# Jharkhand University of Technology, Ranchi
## NEP-2020 based Syllabus w.e.f – 2025-26 Batch
## B.Tech in Electronics and Communication



**Semester-V^th^**

| S.No. | Course Code | Course Title | L | T | P | J | Cr | FM | Overall Pass Marks | Internal | External | Categorization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Contact Hours per week | | | | | | | | | | |
| | | **PROGRAMME CORE COURSES (PCC)** | | | | | | | | | | |
| 01 | ECEC501 | PCC-I ( Digital Signal Processing ) | 3 | 1 | 0 | | 4 | 100 | 35 | 30 | 70 | |
| 02 | ECEC502 | PCC-II (Digital Communication) | 3 | 1 | 0 | | 4 | 100 | 35 | 30 | 70 | |
| | | ***PROGRAMME ELECTIVES I & II** | | | | | | | | | | |
| 03 | ECEPEI501, ECEPEI502, ECEPEI503, ECEPEI504, ECEPEI505, ECEPEI506, ECEPEI507, ECEPEI508, ECEPEI509, ECEPEI10 | PE-I (Any One From The Given Basket Of PE-I) | 3 | 0 | 0 | | 3 | 100 | 35 | 30 | 70 | |
| 04 | ECEPEII501, ECEPEII502, ECEPEII503, ECEPEII504, ECEPEII505, ECEPEII506, ECEPEII507, ECEPEII508, ECEPEII509, ECEPEII510 | PE-II(Any One From The Given Basket Of PE- II) | 3 | 0 | 0 | 6 | 3 | 100 | 35 | 30 | 70 | |
| 05 | COM501 | Entrepreneurship Management | 2 | 1 | 0 | | 3 | 100 | 35 | 30 | 70 | |
| | | **Total** | **14** | **3** | | | **17** | **500** | | | | |
| | | **Practical** | **L** | **T** | **P** | | **Cr** | **FM** | **Overall Pass Marks** | **Internal** | **External** | **Categorization** |
| 06 | COMP501 | Seminar & Report Writing –I | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (UN Sustainable Development Goals) | | | | | | | | | | |
| 07 | COMP502 | Business Communications | 0 | 1 | 2 | | 2 | 50 | 25 | 30 | 20 | |
| 08 | ECEP501 | **Lab-I** (Digital Signal Processing Lab) | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |
| 09 | ECEP502 | **Lab-II** **(Data Communication Lab)** | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |
| **Total** | | | **0** | **1** | **11** | | **5** | **200** | -- | -- | -- | |
| **Audit Course** | | | **L** | **T** | **P** | | **Cr** | **FM** | **Overall Pass Marks** | **Internal** | **External** | **Categorization** |
| 10 | AUC501, AUC502, AUC503, AUC504 | **REGIONAL LANGUAGE (ANY ONE THROUGH NPTEL/SWAYAM)**<br>1. MARATHI<br>2. KANNAD<br>3. TAMIL<br>4. TELUGU | | | | | - | 100 | 35 | 30 | 70 | |
| 11 | AUC505 | Sports/NCC/NSS/YOGA/Painting/Music/ Classical Dance | | | | | | 50 | 25 | 30 | 20 | |
| **Total** | | | **6** | | | | **-** | **150** | | | | |
| **Grand Total** | | | **14** | **4** | **11** | | **22** | **850** | | | | |

**Professional Elective-I**

| S. No. | Course Code | Subject |
|---|---|---|
| **01** | ECEPEI501 | Cellular Mobile Communications |
| **02** | ECEPEI502 | MIMO and Multicarrier System |
| **03** | ECEPEI503 | Information Theory and Coding |
| **04** | ECEPEI504 | Modeling and Simulation of Communication Systems |
| **05** | ECEPEI505 | Orthogonal Frequency Division Multiplexing |

