-agent and network control systems
<b>CLO2</b>	To expand the scope of traditional control systems to include large-scale interconnected systems
<b>CLO3</b>	To demonstrate consensus and leader-follower paradigms in a distributed environment
<b>CLO4</b>	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,

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





### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE22
<b>Course Title</b>	:	<b>Industrial Data Communication</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC25
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	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.

<b>CLO1</b>	To expose the students to communication systems emerging in the field of instrumentation.
<b>CLO2</b>	To introduce to the system interconnection and protocol standards.
<b>CLO3</b>	To give an overview of HART Protocols
<b>CLO4</b>	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, 2 <sup>nd</sup> Edition, 1995
2.	B.G. Liptak, Process software and digital networks, CRC press, Florida, 3 <sup>rd</sup> 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., 6 <sup>th</sup> Edition. 2021



### Course Outcomes (CO)

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

<b>CO1</b>	Explain the rationale behind the technological development of industrial networks.
<b>CO2</b>	Understand various buses and serial//parallel interface.
<b>CO3</b>	Exposure to the HART, Field Bus and Profibus protocols functions and their features.
<b>CO4</b>	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
<b>CO1</b>	3	2	3	2	2	3	1	1	1	1	2	3	3	3	1
<b>CO2</b>	3	2	3	3	2	2	2	1	1	2	2	3	3	3	1
<b>CO3</b>	3	2	3	3	2	2	2	1	1	2	2	3	3	3	1
<b>CO4</b>	2	1	3	3	3	3	2	1	2	2	3	3	3	3	2



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide a good understanding of Internet of Things (IoT) and its envisioned deployment domains.
<b>CLO2</b>	To provide an understanding of smart sensors/actuators with their internet connectivity for experimentation and designing systems.
<b>CLO3</b>	To provide a overview about the various protocol standards deployed in the Internet of Things (IoT) domain and to make informed choices.
<b>CLO4</b>	To impart knowledge in the design and development of IoT systems with enablement ensuring security 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 and Jonathan Follett, Foundational Elements of an IoT Solution – The Edge, The Cloud and Application Development, O'Reilly, 1 <sup>st</sup> Edition, 2016.
2.	Designing Connected Products, Elizabeth Goodman, Alfred Lui, Martin Charlier, Ann Light, Claire Rowland, 1 <sup>st</sup> Edition.
3.	The Internet of Things (A Look at Real World Use Cases and Concerns), Kindle Edition, Lucas Darnell, 2016.
4.	The Internet of Things – Opportunities and Challenges <a href="http://www.ti.com/ww/en/internet_of_things/pdf/14-09-17-iotforCap.pdf">http://www.ti.com/ww/en/internet_of_things/pdf/14-09-17-iotforCap.pdf</a> - -



5.	Single Chip Controller and Wi-Fi SOC <a href="http://www.ti.com/lit/ds/symlink/cc3200.pdf">http://www.ti.com/lit/ds/symlink/cc3200.pdf</a>
6.	Wireless Connectivity Solutions <a href="http://www.ti.com/lit/ml/swrb035/swrb035.pdf">http://www.ti.com/lit/ml/swrb035/swrb035.pdf</a>
7.	Wireless Connectivity for the Internet of Things – One size does not fit all <a href="http://www.ti.com/lit/wp/swry010/swry010.pdf">http://www.ti.com/lit/wp/swry010/swry010.pdf</a>
8.	Arshdeep Bahga, Vijay Madiseti, 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,

<b>CO1</b>	Understand the design architecture of IoT
<b>CO2</b>	Make choice of protocols and deployment in solutions
<b>CO3</b>	Comprehend the design perspective of IoT based products /services
<b>CO4</b>	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
<b>CO1</b>	2	2	3	3	3	1	2	1	2	2	1	3	3	3	1
<b>CO2</b>	2	2	3	3	3	2	2	2	2	3	2	3	3	3	2
<b>CO3</b>	3	3	3	3	3	2	3	1	2	3	2	3	3	3	2
<b>CO4</b>	2	2	2	3	3	2	2	3	2	3	2	3	3	3	3



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

### Course Learning Objectives (CLO)

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

### 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, 2 <sup>nd</sup> edition, Springer, 2017
2.	Spong, M.W., Hutchinson, H., and Vidyasagar, M., Robot Modeling and Control, John Wiley (Wiley India Ed.), 2 <sup>nd</sup> 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, 2 <sup>nd</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	1	3	3	3	1	2	1	1	1	1	3	3	3	1
<b>CO2</b>	3	2	3	3	3	2	2	1	2	1	2	3	3	3	1
<b>CO3</b>	3	2	3	3	3	2	2	1	2	1	2	3	3	3	1
<b>CO4</b>	3	2	3	3	3	3	3	1	2	2	2	3	3	3	2



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To understand the Industrial security environment and cyberattacks
<b>CLO2</b>	To analyze and assess risks in the industrial environment
<b>CLO3</b>	To access, design and implement cybersecurity
<b>CLO4</b>	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, 2 <sup>nd</sup> 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, 2 <sup>nd</sup> Edition, 2004

### Course Outcomes (CO)

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

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





### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the basic concepts of Embedded Systems
<b>CLO2</b>	To expose to the design principles of advanced level ARM processors.
<b>CLO3</b>	To provide basic understanding of the concepts of OS and RTOS.
<b>CLO4</b>	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, 5 <sup>th</sup> Edition, 2017
2.	Johnathon M. Valvano, Real Time Operating Systems for ARM Cortex M Microcontrollers, 4 <sup>th</sup> Edition, 2017
3.	Joseph Yiu, The Definitive Guide to ARM Cortex M3 and ARM Cortex M4 Processors, 3 <sup>rd</sup> Edition, 2019
4.	Cortex M4 Technical Reference Manual: ARM Rev r0p0, 2010 <a href="https://documentation-service.arm.com/static/5f19da2a20b7cf4bc524d99a">https://documentation-service.arm.com/static/5f19da2a20b7cf4bc524d99a</a> .
5.	ARMv7-M Architecture Reference Manual. 2019 <a href="https://developer.arm.com/documentation/ddi0403/latest/">https://developer.arm.com/documentation/ddi0403/latest/</a>

### Course Outcomes (CO)

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

<b>CO1</b>	Design an embedded system for simple applications.
<b>CO2</b>	Develop applications using embedded 'C' language.
<b>CO3</b>	Understand RTOS structure and types
<b>CO4</b>	Develop the real time embedded systems



### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students on the basics of optical sources and detectors, optical fiber and fiberoptic sensors.
<b>CLO2</b>	impart knowledge on the characteristics of optical sources and detectors.
<b>CLO3</b>	To provide adequate knowledge about the optical fiber and their characteristics.
<b>CLO4</b>	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, Pearson Education Pvt. Ltd., 1 <sup>st</sup> Edition, 2008.
2.	John M Senior, Optical Fiber Communications: Principles and Practice, 3 <sup>rd</sup> 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, 3 <sup>rd</sup> Edition, 2003.
6.	Fukuda, Optical Semiconductor Devices, John Wiley, 2005.
7.	Safa Kasap, Optoelectronics and Photonics: Principles and Practices: International Edition 2 <sup>nd</sup> edition, 2013
8.	Bhattacharya Pallab, Semiconductor Optoelectronic Devices, Pearson Education; 2 <sup>nd</sup> Edition 2017



### Course Outcomes (CO)

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

<b>CO1</b>	Have familiarity with the fundamental principles of various types of optical sources, characteristics and its applications.
<b>CO2</b>	Understand the operation of different types of optical detectors and its limitations in industrial use.
<b>CO3</b>	Apply the gained knowledge on optical fibers for its use as communication medium in industrial use.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	2	2	-	1	1	1	3	3	3	-
<b>CO2</b>	3	3	3	3	2	3	2	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	2	2	3	2	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	2	2	3	2	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To give basic information about measuring instruments
<b>CLO2</b>	To expose the students about the Statistical methods for estimating errors and uncertainties of real measurements:
<b>CLO3</b>	To introduce the fundamental techniques of measurement for data analysis
<b>CLO4</b>	To apply different measurement techniques that are performed in industry, commerce and experimental 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, Springer Publication, 3 <sup>rd</sup> Edition, 2010.
2.	L. Kirkup, R. B. Frenkel, An Introduction to Uncertainty in Measurement: Using the GUM (Guide to 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, 5 <sup>th</sup> Edition, 2015.
5.	Julius S. Bendat, Allan G. Piersol, Random Data: Analysis and Measurement Procedures, 4 <sup>th</sup> Edition, Wiley, 2010.
6.	Ifan Hughes and Thomas Hase, Measurements and Their Uncertainties: A Practical Guide to Modern Error Analysis, Oxford University Press, 2010.
7.	Patrick F. Dunn, Measurement, Data Analysis, and Sensor Fundamentals for Engineering and Science., CRC Press , 3 <sup>rd</sup> Edition, 2019



### Course Outcomes (CO)

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

<b>CO1</b>	Estimate measurement inaccuracies.
<b>CO2</b>	Evaluate the measurement system based on its quality and cost.
<b>CO3</b>	Acquire both theoretical knowledge and practical skills in working with measurement data.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamental concepts of MEMS and Micro systems and their relevance to current scientific needs.
<b>CLO2</b>	To introduce the state-of-art micromachining techniques including surface micromachining, bulk micromachining, and related methods.
<b>CLO3</b>	To make the students knowledgeable in the design concepts of micro sensors and micro actuators.
<b>CLO4</b>	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, 3 <sup>rd</sup> Edition, 2018.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS, and Smart Devices, John Wiley and Sons Ltd, 1 <sup>st</sup> Edition, reprinted 2007.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1 <sup>st</sup> Edition, 2001.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1 <sup>st</sup> Edition, 2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2 <sup>nd</sup> Edition, 2011.
7.	Stephen D. Senturia., Microsystem Design, Kluwer Academic Publishers, 2001 (Available now at Springer <a href="https://link.springer.com/book/10.1007/b117574">https://link.springer.com/book/10.1007/b117574</a> ).
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)

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

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge on automobile system, its subsystems and components.
<b>CLO2</b>	To expose the students to the concepts of various sensors used in automobile systems.
<b>CLO3</b>	To teach the basic and advanced controls in automotive systems.
<b>CLO4</b>	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, Piston, 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, 8 <sup>th</sup> 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, 10 <sup>th</sup> Edition, 2018.