**Professional Elective-II**

| S. No. | Course Code | Subject |
|---|---|---|
| **01** | ECEPEII501 | Quantum Information Theory |
| **02** | ECEPEII502 | Analog IC Design |
| **03** | ECEPEII503 | Digital IC Design |
| **04** | ECEPEII504 | Functional Verification |
| **05** | ECEPEII505 | Physical Design of ICs |

| | | | | | | |
|---|---|---|---|---|---|---|
| **06** | ECEPEI506 | Signal Estimation and Detection | | **06** | ECEPEII506 | Mixed Signal IC Design |
| **07** | ECEPEI507 | Satellite Communication | | **07** | ECEPEII507 | VLSI Testing and Testability |
| **08** | ECEPEI508 | Wireless Local Area Networks | | **08** | ECEPEII508 | System on Chip |
| **09** | ECEPEI509 | Performance Evaluation of Networks and Computing Systems | | **09** | ECEPEII509 | VLSI Fabrication Technology |
| **10** | ECEPEI510 | Molecular Communication | | **10** | ECEPEII510 | Semiconductor memories |

**Abbreviations: - AU-Audit Course; L: Lecture, T: Tutorial, P: Practice.**
**J-Self learning hours shall not be reflected in the Time table. Self-learning includes micro projects/assignments/other activities as mentioned in earlier semesters.**
***Passing in the Audit Course shall be mandatory.**
**Note:- Students may choose their two Professional Electives (PE-1 & PE-II) from NPTEL/SWAYAM also on the approval of departmental academic council if that subject is not mentioned in the above basket.**
**Students will complete the Elective Papers (Professional) of 12 weeks duration from NPTEL/SWAYAM. Student may register on NPTEL/SWAYAM at any time from 1st to 5th semester also but the passing marks and credits will be reflected only in the 5th semester.**
**The secured percentage of marks and passing certificate of the subject shall be forwarded by the institute to Controller of Examination (CoE), JUT, Ranchi timely.**
**The institute will inform University Examination Session about selection of PE-1 and PE-2 subjects by the students also before 1" mid-semester examination of that semester.**

**Jharkhand University of Technology, Ranchi**
**NEP-2020 based Syllabus w.e.f – 2025-26 batch**
**B.Tech in –Electronics and Communication Engineering**

**Semester- VIth**

| S.No. | Course Code | Course Title | L | T | P | J | Cr | FM | Overall Pass Marks | Internal | External | Categorization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Contact Hours per week | | | | | | | | | |
| | | **PROGRAMME CORE COURSES (PCC)** | | | | | | | | | | |
| 01 | ECEC601 | PCC-I (_ Wireless Communication & Networks ) | 3 | 1 | 0 | | 4 | 100 | 35 | 30 | 70 | |
| 02 | ECEC602 | PCC-II ( IOT &Embedded Systems ) | 3 | 1 | 0 | | 4 | 100 | 35 | 30 | 70 | |
| | | **PROGRAMME ELECTIVES III & IV** | | | | | | | | | | |
| 03 | ECEPEIII601, ECEPEIII602, ECEPEIII603, ECEPEIII604, ECEPEIII605, ECEPEIII606, ECEPEIII607, ECEPEIII608, ECEPEIII609, ECEPEIII610 | PE-III (Any One From The Given Basket of PE-III ) | 3 | 0 | 0 | | 3 | 100 | 35 | 30 | 70 | |
| 04 | ECEPEIV601, ECEPEIV602, ECEPEIV603, ECEPEIV604, ECEPEIV605, ECEPEIV606, ECEPEIV607, ECEPEIV608, ECEPEIV609, ECEPEIV610 | PE-IV (Any One From The Given Basket of PE- IV) | 3 | 0 | 0 | | 3 | 100 | 35 | 30 | 70 | |
| | | **OPEN ELECTIVE-I** | | | | | | | | | | |
| 05 | ECEOEI601, ECEOEI602, ECEOEI603, ECEOEI604, ECEOEI605, ECEOEI606, | OE-I (Any one From The Given Basket of OE-I) | 3 | 0 | 0 | 6 | 3 | 100 | 35 | 30 | 70 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ECEOEI607, ECEOEI608, ECEOEI609, ECEOEI610, ECEOEI611, ECEOEI612, ECEOEI613, ECEOEI614, ECEOEI615, ECEOEI616, ECEOEI617, ECEOEI618, ECEOEI619, ECEOEI620 | | | | | | | | | | | |
| **Total** | | | **15** | **2** | **0** | | **17** | **500** | **--** | **--** | **--** | |
| **Practical** | | | **L** | **T** | **P** | | **Cr** | **FM** | **Overall Pass Marks** | **Internal** | **External** | **Categorization** |
| 06 | ECEP601 | **Lab-I** (__ **IOT & Embedded System** ____________________) | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |
| 07 | ECEP602 | **Lab-II** (_ Wireless Communication and Networks Laboratory ______________________) | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |
| 08 | ECEP603 | **Lab-III** ( **Advance Electronics &Communication Lab** ) | 0 | 0 | 3 | | 1 | 50 | 25 | 30 | 20 | |
| **Total** | | | **0** | **0** | **9** | | **3** | **150** | **--** | **--** | **--** | |
| **Audit Course** | | | **L** | **T** | **P** | | **Cr** | **FM** | **Overall Pass Marks** | **Internal** | **External** | **Categorization** |
| 09 | AUC601, AUC602, AUC603, AUC604, AUC605, AUC606, AUC607 | **FOREIGN LANGUAGE (ANY ONE THROUGH NPTEL / SWAYAM)** 1. GERMAN 2. JAPANESE 3. CHINESE 4. KOREAN 5. SPAINISH 6. RUSSIAN 7. FRENCH | | | | | - | 100 | 35 | 30 | 70 | |
| | | | | | | | Student will complete this Audit Paper of 12 weeks duration from NPTEL/SWAYAM. It is mandatory to pass this paper in order to pass this semester. Students may register on NPTEL/SWAYAM at any time from 1st to 6th semester also but the passing marks and credits will be reflected only in the 6th semester. The passing marks and certificate shall be forwarded by the institute to Controller of Examination (CoE), JUT, Ranchi timely. | | | | | |
| 10 | AUC608 | Sports/NCC/NSS/YOGA/Painting/Music/ | | | | | -- | 50 | 25 | 30 | 20 | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Classical Dance | | | | | Students shall participate actively in one of the activities and for Passing of the semester "Participation Certificate" in activity will be mandatory student participation shall be monitored and participation record shall be maintained at institute level. The marks obtained shall be forwarded to controller of Examination (CoE), JUT, Ranchi timely. | | | | | | |
| **Internship** | | | **L** | **T** | **P** | | **Cr** | **FM** | **Overall Pass Marks** | **Internal** | **External** | **Categorization** | |
| 11 | | Industrial Internship | 08 weeks | | | | **2** | **50** | **25** | **30** | **20** | | |
| **Minor Project (For Exit Option)** | | | 12 weeks | | | | **4** | **100** | **50** | **60** | **40** | | |
| **Total** | | | -- | -- | -- | | **2** | **200** | -- | -- | -- | | |
| **Grand Total** | | | **15** | **2** | **9** | | **22** | **850** | -- | -- | -- | | |

## Professional Elective- III

| S. No. | Course Code | Subject |
|---|---|---|
| **01** | **ECEPEIII601** | FPGA based System Design |
| **02** | **ECEPEIII602** | Hardware Security and Trust |
| **03** | **ECEPEIII603** | VLSI System Design |
| **04** | **ECEPEIII604** | Design of ICs for Optical Communication |
| **05** | **ECEPEIII605** | Optoelectronic Integrated Circuit Design |
| **06** | **ECEPEIII606** | Radio Frequency Integrated Circuits |
| **07** | **ECEPEIII607** | Microwave Circuits for Wireless Communications |
| **08** | **ECEPEIII608** | Design of Millimeter-Wave Circuits and Systems |
| **09** | **ECEPEIII609** | Microelectromechanical Devices |
| **10** | **ECEPEIII610** | Energy Harvesting Technologies and Circuits |

## Professional Elective- IV

| S. No. | Course Code | Subject |
|---|---|---|
| **01** | **ECEPEIV601** | FinFET Technology |
| **02** | **ECEPEIV602** | Nano Electronics |
| **03** | **ECEPEIV603** | Energy Materials |
| **04** | **ECEPEIV604** | Thin Electronic Films |
| **05** | **ECEPEIV605** | Operating Systems |
| **06** | **ECEPEIV606** | MIPS Architecture |
| **07** | **ECEPEIV607** | Parallel and Pipelined based Computer Architecture |
| **08** | **ECEPEIV608** | Parallel Computing |
| **09** | **ECEPEIV609** | Embedded Systems for Robotics |
| **10** | **ECEPEIV610** | Multi-Core Architecture |