### Course Outcomes (CO)

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

<b>CO1</b>	Identify the automotive system and its components.
<b>CO2</b>	Attain knowledge of various sensors and conditioning circuit used in automotive systems.
<b>CO3</b>	Gain knowledge about various control strategies, the electronics and software used in automotive application.
<b>CO4</b>	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	PS01	PS02	PS03
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to various power generation methods.
<b>CLO2</b>	To impart knowledge on various processes/systems involved in thermal power generation.
<b>CLO3</b>	To provide the knowledge on specific measurement techniques and control systems practiced in boiler and turbine units.
<b>CLO4</b>	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 pulverizers. 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 CO<sub>2</sub> 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, 2 <sup>nd</sup> 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, 1 <sup>st</sup> 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,

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

**Course Outcome and Programme Outcome Mapping**

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to various petroleum production processes.
<b>CLO2</b>	To impart knowledge on various processes involved in petroleum refinery.
<b>CLO3</b>	To provide knowledge on specific measurement techniques practiced, control systems and automation involved 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, N<sub>2</sub>, 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 Reinhold Company, New York, 1988
3.	Liptak B.G., Instrument Engineers' Handbook, CRC PRESS, 4 <sup>th</sup> 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,

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



### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To familiarize the students to the paper making process.
<b>CLO2</b>	To expose the students to the instrumentation used in Paper industries.
<b>CLO3</b>	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, New York, 3 <sup>rd</sup> Edition, 1983.





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

**Course Outcomes (CO)**

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

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

**Course Outcome and Programme Outcome Mapping**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide an understanding on the need of instrumentation in agriculture and food processing sector.
<b>CLO2</b>	To provide an understanding of food quality assessment and instruments used for the same.
<b>CLO3</b>	To provide an understanding on agriculture associated activities and instruments used for the same.
<b>CLO4</b>	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 its 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 Francis Publications, 2007
3.	P.J. Fellows, Food Processing Technology Principles and Practice, Woodhead Publishing, 3 <sup>rd</sup> Edition, 2009.
4.	Semioh Otles, Methods of analysis of food components and additives, CRC Press, Taylor and Francis group, 2 <sup>nd</sup> Edition, 2012.



5.	McMillan G. K., Considine D. M., Process/Industrial Instruments and Controls Handbook, McGrawHill International, 5 <sup>th</sup> edition, 1999.
6.	Liptak B. G., Instrument Engineers Handbook, Process Measurement Volume I and Process Control Volume II, CRC press, 4 <sup>th</sup> 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,

<b>CO1</b>	Understand the necessity of instrumentation in agriculture and food processing.
<b>CO2</b>	Have familiarity with instrumentation requirement in agriculture and food processing.
<b>CO3</b>	Analyse and design systems/instruments for agriculture and food processing.
<b>CO4</b>	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
<b>CO1</b>	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
<b>CO2</b>	2	2	2	2	2	-	-	-	3	3	3	2	2	2	1
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	-	-	-	-	-	3	3	3	1	1	1	-	-	-	3



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce various flow sheet design using process flow diagram.
<b>CLO2</b>	To impart knowledge on P and I symbols for pumps, compressors and process vessels.
<b>CLO3</b>	To teach the line diagram symbols, logic gates of instruments.
<b>CLO4</b>	To learn the simulation software for P and ID 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, P and I D development, various stages of P and I D, P and I 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 P and ID'S: Applications of P and ID in design state, construction stage, commissioning state, operating stage, revamping state, applications of P and ID in HAZAMPS and risk analysis

### References

1.	Ernest E. Ludwig, Applied Process Design for Chemical and Petrochemical Plants Vol-1, Gulf Publishing Company, Houston, 1989.
2.	Max. S. Peters and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill Inc., New York, 1991.
3.	Moe Toghræi., Piping and Instrumentation Diagram Development ., Wiley-AIChE Publication. 2019.
4.	Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill, New Delhi, 1981.
5.	A.N. Westerberg et al., Process Flow sheeting, Cambridge University Press, New Delhi, 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce students to principles behind communication systems and techniques in handling analog and digital communication signals
<b>CLO2</b>	To introduce students to the communication protocols and standards that are relevant to industrial automation
<b>CLO3</b>	To provide an overview of state-of-the-art communication protocols used in the industrial environment
<b>CLO4</b>	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,

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

**Course Outcome and Programme Outcome Mapping**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
<b>CO2</b>	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
<b>CO3</b>	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1
<b>CO4</b>	3	3	3	3	3	2	2	2	1	1	1	-	3	3	1



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the basic blocks of Building Management System.
<b>CLO2</b>	To impart knowledge in the design of various sub systems (or modular system) of building automation.
<b>CLO3</b>	To provide insight into some of the advanced principles for safety in automation.
<b>CLO4</b>	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, 2 <sup>nd</sup> Edition., 2010.
2.	Albert Ting Pat So, WaiLok Chan, Intelligent Building Systems, Kluwer Academic publisher, 3 <sup>rd</sup> 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: 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,

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

**Course Outcome and Programme Outcome Mapping**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce and elaborate the characteristics of nonlinear systems.
<b>CLO2</b>	To gain understanding in the methods (both classical and modern) of analysis of stability and performance of nonlinear systems
<b>CLO3</b>	To study the design of controllers as applicable to various case studies in robotics, aerospace and other domains.
<b>CLO4</b>	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, 3 <sup>rd</sup> 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 and Engineering, 2 <sup>nd</sup> Edition, Westview Press, 2014.
6.	Vidyasagar.M, Nonlinear System Analysis, 2 <sup>nd</sup> Edition, SIAM, 2002.
7.	Sontag, Mathematical Control Theory, 2 <sup>nd</sup> Edition, Springer Verlag, 1998



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce empirical and data-based modeling of large-scale systems.
<b>CLO2</b>	To train the students in parametric and nonparametric statistical models and estimation techniques.
<b>CLO3</b>	To expose to the students, the algorithms and computational overheads involved in large-scale system modeling 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, Paperback Edition, 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,

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge in fault detection and identification.
<b>CLO2</b>	To introduce different structure residual technique for the fault identification.
<b>CLO3</b>	To introduce different directional residual technique for the fault identification.
<b>CLO4</b>	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, 2 <sup>nd</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

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

### 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 cost Indian edition available including CD ROM).
2.	G.H. Golub and C.F. Van Loan, Matrix Computations, 4 <sup>th</sup> 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.	<a href="http://www.scilab.org">www.scilab.org</a>
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,

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

### Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to various electrical components used in industrial control systems.
<b>CLO2</b>	To expose the students to various mechanical components used in industrial control systems
<b>CLO3</b>	To teach various mechanical and pneumatic systems used in industrial control systems.
<b>CLO4</b>	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. Majumdar, Pneumatic Systems, Tata McGraw-Hill Publisher, 2009.
4.	Meixner H and Sauer E, Intro to Electro-Pneumatics, Festo didactic, 1 <sup>st</sup> 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 1 <sup>st</sup> Edition, 1996.



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the students about the theory and applications of power electronic systems for highefficiency, renewable and energy saving conversion systems.
<b>CLO2</b>	To impart knowledge on the characteristics of different power electronics switches, drivers andselection of components for different applications.
<b>CLO3</b>	To teach about the switching behavior and design of the converter, inverter and chopper circuits.
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2017.
2.	Dubey G. K, Doradla S.R, Joshi and Sinha R.M, Thyristorised Power Controllers, New Age International Publishers, New Delhi, 2012.
3.	John G. Kassakian, Principles of Power electronics, Addison Wesley, 2010.
4.	P. S. Bimbhra, Power Electronics, Khanna Publishers, 5 <sup>th</sup> Edition, 2012. Vedam Subramanyam K, Power Electronics, New Age International Publishers, New Delhi, 2 <sup>nd</sup> Edition, 2022.
5.	Mohan, Undeland and Robbins, Power Electronics: Converters, Applications and Design, JohnWiley and Sons, New York, 3 <sup>rd</sup> 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,

<b>CO1</b>	Work professionally in the area of power and power related fields.
<b>CO2</b>	Have good understanding of the basic principles of switch mode power conversion.
<b>CO3</b>	Apply knowledge of mathematics and engineering and identify formulas to solve power and power electronics engineering problems.
<b>CO4</b>	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

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce to the students on the concept of employing power convertors for the design of electric drives.
<b>CLO2</b>	To impart knowledge on the analysis of electric drive system dynamics.
<b>CLO3</b>	To apply the knowledge of drives to choose the right solid-state drive for a given application.
<b>CLO4</b>	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.2 <sup>nd</sup> 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-2 <sup>nd</sup> 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,

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

## Course Outcome and Programme Outcome Mapping

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



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

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose to the basics of sensors used in industries.
<b>CLO2</b>	To provide adequate knowledge on smart instrumentation and wireless sensor networks.
<b>CLO3</b>	To impart knowledge on various standard protocols used in wireless instrumentation.
<b>CLO4</b>	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 (CO<sub>2</sub>) 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 and Francis Group, 2018.
3.	Uvais Qidwai, Smart Instrumentation: A data flow approach to Interfacing, Chapman and Hall, 1 <sup>st</sup> Edition, 2019.





### Course Outcomes (CO)

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

<b>CO1</b>	Understand about smart instrumentation system and wireless technologies in WSN
<b>CO2</b>	Design self-diagnosing instrumentation system.
<b>CO3</b>	Identify the issues in power efficient systems and implement energy management techniques in WSN
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE46
<b>Course Title</b>	:	<b>Principles of Communication Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC13
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the concept of communication systems.
<b>CLO2</b>	To understand the need for modulation.
<b>CLO3</b>	To impart knowledge in the different methods of analog and digital communications and their significance.
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2009.
2.	H. Tauband D. Schilling, Principles of Communication System, Tata McGraw Hill, 4 <sup>th</sup> Edition, 2017
3.	J.S. BeasleyandG.M. Miler, Modern Electronic Communication, Prentice-Hall, 9 <sup>th</sup> Edition, 2009.
4.	B.P. Lathi, Modern Analog and Digital Communication systems, Oxford University Press, 3 <sup>rd</sup> Edition, 2011
5.	B. Carlson, Communication Systems, McGraw Hill Book Co., 5 <sup>th</sup> Edition, 2001.
6.	Sam Shanmugam, Digital and analog Communication Systems, John Wiley, 2019.
7.	John G. Proakis, Masoud Salehi - Fundamentals of Communication Systems, 2 <sup>nd</sup> Edition, Pearson, 2015.