## Open Elective I

| S. No. | Course Code | Subject | S. No. | Course Code | Subject |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 01 | ECEOEI601 | Sensor Networks | 11 | ECEOEI611 | **Cyber Physical Systems** |
| 02 | ECEOEI602 | Deep Learning | 12 | ECEOEI612 | Physical Chemistry of Materials and Processes |
| 03 | ECEOEI603 | Reinforcement Learning | 13 | ECEOEI613 | Leadership from the Ramayana |
| 04 | ECEOEI604 | Internet of Things | 14 | ECEOEI614 | Strategic Lessons from the Mahabharata |
| 05 | ECEOEI605 | Blockchain Technology | 15 | ECEOEI615 | Lessons from the Upanishads |
| 06 | ECEOEI606 | Understanding ICT Standardization: Principles and Practices | 16 | ECEOEI616 | Message of the Bhagavad Gita |
| 07 | ECEOEI607 | System Engineering | 17 | ECEOEI617 | Life and Message of Swami Vivekananda |
| 08 | ECEOEI608 | Software Defined Networks | 18 | ECEOEI618 | Life and Teachings of Spiritual Masters India |
| 09 | ECEOEI609 | Information Security | 19 | ECEOEI619 | Insights into Indian Arts and Literature |
| 10 | ECEOEI610 | Robotic System Design | 20 | ECEOEI620 | Yoga and Meditation |

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***Passing in the Audit Course shall be mandatory.**
**Note:- Students may choose their two Professional Electives (PE-II1 & PE-IV) & Open Elective-I from NPTEL/SWAYAM also on the approval of departmental academic council if that subject is not mentioned in the above basket.**
**Students will complete the Elective Papers (Professional or Open) of 12 weeks duration from NPTEL/SWAYAM. Student may register on NPTEL/SWAYAM at any time between 1st to 6th semester but the passing marks and credits will be reflected only in the 6th semester.**
**The secured percentage of marks and passing certificate of the subject shall be forwarded by the institute to Controller of Examination (CoE), JUT, Ranchi timely.**
**The institute will inform University Examination Session about selection of PE and OE subjects by the students also before 1" mid-semester examination of that semester.**

# Jharkhand University of Technology
# Ranchi, 834010

**SCHEME OF INSTRUCTION AND SYLLABUS**
**For B.Tech. Program in**
**Electronics and Communication Engineering**
**(Effective from 2024-25)**

# SEMESTER V

# PCC 1 Digital Signal Processing

**Course Code:** **L:T:P-**

**Rationale:**

**Course Outcomes:**

CO1**:** Analyze discrete-time system in both time and transform domain and also through pole –zero placement

CO2: Analyze discrete time signals and system using DFT and FFT

CO3: Design and implement digital finite impulse response (FIR) Filters

CO4: design and implement digital impulse response (IIR) filters

CO5: Understand and develop multirate digital signal processing systems

**Course Content :**

**UNIT-I**

Review of LSI system, DTFT, Frequency response of discrete time systems, all pass inverse, linear phase and minimum phase systems.

**UNIT-II**

DFT, Relationship of DFT to other transforms, FFT, DIT and DIF, FFT algorithm, Linear filtering using DFT and FFT.

**UNIT-III**

Characteristics of FIR Digital Filters, types and frequency response - Design of FIR digital filters using window techniques and frequency sampling technique - basic structures and lattice structure for FIR systems.

**UNIT-IV**

Analog filter approximations – Butter worth and Chebyshev, Design of IIR Digital filters from analog filters, Analog and Digital frequency transformations - Basic structures of IIR systems, Transposed forms.

**UNIT-V**

Sampling rate conversion by an integer and rational factor, Poly phase FIR structures for sampling rate conversion.

**Text Books**

*1. J.G.Proakis, D.G. Manolakis, "Digital Signal Processing", (4/e) Pearson, 2007.*

*2. A.V.Oppenheim & R.W.Schafer, "Discrete Time Signal processing", (2/e), Pearson Education, 2003.*

References :

1. S.K.Mitra, "Digital Signal Processing (3/e)", Tata McGraw Hill, 2006.

2. P.S.R.Diniz, E.A.B.da Silva and S.L.Netto, "Digital Signal Processing", Cambridge, 2002.

3. E.C.Ifeachor & B.W.Jervis, "Digital Signal Processing", (2/e), Pearson Education, 2002.

4. J.R.Jhonson, "Introduction to Digital Signal Processing", Prentice-Hall, 1989

# PCC-II Digital Communication

**Course Code-** **L:T:P-**

**Rationale**

**Course Content:**

CO1: Apply the knowledge of signals and systems and explain the conventional digital communication system.