### Course Outcomes (CO)

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

<b>CO1</b>	Explain the basic concepts of communication systems.
<b>CO2</b>	Understand various analog and pulse modulation and demodulation techniques.
<b>CO3</b>	Understand digital modulation and demodulation techniques
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE47
<b>Course Title</b>	:	<b>Multi Sensor Data Fusion</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamentals of data fusion and multisensor data fusion
<b>CLO2</b>	To expose the students to the different techniques used in sensor data fusion.
<b>CLO3</b>	To impart skills needed to develop and apply data fusion algorithms.
<b>CLO4</b>	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, 2 <sup>nd</sup> 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,

<b>CO1</b>	Understand the importance of data fusion
<b>CO2</b>	Identify and characterise the principle components of data fusion and information systems.
<b>CO3</b>	Apply the concepts of data fusion in sensing.
<b>CO4</b>	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



<b>Course Code</b>	:	ICPE48
<b>Course Title</b>	:	<b>Energy Harvesting Techniques</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce basic energy harvesting techniques using smart materials and structures and combining with mechanisms.
<b>CLO2</b>	To impart knowledge in the design of power converter circuits for ambient energy harvesters.
<b>CLO3</b>	To introduce mathematical modelling of piezoelectric based energy harvesters.
<b>CLO4</b>	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., 1 <sup>st</sup> Edition, 2010.
2.	Danick Briand, Eric Yeatman, and Shad Roundy, Micro energy Harvesting, Wiley-VCH Verlag GmbH and Co, 2015.
3.	Stephen Beeby, Neil white, Energy Harvesting for Autonomous Systems, Artech house, Norwood, 1 <sup>st</sup> Edition, 2010.
4.	Alper Erturk and Daniel J Inman, Piezoelectric Energy Harvesting, John Wiley and Sons. Ltd. 1 <sup>st</sup> Edition, 2011.
5.	Tom J. Kazmiershi, Steve Beeby, Energy Harvesting System, Principles, Modelling and Application, Springer, New York, 2014.



### Course Outcomes (CO)

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

<b>CO1</b>	Comprehend in the concept of various ambient energy harvesting techniques.
<b>CO2</b>	Design optimal power converting circuits for different harvesters.
<b>CO3</b>	Design vibration, electromagnetic and thermoelectric based energy harvesters.
<b>CO4</b>	Apply the energy harvesting concepts to common engineering problems.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE49
<b>Course Title</b>	:	<b>Smart Materials and Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To familiarize the students with the different smart materials and their characteristics.
<b>CLO2</b>	To expose the students to understand the functionalities through the mathematical equations.
<b>CLO3</b>	To teach the students about the significant features of smart materials in sensing, actuation and control.
<b>CLO4</b>	To teach the students to design and develop smart structures using smart material-based actuators and 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, polyvinylidene 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, Magnetostrictive 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 Hall Publishers, 1 <sup>st</sup> Edition, 1992.
2.	Mel Schwartz, Encyclopaedia of smart materials, John Wiley and Sons, 1 <sup>st</sup> Edition, 2002.
3.	Srinivasan A.V., Michael McFarland D., Smart Structures Analysis and Design, Cambridge University Press, 1 <sup>st</sup> Edition, 2010.
4.	Culshaw B., Smart structures and Materials, Artech house, 1 <sup>st</sup> Edition, 2004.
5.	Leo, D.J. Engineering Analysis of Smart Material Systems, John Wiley and sons, 1 <sup>st</sup> 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, 2 <sup>nd</sup> Edition, 2007.
8.	<a href="http://www.iop.org/sms">www.iop.org/sms</a>
9.	<a href="http://jim.sagepub.com">http://jim.sagepub.com</a> .

**Course Outcomes (CO)**

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

<b>CO1</b>	Acquire knowledge about the smart materials, their characteristics and design aspects.
<b>CO2</b>	Design, model and control smart materials-based structures/systems, through simulation and experimentation.
<b>CO3</b>	Choose appropriate smart materials for sensing and actuation.
<b>CO4</b>	Analyze and design techniques, to offer solutions to industrial problems using smart materials.

**Course Outcome and Programme Outcome Mapping**

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



<b>Course Code</b>	:	ICPE50
<b>Course Title</b>	:	<b>Hydraulics and Pneumatics</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide an understanding of the working of hydraulic and pneumatic systems.
<b>CLO2</b>	To provide an understanding of energy transfer in hydraulic actuators and motors
<b>CLO3</b>	To provide knowledge about controlling components of hydraulic and pneumatic systems.
<b>CLO4</b>	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. Structure of 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., 5 <sup>th</sup> Edition, 2008.
2.	Andrew Parr, Pneumatics and Hydraulics, Jaico Publishing Co. 2005.
3.	Dr. Niranjana 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, 2 <sup>nd</sup> 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,

<b>CO1</b>	Acquire knowledge about working of hydraulic and pneumatic systems.
<b>CO2</b>	Identify the controlling components of hydraulic and pneumatic systems.
<b>CO3</b>	Analyse and compile the design of hydraulic and pneumatic systems
<b>CO4</b>	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	PS01	PS02	PS03
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE51
<b>Course Title</b>	:	<b>Engineering Mechanics</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamentals of mechanics and machines to the instrumentation and control engineering students.
<b>CLO2</b>	To explain the application of basic mechanical science concepts
<b>CLO3</b>	To apply different physical principles to the analysis of mechanics and machines
<b>CLO4</b>	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 vibrations of 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, 3 <sup>rd</sup> Edition. 2006.
2.	R. C. Hibbeler, Engineering Mechanics - Statics, Pearson Education Inc. 14 <sup>th</sup> Edition. 2015.
3.	R. C. Hibbeler, Engineering Mechanics - Dynamics, Pearson Education Inc. 14 <sup>th</sup> Edition 2015.
4.	Timoshenko and Young, Engineering Mechanics, McGraw-Hill Book Company, 5 <sup>th</sup> Edition, 2016.



### Course Outcomes (CO)

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

<b>CO1</b>	Analyze simple mechanisms and their principles of operation.
<b>CO2</b>	Write the mathematical equations for static and dynamic loading in simple mechanical systems.
<b>CO3</b>	Write the equations for energy and power in simple mechanical systems.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE52
<b>Course Title</b>	:	<b>Software Design Tools for Sensing and Control</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC18
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the software tools available for sensor and control system design.
<b>CLO2</b>	To teach the analytical and numerical modelling of various sensors in macro, meso and micro scale and to study its characteristics through simulation.
<b>CLO3</b>	To expose the students to modelling of physical systems, design and evaluation of various control methods.
<b>CLO4</b>	To expose the students to real time control implementation platforms and to practice on implementation 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, Jones and Bartlett Publishers, 1 <sup>st</sup> Edition, 2011.
2.	Tamara Bechtold, Gabriela Schrag and Lihong Feng, System-level Modeling of MEMS, Wiley-VCH verlag GmbH and Co, 1 <sup>st</sup> Edition, 2013.
3.	Holly Moore, MATLAB for Engineers, Pearson Education, 6 <sup>th</sup> Edition, 2022.
4.	Brian Hahn and Daniel Valentine, Essential MATLAB for Engineers and Scientists, Elsevier, Academic press, 7 <sup>th</sup> edition, 2019.
5.	Mehrzad Tabatabaian, COMSOL 5 for Engineers, Mercury Learning and Information, 1 <sup>st</sup> Edition, 2015.
6.	S R Otto and J P Denier, An Introduction to Programming and Numerical Methods in MATLAB, Springer-verlag, 1 <sup>st</sup> Edition, 2005.
7.	Stephen J Chapman, MATLAB Programming for Engineers, Bookware Companion Series, 7 <sup>th</sup> Edition, 2024.
8.	Amos Gilat, MATLAB – An Introduction with Applications, John Wiley and Sons, Inc., 6 <sup>th</sup> Edition, 2017.

## Course Outcomes (CO)

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

<b>CO1</b>	Select an appropriate software tools for sensor and actuator design.
<b>CO2</b>	Design, model and simulate various sensing and actuating mechanisms.
<b>CO3</b>	Design and evaluate the performance of cascade and state-space controller
<b>CO4</b>	Acquire knowledge in the selection and usage of hardware for real time implementation of controllers.

## Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE53
<b>Course Title</b>	:	<b>Numerical Methods</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	Numerical methods for Solving Linear Systems
<b>CLO2</b>	Numerical methods to solve equations of one variable as well as system of equations with two variables.
<b>CLO3</b>	Interpolating Polynomials and best curve fitting methods for the given data.
<b>CLO4</b>	Numerical differentiation and integration
<b>CLO5</b>	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's 1/3 rule and 3/8 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 2<sup>nd</sup> 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, 5 <sup>th</sup> edition, 2012.
3.	David Kincaid and Ward Cheney, Numerical Analysis, 3 <sup>rd</sup> edition, American Mathematics Society, (Indian edition) –2012.
4.	Gerald, C.F., and Wheatley, P.O., Applied Numerical Analysis, Addison-Wesley Publishing Company, 7 <sup>th</sup> 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,

<b>CO1</b>	Compute numerical solution of given system by direct and iterative methods.
<b>CO2</b>	Compute largest eigenvalue and its corresponding eigenvector of matrix A.
<b>CO3</b>	Interpolate function and approximate the function by polynomials and compute differentiation and integration
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE54
<b>Course Title</b>	:	<b>Analytical Instrumentation</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14, ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To teach the students about the analysis of materials which is an important requirement of process control and quality control in industry
<b>CLO2</b>	To expose the students to principles of various analytical methods.
<b>CLO3</b>	To impart knowledge on various spectroscopic instruments used in the analysis of materials
<b>CLO4</b>	To introduce the concept of analytical instruments used in drug and pharmaceutical lab
<b>CLO5</b>	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, 2 <sup>nd</sup> Edition, 2012.
2.	Ewing, G.W., Instrumental Methods of Analysis, McGraw Hill, Singapore, 5 <sup>th</sup> 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, 4 <sup>th</sup> Edition, 2003.
5.	Considine, D.M. Process/Industrial Instruments and Controls Handbook, McGraw Hill, Singapore, 4 <sup>th</sup> 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, 2 <sup>nd</sup> Edn.2006

**Course Outcomes (CO)**

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

<b>CO1</b>	Appreciate the relevance of material sampling and analysis in process control and quality control in industry.
<b>CO2</b>	Understand the physical principles behind the various widely used analytical methods in the industry.
<b>CO3</b>	Understand the important components and concepts of various spectroscopic instruments and instruments used in drug and pharmaceutical lab and pollution monitoring.
<b>CO4</b>	Select an appropriate analytical instrument for an industrial requirement.