CO2: Apply the knowledge of statistical theory of communication and evaluate the performance of digital communication system in the presence of noise.

CO2: Apply the knowledge of statistical theory of communication and evaluate the performance of digital communication systems in the presence of noise.

CO3: Describe and analyse the performance of digital modulation techniques.

CO4: Apply the knowledge of digital electronics and describe the error control codes like block code, cyclic code.

CO5: Describe and analyze the digital communication system with spread spectrum modulation.

## Course Content

### UNIT-I

Base band transmission. Sampling theorem, Pulse code modulation (PCM), DM, Destination SNR in PCM systems with noise. Matched filter. Nyquist criterion for zero ISI. Optimum transmit and receive filters. Correlative Coding, M-Ary PAM. Equalization- zero-forcing and basics of adaptive linear equalizers.

### UNIT-II

BASK, BFSK, and BPSK- Transmitter, Receiver, Signal space diagram, Error probabilities.

### UNIT-III

M-Ary PSK, M-Ary FSK, QAM, MSK and GMSK- Optimum detector, Signal constellation, error probability.

### UNIT-IV

Linear block codes-Encoding and decoding. Cyclic codes – Encoder, Syndrome Calculator. Convolutional codes – encoding, Viterbi decoding. TCM.

**UNIT-V**

Spread Spectrum (SS) Techniques - Direct Sequence Spread Spectrum modulation, Frequency-hop Spread Spectrum modulation - Processing gain and jamming margin.

## References

1. B.Sklar, “Digital Communications: Fundamentals & Applications”, Pearson Education, (2/e), 2001.

2. A.B.Carlson, “Communication Systems”, McGraw Hill, 3/e,2002.

3. R.E.Zimer and R.L.Peterson,” Introduction to Digital Communication”, PHI,3/e, 2001

# Digital Signal Processing Lab

**Course Code-** **L:T:P-**

## Rationale

## Course Outcome:

**CO1:** Generate and analyze discrete-time signals using simulation tools.

**CO2:** Apply convolution and correlation techniques to discrete signals.

**CO3:** Compute and interpret frequency-domain representation using DFT/FFT.

**CO4:** Design and implement FIR and IIR digital filters.

**CO5:** Demonstrate DSP applications in real-time using MATLAB / Python / DSP kits.

## Course Content:

1. Signal Generation and Basic Operations

- Generation of discrete-time signals (sine, cosine, exponential, square, triangular, ramp, unit step, delta).
- Signal transformations: shifting, scaling, folding.

2. Convolution and Correlation

- Linear convolution using MATLAB/Python/Scilab.
- Circular convolution using DFT.
- Auto-correlation and cross-correlation.

3. Frequency Domain Analysis

- Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT).
- Verification of properties of DFT.
- Power Spectrum and Energy Spectrum analysis.

4. Digital Filter Design

- FIR Filter design using window techniques (Rectangular, Hamming, Hanning).
- IIR Filter design (Butterworth, Chebyshev).
- Frequency response analysis of filters.

5. Z-transform Applications

- Verification of properties of Z-transform.
- Implementation using MATLAB/Python.

6. Real-Time DSP (Optional/Advanced if hardware available)

- Implementation of FIR/IIR filters on DSP processor or using MATLAB real-time toolbox.
- Audio signal processing applications.

Reference Books:


1. Alan V. Oppenheim and Ronald W. Schafer – *Signals and Systems*, Prentice Hall.
2. Sanjit K. Mitra – *Digital Signal Processing: A Computer-Based Approach*, McGraw-Hill, 4th Edition.
3. Monson H. Hayes – *Digital Signal Processing*, Schaum's Outlines, McGraw-Hill.
4. Emmanuel C. Ifeachor and Barrie W. Jervis – *Digital Signal Processing: A Practical Approach*, Pearson, 2nd Edition.
5. B. P. Lathi – *Principles of Signal Processing and Linear Systems*, Oxford University Press.