**Course Outcome and Programme Outcome Mapping**

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



<b>Course Code</b>	:	ICPE55
<b>Course Title</b>	:	<b>Data structures and algorithms</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce first level topics covering basics in Algorithms and Data Structures
<b>CLO2</b>	To provide examples for various design paradigms
<b>CLO3</b>	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 of Quick-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, 3 <sup>rd</sup> Edition, Prentice Hall of India. (This book is popularly called as C-L-R)
2.	Ellis Horowitz, Sartaj Sahni and Sanguthevar Rajasekaran, —Fundamentals of Computer Algorithms II, 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 Computer Algorithms II, First Edition, Pearson Education, 2006.
5.	Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, Introduction to Algorithms, 4 <sup>th</sup> Edition, MIT Press, PHI, 2021.



### Course Outcomes (CO)

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

<b>CO1</b>	Use linear and nonlinear data structures to solve real-time problems
<b>CO2</b>	Apply basic searching and sorting techniques in different application domains
<b>CO3</b>	Apply basic sorting techniques in different application domains
<b>CO4</b>	Use design strategies to solve complex problems

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE56
<b>Course Title</b>	:	<b>Nuclear Instrumentation</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14, ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the basic concept of radioactivity, properties of alpha, beta and gamma rays
<b>CLO2</b>	To study various radiation detectors, detector classification
<b>CLO3</b>	To study the electronics and counting systems
<b>CLO4</b>	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, 2 <sup>nd</sup> 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 Eastern 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,

<b>CO1</b>	The students get well versed with construction and working of various radiation detectors.
<b>CO2</b>	Students also get thorough knowledge of electronics and counting systems used in nuclear instrumentation
<b>CO3</b>	Understand the radiation monitors in medical applications
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1



<b>Course Code</b>	:	ICPE57
<b>Course Title</b>	:	<b>Condition Monitoring</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14, ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the importance of condition monitoring in the automotive, structural and process industries
<b>CLO2</b>	To make understand the role of different sensors and signal conditioning techniques in the condition monitoring
<b>CLO3</b>	To expose to wireless sensor networks and their protocols
<b>CLO4</b>	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,

<b>CO1</b>	Familiar with the need of condition monitoring in the automotive, structural and process industries and gain knowledge of sensors and signal conditioning techniques
<b>CO2</b>	Understand the operation of wireless sensor networks and their deployment.
<b>CO3</b>	Gain the knowledge of machine learning and its application in condition monitoring.
<b>CO4</b>	Develop/Design an application specific condition monitoring system for fault diagnosis andPrognosis.

## Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-



<b>Course Code</b>	:	ICPE58
<b>Course Title</b>	:	<b>Safety Instrumented system</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To make the students aware of basic concepts of safety instrumented system, standards and risk analysis techniques.
<b>CLO2</b>	To make the students understand different layers of protection.
<b>CLO3</b>	To make student conscious about safety instrumentation applications.
<b>CLO4</b>	To make the students aware of potential events and impact of failures.
<b>CLO5</b>	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, exida2 <sup>nd</sup> 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,

<b>CO1</b>	Analyse the role of safety instrumented system in the industry and identify the hazards.
<b>CO2</b>	Determine the safety integrity level for an application and characterize the safety environment in industry.
<b>CO3</b>	Analyse the failure modes, failure rates and MTBF using various reliability engineering tools.
<b>CO4</b>	Apply the design, installation and maintenance procedures for SIS applied to industrial processes.

**Course Outcome and Programme Outcome Mapping**

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



<b>Course Code</b>	:	ICPE59
<b>Course Title</b>	:	<b>Modern Optimization Techniques and Algorithms</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	MAIR courses
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments (3), End Assessment (1)

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce and elaborate the field of optimization and applications in dynamical systems and engineering.
<b>CLO2</b>	To gain understanding in the methods, both classical and modern, of obtaining optimal solutions under various conditions.
<b>CLO3</b>	To estimate the size of search space in which solutions are sought and appreciate the fundamentals of complex systems.
<b>CLO4</b>	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: <a href="https://tinyurl.com/sdalinks/">https://tinyurl.com/sdalinks/</a>
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, <a href="https://tinyurl.com/sdamodeling/">https://tinyurl.com/sdamodeling/</a> (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,

<b>CO1</b>	Model engineering problems as computational optimization problems.
<b>CO2</b>	Understand the curse of dimensionality and need for heuristics in optimization in terms of Genetic Algorithms and the like.
<b>CO3</b>	Cast engineering design as solution to dynamic optimization problems modelled in learning paradigms.
<b>CO4</b>	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	PS01	PS02	PS03
<b>CO1</b>															
<b>CO2</b>															
<b>CO3</b>															
<b>CO4</b>															



<b>Course Code</b>	:	ICPE60
<b>Course Title</b>	:	<b>Robot Dynamics and Control</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC18, ICPC21
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To understand the importance of Position and Orientation in specifying the complete description of Robots.
<b>CLO2</b>	To study the Robot Dynamics and its properties.
<b>CLO3</b>	To design various Controllers for the Trajectory Tracking Problem of the Robot.
<b>CLO4</b>	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,

<b>CO1</b>	To explain the basic concepts of Mathematical Representation of Robot.
<b>CO2</b>	Understand the Dynamic Model of the Robot and its properties.
<b>CO3</b>	Design various Controllers for Trajectory Tracking Problem of Robot.
<b>CO4</b>	Analyze the Stability of Robot Motion Control System.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE61
<b>Course Title</b>	:	<b>CMOS Analog IC Design</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC12, ICPC20
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To develop skill for analog circuit design specifically relevant to CMOS IC design.
<b>CLO2</b>	To develop ability for the analysis of CMOS circuit noise and mismatch, and their impact on the circuit design.
<b>CLO3</b>	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 Edition 2002.
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,

<b>CO1</b>	Design CMOS based analog integrated circuits (IC) and analyze their performance.
<b>CO2</b>	Understand the negative feedback control applied in the design of CMOS circuit.
<b>CO3</b>	Examine the noise found in CMOS circuits and frequency response of CMOS circuits and assess its impact on circuit performance.
<b>CO4</b>	Develop and evaluate various CMOS operational amplifier (OpAmp) designs at the transistor level.

### Course Outcome and Programme Outcome Mapping

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P010	P011	P012	PS01	PS02	PS03
<b>CO1</b>	3	3	3	3	3	-	-	-	-	1	1	2	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	-	1	2	2	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	-	1	1	2	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	-	1	2	2	3	3	-



<b>Course Code</b>	:	ICPE62
<b>Course Title</b>	:	<b>Sensor Interface Design</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC11, ICPC12, ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	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.
<b>CLO2</b>	To offer knowledge regarding the design of transmitters adhering to industrial standards.
<b>CLO3</b>	To provide understanding of data acquisition system design and tackle associated challenges.
<b>CLO4</b>	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,

<b>CO1</b>	Design electronic interface circuits for resistive, capacitive, inductive, and piezoelectric sensors.
<b>CO2</b>	Design analog electronic circuits and integrated circuits-based transmitters for specified physical parameters.
<b>CO3</b>	Design digital interface circuits for resistive and capacitive sensors.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	1	2	2	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	2	2	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	1	2	2	3	3	3	-
<b>CO4</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1



<b>Course Code</b>	:	ICPE63
<b>Course Title</b>	:	<b>Artificial Intelligence in Instrumentation and Measurement</b>
<b>Type of Course</b>	:	PE/OE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	3 hours (42 hrs max)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the basic concepts of neural networks
<b>CLO2</b>	To impart knowledge on the development of classical deep neural networks such as CNN and RNN
<b>CLO3</b>	To make the students aware of graph neural networks and generative AI
<b>CLO4</b>	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,

<b>CO1</b>	Understand the basic concepts of artificial neural networks
<b>CO2</b>	Gain the knowledge of classical deep learning algorithms and its variants
<b>CO3</b>	Understand the concepts of graph neural networks and generative AI along with its importance
<b>CO4</b>	Design and develop deep learning architectures for real-world applications

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE64
<b>Course Title</b>	:	<b>Thermodynamics and Fluid Mechanics</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge about the fundamentals of thermodynamic laws, concepts and principles.
<b>CLO2</b>	To introduce the principles of various cycles and to apply the thermodynamic concepts in various applications.
<b>CLO3</b>	To introduce the fundamental concepts of fluid mechanics, pressure distribution and dimensional analysis.
<b>CLO4</b>	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 - Buckingham 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, 7 <sup>th</sup> Edition, 1997.
2.	Ojha C.S.P., Berndtsson R., Chandramouli P.N., Fluid Mechanics and Machinery, Oxford University Press, 2010.
3.	Streeter V.L. and Wylie E.B., Fluid Mechanics, McGraw Hill, New York, 9 <sup>th</sup> Edition, 1997.
4.	Van Wylen G.A., Fundamentals of classical Thermodynamics, John Wiley and Sons, 4 <sup>th</sup> Edition, 1994.
5.	Cengel Y.A., Bogles M.A., Micheal Boles, Thermodynamics, McGraw Hill Book Company, 2 <sup>nd</sup> Edition, 1994.



6.	Nag P.K., Engineering Thermodynamics, Tata McGraw Hill, 2 <sup>nd</sup> Edition, 1995.
7.	Crowe C.T., Elger D.F., Williams B.C., Roberson J.A., Engineering Fluid Mechanics John Wiley and Sons, 9 <sup>th</sup> Edition, 2009.
8.	S. K. Som, Gautam Biswas, Suman Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, 3rd Edition. Tata McGraw-Hill Education. (2013)

**Course Outcomes (CO)**

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

<b>CO1</b>	Apply the fundamentals of thermodynamics to various process.
<b>CO2</b>	Understand various thermodynamic cycles and their applications to heat engines.
<b>CO3</b>	Apply the knowledge of fundamental concepts in fluids mechanics and usage of dimensional analysis for scaling experimental results.
<b>CO4</b>	Select the metering equipment and fluid moving machinery for an appropriate process engineering operation.

**Course Outcome and Programme Outcome Mapping**

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	2	2	1	1	1	3	1	-	1	2	2	3	2	1
<b>CO2</b>	3	1	3	1	1	2	3	1	-	1	3	3	3	3	2
<b>CO3</b>	3	-	3	2	2	1	2	1	1	1	2	2	3	2	1
<b>CO4</b>	3	-	3	2	2	2	2	1	1	2	2	3	3	3	2



<b>Course Code</b>	:	ICPE65
<b>Course Title</b>	:	<b>Design and Applications of Sensors and Transducers</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide fundamentals of various types of diaphragm design.
<b>CLO2</b>	To familiarize with design of strain gauge, capacitive and inductive based transducers and its applications.
<b>CLO3</b>	To furnish the knowledge on design of accelerometer and gyroscope.
<b>CLO4</b>	To provide the basics of various chemical sensors and its design criterion.

### Course Content

Introduction to diaphragm; Diaphragm performance and materials, Design of flat diaphragms, 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 Effect sensors, and practical demonstration of few applications.

Introduction to chemical Sensors, characteristics. Design of DO<sub>2</sub> 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, Springer, 3rd Editions, 2010.
7.	Alexander D. Khazan, Transducers and Their Elements: Design and Application, PTR Prentice Hall, 1994
8.	B.E. Nolingk, 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., Shpak N.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,

<b>CO1</b>	Select and design diaphragm for different practical applications.
<b>CO2</b>	Design strain gauge-based torque, force, load and pressure measurement systems.
<b>CO3</b>	Design capacitance/ inductance transducers for the measurement of displacement, pressure and level.
<b>CO4</b>	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	PS01	PS02	PS03
<b>CO1</b>	3	2	3	-	2	3	3	2	-	2	-	3	3	3	2
<b>CO2</b>	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-
<b>CO4</b>	3	3	3	3	3	-	-	-	-	-	2	2	3	3	-



<b>Course Code</b>	:	ICPE66
<b>Course Title</b>	:	<b>Design of Instrumentation Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC17, ICPC20
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart the design knowledge of flow measurement and temperature measurement devices.
<b>CLO2</b>	To introduce about control valve sizing and section of pumps for practical applications.
<b>CLO3</b>	To introduce the process of Electronic product design
<b>CLO4</b>	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 Edition 2009.
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,

<b>CO1</b>	Design temperature and flow measurement system for process application.
<b>CO2</b>	Design and Analyze CV Sizing
<b>CO3</b>	Identify various Control panels and Control Room details
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	2	3	2	2	-	2	-	3	3	3	2
<b>CO2</b>	2	-	3	-	3	3	2	2	-	2	-	3	3	3	2
<b>CO3</b>	2	3	3	3	3	3	3	3	-	3	-	3	3	3	2
<b>CO4</b>	3	3	3	3	3	3	3	3	-	3	-	3	3	3	2



<b>Course Code</b>	:	ICPE67
<b>Course Title</b>	:	<b>Design of Micro Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide knowledge on MEMS design and various fabrication processes.
<b>CLO2</b>	To impart knowledge on mechanics of membranes and beams in micro scale.
<b>CLO3</b>	To convey the design principles of electrostatic actuation and sensing.
<b>CLO4</b>	To impart design knowledge on micro pressure sensor and micro accelerometer.
<b>CLO5</b>	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,

<b>CO1</b>	Design and fabricate simple micro devices.
<b>CO2</b>	Design and analyze simple mechanical structures used in sensor actuators.
<b>CO3</b>	Design electrostatic based actuation and sensing devices, micro pressure sensor and micro accelerometer.
<b>CO4</b>	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



<b>Course Code</b>	:	ICPE68
<b>Course Title</b>	:	<b>Design of Control Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC18, ICPC21
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge in the concepts and techniques of linear and nonlinear control system analysis and synthesis in the modern control (state space) framework.
<b>CLO2</b>	To teach the control design using the classical design principles
<b>CLO3</b>	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, Riccati 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,

<b>CO1</b>	Develop mathematical models for various physical systems.
<b>CO2</b>	Design state feedback controllers and observers.
<b>CO3</b>	Design nonlinear controllers using Lyapunov theory.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	2	2	2	-	-	-	3	3	3	2
<b>CO2</b>	3	3	3	3	3	2	2	3	-	-	-	3	3	3	2
<b>CO3</b>	2	3	3	-	3	3	2	3	-	-	-	3	3	3	2
<b>CO4</b>	2	3	3	-	3	3	3	3	-	-	-	3	3	3	2



<b>Course Code</b>	:	ICPE69
<b>Course Title</b>	:	<b>Advanced Process Control Methods</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC18, ICPC21
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose students to the advanced control methods used in industries and research.
<b>CLO2</b>	To teach various system identification and parameter estimation techniques.
<b>CLO3</b>	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, 1 <sup>st</sup> Edition, Wiley-AIChE .
4.	B.A. Ogunnaikand, W.H. Ray, Process Dynamics, Modelling and Control, OxfordPress, 1997.
5.	W.L. Luyben, Process Modelling Simulation and Control for Chemical Engineers, McGraw Hill, 2 <sup>nd</sup> Edition, 1990.
6.	S. Bhanot, Process Control: Principles and Applications, Oxford University Press, 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,

<b>CO1</b>	Design an appropriate advanced controller for specific problems in process industries.
<b>CO2</b>	Develop suitable filters for linear/non-linear system
<b>CO3</b>	Design of SDCS for multivariable systems.
<b>CO4</b>	Develop the MPC and next generation controller for multivariate system

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICPE70
<b>Course Title</b>	:	<b>Robust and Optimal Control Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC18, ICPC22
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce analysis and design techniques for multivariable control systems to undergraduate students
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### 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 H<sub>2</sub> 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,

<b>CO1</b>	Apply Optimization tools to multivariable feedback systems.
<b>CO2</b>	Use computer software to design MIMO robust controllers.
<b>CO3</b>	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	-



<b>Course Code</b>	:	ICPE71
<b>Course Title</b>	:	<b>Design of Sensors Systems</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	ICPC17
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide knowledge on the design of signal conditioning circuits for resistive, capacitive and thermal transducers to improve the sensor characteristics.
<b>CLO2</b>	To provide knowledge on the design of transmitters with industrial standard.
<b>CLO3</b>	To impart the knowledge of data acquisition system design, sensor networks and buses
<b>CLO4</b>	To provide knowledge about the smart sensor design, direct sensor microcontroller interface 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, 2 <sup>nd</sup> Edition, John Wiley and Sons, 2000.
2.	Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal 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; 5 <sup>th</sup> 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, and Applications, 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, 2 <sup>nd</sup> Edition 1995.

**Course Outcomes (CO)**

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

<b>CO1</b>	Design signal conditioning circuits for resistive, capacitive and thermal transducers
<b>CO2</b>	Design transmitters for the required physical parameters using analog circuits and IC.
<b>CO3</b>	Interface sensors signal with DAQ, Microcontroller and will be familiar with sensor buses and protocols.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
<b>CO2</b>	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
<b>CO3</b>	3	3	3	3	-	-	-	-	-	2	-	-	3	3	-
<b>CO4</b>	2	3	3	3	-	3	3	2	-	2	-	-	3	3	2



## OPEN ELECTIVES (**OE**)



<b>Course Code</b>	:	ICOE11
<b>Course Title</b>	:	<b>Biomedical Signal Processing</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the importance of biomedical signals and analysis
<b>CLO2</b>	To introduce different types of bio signals and their characteristics
<b>CLO3</b>	To study different noise removal mechanisms for biomedical signals
<b>CLO4</b>	To analyze 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 electroencephalogram (ENG), electromyogram (EMG), electrocardiogram (ECG), electroencephalogram (EEG), event related potentials (ERP), electrogastrogram (EGG), phonocardiogram (PCG), vibromyogram (VMG) and vibroarthrogram (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. (2015). Biomedical signal analysis (2nd Edition). Wiley-IEEE Press. ISBN: 0470911396 (Online ISBN 1119068129).
2.	Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, A Wiley-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, 2nd Edition, 2009
4.	Le Cerutti, S., and Marchesi, C. (Eds.). (2011). Advanced methods of biomedical signal processing (Vol. 27). John Wiley and Sons.
5.	Webster, J. G. (2009). Medical instrumentation application and design. John Wiley and Sons.
6.	Mitra, S.K., Digital Signal Processing: A Computer-Based Approach, McGraw Hill, NY, 4 <sup>th</sup> Edition, 2013



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P010	P011	P012	PS01	PS02	PS03
<b>CO1</b>	3	2	3	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO2</b>	2	3	3	3	2	3	2	2	-	-	-	3	3	3	-
<b>CO3</b>	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
<b>CO4</b>	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-





<b>Course Code</b>	:	ICOE12
<b>Course Title</b>	:	<b>Micro Electro Mechanical Systems</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamental concepts of MEMS and Micro systems and their relevance to current scientific needs.
<b>CLO2</b>	To introduce the state-of-art micromachining techniques including surface micromachining, bulk micromachining, and related methods.
<b>CLO3</b>	To make the students knowledgeable in the design concepts of micro sensors and microactuators.
<b>CLO4</b>	To introduce the challenges and limitations in the design of MEMS devices
	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 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 Delhi 2017.
2.	Marc Madou, Fundamentals of Micro fabrication, CRC Press, 2 <sup>nd</sup> Edition, 2002.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS, and Smart Devices, JohnWiley and Sons Ltd, 1 <sup>st</sup> Edition, reprinted, 2013.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1 <sup>st</sup> Edition, 2012.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1 <sup>st</sup> Edition, 2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2 <sup>nd</sup> 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, 2019.



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICOE13
<b>Course Title</b>	:	<b>Measurement and Control</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge in the basics of measurement system.
<b>CLO2</b>	To expose the students to various measurement techniques used for the measurement of important process variables.
<b>CLO3</b>	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, 3 <sup>rd</sup> edition. 2017
2.	A. K. Ghosh, Introduction to Instrumentation and Control, PHI publications, 4 <sup>th</sup> edition. 2012
3.	Nakra Chaudhari, Instrumentation measurement and analysis, Mc Graw hill, 3 <sup>rd</sup> edition.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. Doebelin, 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,

<b>CO1</b>	Familiar with the basics of measurement system, its characteristics and principles of few transducers.
<b>CO2</b>	Familiar with the different temperature, pressure, flow and level measurement techniques used in process industries.
<b>CO3</b>	Able to select and make measurements of temperature, flow, pressure and level in any process industry.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-
<b>CO2</b>	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
<b>CO3</b>	3	3	3	3	2	3	2	2	-	-	-	3	3	3	-
<b>CO4</b>	3	3	3	3	3	3	2	2	-	-	-	3	3	3	-



<b>Course Code</b>	:	ICOE14
<b>Course Title</b>	:	<b>Industrial Measurements</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the importance of process variable measurements.
<b>CLO2</b>	To expose the students to various measurement techniques used for the measurement of temperature, flow, pressure and level in process industries.
<b>CLO3</b>	To make the students knowledgeable in the design, installation and troubleshooting of process instruments.

### 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 Hill Education, 7 <sup>th</sup> Edition, 2019.
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4 <sup>th</sup> Edition, 2003.
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3 <sup>rd</sup> Edition, 2010.
4.	B.E. Noltingk, Instrumentation Reference Book, Butterworth Heinemann, 2 <sup>nd</sup> Edition, 1995.
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill, Singapore, 5 <sup>th</sup> Edition, 2009.
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I and Vol II, Gulf Publishing Company, Houston, 2001
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3 <sup>rd</sup> 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,

<b>CO1</b>	Familiar with the different temperature, pressure, flow and level measurement techniques used in process industries.
<b>CO2</b>	Able to select and make measurements of temperature, flow, pressure and level in any process industry.
<b>CO3</b>	Able to identify or choose temperature, flow, pressure and level measuring device for specific process.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICOE15
<b>Course Title</b>	:	<b>Virtual Instrument Design</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce to the students about the interfacing techniques of various transducers.
<b>CLO2</b>	To expose the students to different signal conditioning circuits.
<b>CLO3</b>	To impart knowledge on the hardware required to build Virtual Instrument.
<b>CLO4</b>	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, 2 <sup>nd</sup> Edition. RandD Books, 2020
5.	Jean Labrosse, MicroC/OS-II – The Real-Time Kernel, 2 <sup>nd</sup> Edition. CMP Books, 2002

**Course Outcomes (CO)**

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

<b>CO1</b>	Interface the target transducer to the signal conditioning board.
<b>CO2</b>	Condition the acquired signal from the transducer to standard data formats.
<b>CO3</b>	Select the most appropriate hardware for the virtual instrument to be built.
<b>CO4</b>	Implement the real-time OS for the selected micro-controller and the GUI interface for the virtual instrument.

**Course Outcome and Programme Outcome Mapping**

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





<b>Course Code</b>	:	ICOE16
<b>Course Title</b>	:	<b>Neural Networks and Fuzzy Logic</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide an overview of intelligent techniques.
<b>CLO2</b>	Develop skills to gain a basic understanding of neural network and fuzzy logic theory.
<b>CLO3</b>	To introduce different architectures and algorithms of Neural Networks.
<b>CLO4</b>	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, Kohonen'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, 4 <sup>th</sup> 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, 2 <sup>nd</sup> 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, 1 <sup>st</sup> 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,

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

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICOE17
<b>Course Title</b>	:	<b>Network Control Systems</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the emerging field of multi-agent and network control systems
<b>CLO2</b>	To expand the scope of traditional control systems to include large-scale interconnected systems
<b>CLO3</b>	To demonstrate consensus and leader-follower paradigms in a distributed environment
<b>CLO4</b>	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,

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



### Course Outcome and Programme Outcome Mapping

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P010	P011	P012	PS01	PS02	PS03
CO1															
CO2															
CO3															
CO4															



<b>Course Code</b>	:	ICOE18
<b>Course Title</b>	:	<b>Control Systems</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the concept of feedback control system.
<b>CLO2</b>	To impart knowledge in mathematical modeling of physical systems.
<b>CLO3</b>	To impart knowledge in characteristics and performance of feedback control system.
<b>CLO4</b>	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 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, 14 <sup>th</sup> edition, 2022.
2.	Katsuhiko Ogata, Modern Control Engineering, PHI Learning Private Ltd, 5 <sup>th</sup> Edition, 2010.
3.	Franklin, G.F., David Powell, J., Emami-Naeini, A., Feedback Control of Dynamic Systems, Prentice Hall, 8 <sup>th</sup> Edition, 2020
4.	Nise, N.S., Control Systems Engineering, Wiley, 8 <sup>th</sup> Edition, 2019.
5.	John J.D., Azzo Constantine, H. and Houpis Stuart, N Sheldon, "Linear Control System Analysis and Design with MATLAB", 6 <sup>th</sup> Edition 2013
6.	Dutton, K., Thompson, S., Barralough, B., The Art of Control Engineering, Prentice Hall, 1997.
7.	M. Gopal., Control Systems: Principles and Design, 4 <sup>th</sup> 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,

<b>CO1</b>	Generate mathematical models of dynamic control system by applying differential equations.
<b>CO2</b>	Analyze and characterize the behavior of a control system in terms of different system, performance parameters and assess system stability.
<b>CO3</b>	Evaluate and analyses system performance using frequency and transient response analysis.
<b>CO4</b>	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
<b>CO1</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO2</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO3</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO4</b>	2	-	-	3	3	3	2	2	-	-	-	3	3	3	-



<b>Course Code</b>	:	ICOE19
<b>Course Title</b>	:	<b>Energy Harvesting Techniques</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce basic energy harvesting techniques using smart materials and structures and combining with mechanisms.
<b>CLO2</b>	To impart knowledge in the design of power converter circuits for ambient energy harvesters.
<b>CLO3</b>	To introduce mathematical modelling of piezoelectric based energy harvesters.
<b>CLO4</b>	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., 1 <sup>st</sup> Edition, 2010.
2.	Danick Briand, Eric Yeatman, and Shad Roundy, Micro energy harvesting, Wiley-VCH Verlag GmbH and Co, 2015.
3.	Stephen Beeby, Neil White, Energy Harvesting for Autonomous Systems, Artech House, Norwood, 1 <sup>st</sup> Edition, 2010.



4.	Alper Erturk and Daniel J Inman, Piezoelectric Energy Harvesting, John Wiley and Sons.Ltd.1 <sup>st</sup> Edition ,2011.
5.	Tom J. Kazmiershi, Steve Beeby, Energy Harvesting System, Principles, Modelling and Application, springer, Newyork,2011.

### Course Outcomes (CO)

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

<b>CO1</b>	Comprehend in the concept of various ambient energy harvesting techniques.
<b>CO2</b>	Design optimal power converting circuits for different harvesters.
<b>CO3</b>	Design electromagnetic and thermoelectric based energy harvesters.
<b>CO4</b>	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
<b>CO1</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO2</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO3</b>	3	2	2	2	3	3	2	2	-	-	-	3	3	3	-
<b>CO4</b>	2	-	-	3	3	3	2	2	-	-	-	3	3	3	-





<b>Course Code</b>	:	ICOE20
<b>Course Title</b>	:	<b>Smart Materials and Systems</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose to the basics of sensors used in industries.
<b>CLO2</b>	To provide adequate knowledge on smart instrumentation and wireless sensor networks.
<b>CLO3</b>	To impart knowledge on various standard protocols used in wireless instrumentation.
<b>CLO4</b>	To apply the knowledge of sensors, transceivers, controllers and power supplies to implement 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<sub>2</sub>) 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 ebook published in 2018
3.	Uvais Qidwai, Smart Instrumentation: A data flow approach to Interfacing, Chapman and Hall, CRC 1 <sup>ST</sup> Edition 2019



### Course Outcomes (CO)

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

<b>CO1</b>	Understand about smart instrumentation system.
<b>CO2</b>	Design self-diagnosing instrumentation system..
<b>CO3</b>	Identify the issues in power efficient systems and implement energy management techniques in WSN
<b>CO4</b>	Design wireless instrumentation systems for the given requirement.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICOE21
<b>Course Title</b>	:	<b>Product Design and Development (Theory and Practice)</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	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.
<b>CLO2</b>	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.
<b>CLO3</b>	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
<b>CLO4</b>	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, 7 <sup>th</sup> 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,

<b>CO1</b>	Make market surveys for new product development
<b>CO2</b>	Select an appropriate product design and development process for a given application
<b>CO3</b>	Plan the entire cycle of new product design and development and fabricate prototypes of new products and test them.
<b>CO4</b>	Choose an appropriate agronomy for the product and adopt methods to minimize the cost.

## Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICOE22
<b>Course Title</b>	:	<b>Medical Imaging Systems</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the methods of medical imaging.
<b>CLO2</b>	To impart knowledge in the physics behind the various imaging techniques.
<b>CLO3</b>	To teach the construction and working of various imaging techniques.
<b>CLO4</b>	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
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### Course Outcomes (CO)

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

<b>CO1</b>	Acquire basic domain knowledge about the various medical imaging techniques.
<b>CO2</b>	Understand the construction and working of various medical imaging equipments.
<b>CO3</b>	Provide a foundational understanding of algorithms used in medical imaging
<b>CO4</b>	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
<b>CO1</b>	3	2	3	2	1	1	2	1	1	2	1	3	3	3	1
<b>CO2</b>	3	2	3	3	2	2	1	1	1	2	2	3	3	3	1
<b>CO3</b>	3	2	3	3	3	-	1	2	1	2	2	3	3	3	2
<b>CO4</b>	2	1	3	3	3	1	1	2	2	1	2	3	3	3	2



<b>Course Code</b>	:	ICOE23
<b>Course Title</b>	:	<b>Building Automation</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the basic blocks of Building Management System.
<b>CLO2</b>	To impart knowledge in the design of various sub systems (or modular system) of building automation..
<b>CLO3</b>	To provide insight into some of the advanced principles for safety in automation.
<b>CLO4</b>	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,

<b>CO1</b>	Understand the concept behind building automation.
<b>CO2</b>	Plan for building automation.
<b>CO3</b>	Design sub systems for building automation and integrate those systems.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	2	2	2	2	1	3	2	1	3	3	3	2
<b>CO2</b>	2	2	3	3	2	2	2	1	2	2	2	3	3	3	1
<b>CO3</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	2
<b>CO4</b>	3	3	3	3	3	1	2	2	2	1	3	3	3	3	1





<b>Course Code</b>	:	ICOE24
<b>Course Title</b>	:	<b>Biomedical Instrumentation</b>
<b>Type of Course</b>	:	Open Elective (OE)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Assignments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To educate the students on the different medical instruments.
<b>CLO2</b>	To familiarize the students with the analysis and design of instruments to measure bio-signals like ECG, EEG, EMG, etc.
<b>CLO3</b>	To have a basic knowledge in therapeutic devices
<b>CLO4</b>	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 measurements: 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, Automated Biochemical Analysis System. Blood gas analyzer, Acid -base balance, Blood PH measurement, blood PCO<sub>2</sub>, blood PO<sub>2</sub>, 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.	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, 2nd Edition, Pearson Prentice Hall, published by Pearson in 2022.
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.	Joseph J. Carr and John M. Brown, Introduction to Biomedical Equipment Technology, 4th Edition, Pearson publishing, 2013.
10.	Onkar N. Pandey, Rakesh Kumar, Bio Medical Electronics and Instrumentation, Katson Books, 5 <sup>th</sup> 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,

<b>CO1</b>	Understand the concept behind building automation.
<b>CO2</b>	Plan for building automation.
<b>CO3</b>	Design sub systems for building automation and integrate those systems.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	2	2	2	2	1	3	2	1	3	3	3	2
<b>CO2</b>	2	2	3	3	2	2	2	1	2	2	2	3	3	3	1
<b>CO3</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	2
<b>CO4</b>	3	3	3	3	3	1	2	2	2	1	3	3	3	3	1



## HONOURS (HO) COURSES



<b>Course Code</b>	:	ICHO11
<b>Course Title</b>	:	<b>Design of sensors and Transducer</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide fundamentals of various types of diaphragm design.
<b>CLO2</b>	To familiarize with design of strain gauge, capacitive and inductive based transducers and its applications.
<b>CLO3</b>	To furnish the knowledge on design of accelerometer and gyroscope.
<b>CLO4</b>	To provide the basics of various chemical sensors and its design criterion.

### Course Content

Introduction to diaphragm; Diaphragm performance and materials, Design of flat diaphragms, 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 Effect sensors, and practical demonstration of few applications.

Introduction to chemical Sensors, characteristics. Design of DO<sub>2</sub> 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, 4 <sup>th</sup> 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, Springer, 4 <sup>th</sup> Editions, 2010.
7.	Alexander D. Khazan, Transducers and Their Elements: Design and Application, PTR Prentice Hall, 1994
8.	B.E. Nolingk, 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,

<b>CO1</b>	Select and design diaphragm for different practical applications.
<b>CO2</b>	Design strain gauge-based torque, force, load and pressure measurement systems.
<b>CO3</b>	Design capacitance/ inductance transducers for the measurement of displacement, pressure and level.
<b>CO4</b>	Acquire knowledge in design of accelerometer and gyroscope.

**Course Outcome and Programme Outcome Mapping**

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



<b>Course Code</b>	:	ICHO12
<b>Course Title</b>	:	<b>Instrumentation System Design</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC17, ICPC20
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart the design knowledge of flow measurement and temperature measurement devices.
<b>CLO2</b>	To introduce about control valve sizing and section of pumps for practical applications.
<b>CLO3</b>	To introduce the process of Electronic product design
<b>CLO4</b>	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 Edition 2009.
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 2005.
8.	Kim R Fowler, Electronic Instrument Design, Oxford University-paperback 2006
9.	Manual on product design: IISc C.E.D.T.
10.	Harshvardhan, Measurement Principles and Practices, Macmillan India Ltd-2000
11.	Mourad Samiha and Zorian Yervant, Principles of Testing Electronic Systems, New York. John Wiley and Sons, 2009.
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,

<b>CO1</b>	Design temperature and flow measurement system for process application.
<b>CO2</b>	Design and Analyze CV Sizing
<b>CO3</b>	Identify various Control panels and Control Room details
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	2	3	2	2	-	2	-	3	3	3	2
<b>CO2</b>	2	-	3	-	3	3	2	2	-	2	-	3	3	3	2
<b>CO3</b>	2	3	3	3	3	3	3	3	-	3	-	3	3	3	2
<b>CO4</b>	3	3	3	3	3	3	3	3	-	3	-	3	3	3	2



<b>Course Code</b>	:	ICHO13
<b>Course Title</b>	:	<b>Micro System Design</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC14
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide knowledge on MEMS design and various fabrication processes.
<b>CLO2</b>	To impart knowledge on mechanics of membranes and beams in micro scale.
<b>CLO3</b>	To convey the design principles of electrostatic actuation and sensing.
<b>CLO4</b>	To impart design knowledge on micro pressure sensor and micro accelerometer.
<b>CLO5</b>	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,

<b>CO1</b>	Design and fabricate simple micro devices.
<b>CO2</b>	Design and analyze simple mechanical structures used in sensor actuators.
<b>CO3</b>	Design electrostatic based actuation and sensing devices, micro pressure sensor and micro accelerometer.
<b>CO4</b>	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



<b>Course Code</b>	:	ICHO14
<b>Course Title</b>	:	<b>Control System Design</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC18, ICPC21
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To impart knowledge in the concepts and techniques of linear and nonlinear control system analysis and synthesis in the modern control (state space) framework.
<b>CLO2</b>	To teach the control design using the classical design principles
<b>CLO3</b>	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, Riccati 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. 3 <sup>rd</sup> 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

<b>CO1</b>	Develop mathematical models for various physical systems.
<b>CO2</b>	Design state feedback controllers and observers.
<b>CO3</b>	Design nonlinear controllers using Lyapunov theory.
<b>CO4</b>	Analyze the stability of nonlinear system.

**Course Outcome and Programme Outcome Mapping**

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



<b>Course Code</b>	:	ICHO15
<b>Course Title</b>	:	<b>Advanced Process Control</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC18, ICPC21
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose students to the advanced control methods used in industries and research.
<b>CLO2</b>	To teach various system identification and parameter estimation techniques.
<b>CLO3</b>	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, 1 <sup>st</sup> 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, 2 <sup>nd</sup> 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

<b>CO1</b>	Design an appropriate advanced controller for specific problems in process industries.
<b>CO2</b>	Develop suitable filters for linear/non-linear system
<b>CO3</b>	Design of SDCS for multivariable systems.
<b>CO4</b>	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
<b>CO1</b>	3	-	3	2	3	3	2	3	-	-	-	3	3	3	2
<b>CO2</b>	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
<b>CO3</b>	3	3	3	2	3	3	2	3	-	-	-	3	3	3	2
<b>CO4</b>	3	-	3	3	3	3	2	3	-	-	-	3	3	3	2



<b>Course Code</b>	:	ICHO16
<b>Course Title</b>	:	<b>Optimal and Robust Control</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC18, ICPC22
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	Introduce analysis and design techniques for multivariable control systems to undergraduate students
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### 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 H<sub>2</sub> 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

<b>CO1</b>	Apply Optimization tools to multivariable feedback systems.
<b>CO2</b>	Use computer software to design MIMO robust controllers.
<b>CO3</b>	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
<b>CO1</b>	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
<b>CO2</b>	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-
<b>CO3</b>	3	2	3	3	3	2	3	-	2	3	-	3	3	3	-
<b>CO4</b>	3	2	3	3	3	2	2	-	2	3	-	3	3	3	-



<b>Course Code</b>	:	ICHO17
<b>Course Title</b>	:	<b>Sensors System Design</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	ICPC17
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To provide knowledge on the design of signal conditioning circuits for resistive, capacitive and thermal transducers to improve the sensor characteristics.
<b>CLO2</b>	To provide knowledge on the design of transmitters with industrial standard.
<b>CLO3</b>	To impart the knowledge of data acquisition system design, sensor networks and buses
<b>CLO4</b>	To provide knowledge about the smart sensor design, direct sensor microcontroller interface 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, 2 <sup>nd</sup> Edition, John Wiley and Sons, 2000.
2.	Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal 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; 5 <sup>th</sup> Edition, 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. Noltink, Instrumentation Reference Book, Butterworth- Heinemann, 2 <sup>nd</sup> Edition 1995.

### Course Outcomes (CO)

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

<b>CO1</b>	Design signal conditioning circuits for resistive, capacitive and thermal transducers
<b>CO2</b>	Design transmitters for the required physical parameters using analog circuits and IC.
<b>CO3</b>	Interface sensors signal with DAQ, Microcontroller and will be familiar with sensor buses and protocols.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
<b>CO2</b>	3	3	3	3	3	2	2	2	-	2	-	-	3	3	2
<b>CO3</b>	3	3	3	3	-	-	-	-	-	2	-	-	3	3	-
<b>CO4</b>	2	3	3	3	-	3	3	2	-	2	-	-	3	3	2



<b>Course Code</b>	:	ICHO18
<b>Course Title</b>	:	<b>Project-based Learning</b>
<b>Type of Course</b>	:	HO
<b>Prerequisites</b>	:	-
<b>Contact Hours</b>	:	56 (4 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To enable the student to design, develop and construct hands-on solution to a problem.
<b>CLO2</b>	To build student's creative capacity to work through problems that may or may not be well-defined.
<b>CLO3</b>	To provide students opportunities to work across disciplines, on real-world problems of technical interest
<b>CLO4</b>	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,

<b>CO1</b>	Identify a problem of significance to the industry and the academic community, with the help of mentor
<b>CO2</b>	Design the most effective solution to the problem, given the constraints and challenges
<b>CO3</b>	Develop a prototype, that would be an embodiment of the proposed solution.
<b>CO4</b>	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**



<b>Course Code</b>	:	ICMI11
<b>Course Title</b>	:	<b>Transducer Engineering</b>
<b>Type of Course</b>	:	PE
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to various sensors and transducers for measuring mechanical quantities.
<b>CLO2</b>	To make the students familiar with the specifications of sensors and transducers.
<b>CLO3</b>	To teach the basic conditioning circuits for various sensors and transducers.
<b>CLO4</b>	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, 4 <sup>th</sup> Edition, 2005.
2.	Doebelin E.O, Measurement Systems - Application and Design, McGraw-Hill, 4 <sup>th</sup> 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 Típek, 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 Science and Business Media, 2004.
10.	Tumanski, Slawomir. Handbook of magnetic measurements. CRC Press, 2016.
11.	Murthy D. V. S, Transducers and Instrumentation, Prentice Hall, 2 <sup>nd</sup> Edition, 2011.



12.	James W. Dally, Instrumentation for Engineering Measurements, Wiley, 2 <sup>nd</sup> Edition, 1993.
13.	John G. Webster, Sensors and Signal Conditioning, Wiley Inter Science, 2 <sup>nd</sup> Edition, 2008.
14.	B.E. Noltingk, Instrumentation Reference Book, Butterworth-Heinemann, Second edition 1995
15.	Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynaga 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,

<b>CO1</b>	Have familiarity with the basics of measurement system and its input, output configuration.
<b>CO2</b>	Have familiarity with both static and dynamic characteristics of measurement system.
<b>CO3</b>	Have familiarity with the principle and working of various sensors and transducers.
<b>CO4</b>	Select proper transducer / sensor for a specific measurement application.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICMI12
<b>Course Title</b>	:	<b>Test and Measuring Instruments</b>
<b>Type of Course</b>	:	Minor(MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To give an overview of current, voltage and power measuring electrical, electronics and digital instruments.
<b>CLO2</b>	To expose the students to the design of bridges for the measurement of resistance, capacitance and inductance.
<b>CLO3</b>	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, 5 <sup>th</sup> Edition, 2011.
2.	David A. Bell, Electronic Instrumentation and Measurements, Oxford University Press, 3 <sup>rd</sup> Edition, 2013.
3.	Shawney A K, A course in Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai and Sons. 19 <sup>th</sup> revised edition, 2013.
4.	Cooper, W.D. and Helfric, A.D., Electronic Instrumentation and Measurement Techniques, PrenticeHall, 1 <sup>st</sup> Edition, 2009.
5.	Kalsi.H. S, Electronic Instrumentation, Tata McGraw Hill Education Private Limited, 3 <sup>rd</sup> Edition, 2012.



### Course Outcomes (CO)

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

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

### Course Outcome and Programme Outcome Mapping

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





<b>Course Code</b>	:	ICMI13
<b>Course Title</b>	:	<b>Measurements In Process Industries</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the importance of process variable measurements.
<b>CLO2</b>	To expose the students to various measurement techniques used for the measurement of temperature, flow, pressure and level in process industries.
<b>CLO3</b>	To make the students knowledgeable in the design, installation and troubleshooting of process instruments.

### 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, Capacitance pickup, Ultrasonic pickup.

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 Hill Education, 6 <sup>th</sup> Edition, 2011.
2.	B.G. Liptak, Process Measurement and Analysis, CRC Press, 4 <sup>th</sup> Edition, 2003.
3.	Patranabis D, Principles of Industrial Instrumentation, Tata McGraw Hill, 3 <sup>rd</sup> Edition, 2010.
4.	B.E. Nolingk, Instrumentation Reference Book, Butterworth Heinemann, 2 <sup>nd</sup> Edition, 1995.
5.	Douglas M. Considine, Process / Industrial Instruments and Controls Handbook, McGraw Hill, Singapore, 5 <sup>th</sup> Edition, 1999.
6.	Andrew W.G, Applied Instrumentation in Process Industries – A survey, Vol I and Vol II, Gulf Publishing Company, Houston, 2001
7.	Spitzer D. W., Industrial Flow measurement, ISA press, 3 <sup>rd</sup> 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

<b>CO1</b>	Have familiarity with different temperature, pressure, flow and level measurement techniques used in process industries.
<b>CO2</b>	Select and make measurements of temperature, flow, pressure and level in any process industry.
<b>CO3</b>	Understand and calibrate the flow meter
<b>CO4</b>	Identify or choose temperature, flow, pressure and level measuring device for specific process.

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICMI14
<b>Course Title</b>	:	<b>Essentials Of Control Engineering</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To expose the students to the fundamentals of feedback control system.
<b>CLO2</b>	To impart the knowledge on different types of control systems representation in pictorial and mathematical forms.
<b>CLO3</b>	To teach the performance characteristics and analysis of control systems in time and frequency domain.

### 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, 13 <sup>th</sup> Edition, 2016.
2.	Katsuhiko Ogata Modern Control Engineering, Pearson, 5 <sup>th</sup> Edition, 2009.
3.	Franklin G.F., Powell J.D., Emami-Naeini A., Feedback Control of Dynamic Systems, Pearson, 7 <sup>th</sup> Edition, 2015.
4.	B. C. Kuo, F. Golnaraghi, Automatic Control Systems, Wiley Publishers, India, 8 <sup>th</sup> 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, 4 <sup>th</sup> Edition, 2003



### Course Outcomes (CO)

At the end of the course student will be able to

<b>CO1</b>	Appreciate the importance of feedback control system.
<b>CO2</b>	Analyze and design the system performance using time domain and frequency domain techniques.
<b>CO3</b>	Perform the stability analysis of control systems
<b>CO4</b>	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
<b>CO1</b>	3	2	2	2	2	3	1	1	2	2	2	3	3	2	2
<b>CO2</b>	3	2	3	3	3	3	3	2	3	2	3	3	3	3	2
<b>CO3</b>	3	2	3	3	3	3	3	2	3	2	3	3	3	3	2
<b>CO4</b>	3	2	3	3	3	2	2	2	2	2	2	3	3	3	1



<b>Course Code</b>	:	ICMI15
<b>Course Title</b>	:	<b>Industrial Automation and Control</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the importance of process automation techniques.
<b>CLO2</b>	To impart required knowledge in PLC based programming.
<b>CLO3</b>	To introduce to the students to the distributed control system and different communication protocols.

### 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 rigs using 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, 5 <sup>th</sup> 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, 4 <sup>th</sup> 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, 5 <sup>th</sup> 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, 8 <sup>th</sup> Edition, 2005.
9.	Krishna Kant, Computer-based Industrial Control, Prentice Hall, New Delhi, 2 <sup>nd</sup> Edition, 2011.



### Course Outcomes (CO)

At the end of the course student will be able to

<b>CO1</b>	Understand process automation technologies.
<b>CO2</b>	Design and develop PLC ladder programming for simple process applications.
<b>CO3</b>	Identify different security design approaches, engineering and operator interface issues for designing distributed control systems.
<b>CO4</b>	Explain latest communication technologies like HART and Field bus protocol.

### Course Outcome and Programme Outcome Mapping

	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	3	2	2	3	2	1	3	1	1	3	3	3	1
<b>CO2</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
<b>CO3</b>	3	3	3	3	3	2	2	1	3	2	2	3	3	3	1
<b>CO4</b>	3	2	2	2	2	1	1	1	2	1	1	3	3	2	1



<b>Course Code</b>	:	ICMI16
<b>Course Title</b>	:	<b>Digital Electronics</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	An understanding of number systems, codes and their conversions.
<b>CLO2</b>	The capability to reduce Boolean expression using K-map and tabular methods.
<b>CLO3</b>	The ability to design and analyze combinational and sequential logic circuits for a given problemstatement.
<b>CLO4</b>	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,5 <sup>th</sup> 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,2 <sup>nd</sup> Edition, 2000
4.	J.M. Rabaey, Digital Integrated Circuits: A Design Perspective, Prentice Hall of India, 2 <sup>nd</sup> Edition,2003.



5.	N.H.E. Weste, and K. Eshraghian, Principles of CMOS VLSI Design: A Systems Perspective, Pearson Education Inc., (Asia), 3 <sup>rd</sup> 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. Carroll and J.D. Irwin, Digital Logic Circuit Analysis and Design, 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, 12 <sup>th</sup> Edition, Prentice Hall, 2010

### Course Outcomes (CO)

At the end of the course student will be able to

<b>CO1</b>	Understand various number systems, conversions and simplify the logical expressions using Boolean functions.
<b>CO2</b>	Design and develop arithmetic and other special functions using combinational logic circuits and PLDs.
<b>CO3</b>	Design and develop synchronous and asynchronous for the given problem statement.
<b>CO4</b>	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
<b>CO1</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO2</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO3</b>	3	3	3	3	3	-	-	-	2	2	2	3	3	3	-
<b>CO4</b>	2	2	2	2	2	1	1	1	3	3	3	2	2	2	1





<b>Course Code</b>	:	ICMI17
<b>Course Title</b>	:	<b>Microprocessor and Microcontroller</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the architecture of 8, 16 and 32-bit microprocessor and microcontroller.
<b>CLO2</b>	To impart microcontroller programming skills in students.
<b>CLO3</b>	To familiarize the students with data transfer and interrupt services.
<b>CLO4</b>	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 6 <sup>th</sup> Edition, Penram international publishing (India) pvt.Ltd.2013.
2.	Douglas V. Hall, Microprocessors and Interfacing-Programming and Hardware, McGraw-Hill, 2 <sup>nd</sup> Edition, 1999.
3.	Kenneth J. Ayala, The8051Microcontroller, Thomson Delmar Learning, 3 <sup>rd</sup> Edition, 2004.
4.	John H Davies, MSP430 Microcontroller Basics, Newnes, 1 <sup>st</sup> Edition, 2010.
5.	Jonathan W Valvano, Embedded Microcomputer Systems: Real Time Interfacing, CENGAGE Learning Custom Publishing, 3 <sup>rd</sup> Edition, 2010.



### Course Outcomes (CO)

At the end of the course student will be able to

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

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICMI18
<b>Course Title</b>	:	<b>Micro Electro Mechanical Systems</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessment, End Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To introduce the fundamental concepts of MEMS and Micro systems and their relevance to current scientific needs.
<b>CLO2</b>	To introduce the state-of-art micromachining techniques including surface micromachining, bulk micromachining, and related methods.
<b>CLO3</b>	To make the students knowledgeable in the design concepts of micro sensors and micro actuators.
<b>CLO4</b>	To introduce the challenges and limitations in the design of MEMS devices
<b>CLO5</b>	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 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, TataMcGraw Hill, New Delhi 2002.
2.	Marc Madou, Fundamentals of Micro fabrication, CRC Press, 2 <sup>nd</sup> Edition, 2002.
3.	Julian W. Gardner and Vijay K. Varadan, Microsensors, MEMS, Smart Devices, John Wiley and Sons Ltd, 1 <sup>st</sup> Edition, reprinted 2007.
4.	Elwenspoek, Miko, Wiegerink, R, Mechanical Microsensors, Springer-Verlag Berlin Heidelberg GmbH, 1 <sup>st</sup> Edition, 2001.
5.	Simon M. Sze, Semiconductor Sensors, John Wiley and Sons. Inc, 1 <sup>st</sup> Edition, 2008.
6.	Chang Liu, Foundations of MEMS, Pearson Educational limited, 2 <sup>nd</sup> 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

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

### Course Outcome and Programme Outcome Mapping

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



<b>Course Code</b>	:	ICMI19
<b>Course Title</b>	:	<b>Medical Instrumentation</b>
<b>Type of Course</b>	:	Minor (MI)
<b>Prerequisites</b>	:	--
<b>Contact Hours</b>	:	42 (3 credits)
<b>Course Assessment Methods</b>	:	Continuous Assessments, Final Assessment

### Course Learning Objectives (CLO)

<b>CLO1</b>	To educate the students on the different medical instruments.
<b>CLO2</b>	To familiarize the students with the analysis and design of instruments to measure bio-signals like ECG, EEG, EMG, etc.
<b>CLO3</b>	To have a basic knowledge in therapeutic devices
<b>CLO4</b>	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 measurements: 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, Automated Biochemical Analysis System. Blood gas analyzer, Acid -base balance, Blood PH measurement, blood PCO<sub>2</sub>, blood PO<sub>2</sub>, 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.	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, 2nd Edition, 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.	Joseph J .Carr and John M. Brown, Introduction to Biomedical Equipment Technology, 4th Edition, 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,

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

**Course Outcome and Programme Outcome Mapping**

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





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