Software/Tools References

- MATLAB Documentation – MathWorks official resources.
- Scilab DSP Toolbox (open-source alternative to MATLAB).
- Python (NumPy, SciPy, Matplotlib, PyDSP libraries**)** for implementing DSP experiments

# Data Communication Lab

**Course Code-** **L:T:P-**

## Rationale

## Course Outcome:

**CO1:** Demonstrate understanding of transmission media and signal characteristics.

**CO2:** Implement line coding and error detection techniques.

**CO3:** Simulate multiplexing, switching, and framing methods.

**CO4:** Apply data link layer flow control and error control protocols.

**CO5:** Analyze and implement routing algorithms and digital modulation schemes using simulation tools.

## Course Content:

1. Study of transmission media (twisted pair, coaxial, optical fiber) and measurement of their characteristics (attenuation, bandwidth, noise).

2. Simulation of analog and digital signals.

3. Implementation of line coding schemes: NRZ, RZ, Manchester, Differential Manchester.

4. Error detection methods: Parity check, CRC.

5. Framing methods: Character count, Byte stuffing, Bit stuffing.

6. Implementation of ARQ protocols: Stop-and-Wait, Go-Back-N, Selective Repeat.

7. Simulation of multiplexing techniques: TDM and FDM.

8.Study and simulation of switching techniques: Circuit switching, Packet switching, Message switching.

9. Simulation of routing algorithms: Distance Vector and Link State.

10.Study and implementation of digital modulation schemes: ASK, FSK, PSK.

11.Performance analysis of communication systems in noisy channels.

12.Mini Project: Simulation of a small communication network using MATLAB/NS2/Packet Tracer.

**Textbooks:**

1. Behrouz A. Forouzan – *Data Communications and Networking*, McGraw Hill, 5th Edition.
2. William Stallings – *Data and Computer Communications*, Pearson, 10th Edition.
3. Andrew S. Tanenbaum and David J. Wetherall – *Computer Networks*, Pearson, 5th Edition.

# Professional Elective-I

## 1 .Cellular Mobile Communications

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to:
**CO1:** understand the basic concepts of cellular systems
**CO2:** analyze the effect of interference and system capacity
**CO3:** analyze performance of multiple access techniques
**CO4:** understand the working principles of cellular standards

**Course Content**

**UNIT I**

Introduction to cellular systems - Basic Cellular System - Cellular communication infrastructure: Cells – Clusters – Cell Splitting - Frequency reuse concept and reuse distance calculation - Cellular system components - Operations of cellularsystems – Handoff / Handover - Channel assignment - Fixed and dynamic - Cellular interferences: Co-Channel and adjacent channel and sectorization.

**UNIT II**

Channel Models: Properties of mobile radio channels - Intersymbol interference -Multipath and fading effects - Interleavingand diversity - Multiple access schemes (TDMA – FDMA – CDMA – SDMA – OFDMA) – Inter user interference – Traffic issues and cell capacity - Power control strategies.

**UNIT III**

Introduction to modern cellular standards - GSM and CDMA – GPRS – UMTS – LTE – Introduction to 5G; AI/ML to improve channels and other functionalities of networks; Role of AI/ML in resource/channel allocation.

**Textbook(s)**

1. T.S. Rappaport, “Wireless Communication, Principles and Practice, Pearson Education”, Second Edition, 2010.

*2.* Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005.

**Reference(s)**

1. A Molisch, “Wireless Communications”, Wiley 2005.

2. D. Tse and P. Viswanath, “Fundamentals of Wireless Communications”, Cambridge University Press, 2005.

3. Haykin & Moher, “Modern Wireless Communications”, Indian Edition, Pearson 2011.

4. J. G Proakis, “Digital Communications”, McGraw Hill, New York, 1989

# 2. MIMO and Multicarrier System

**Course Code-** **L:T:P-**

**Rationale**

## Course Outcomes

At the end of the course, the students should be able to
**CO1:** understand the fundamental concepts of MIMO wireless systems
**CO2:** model MIMO channels and obtain the channel capacity
**CO3:** apply diversity, spatial multiplexing and signal detection techniques
**CO4:** understand the concepts of MIMO-OFDM systems

### Course Content:

**UNIT I**
Introduction - Crowded spectrum - Need for high data rates –Multiple input multiple output systems –Multi antenna systems and concepts - Spatial multiplexing - MIMO system model- MIMO system capacity- Channel known to the transmitter -Channel unknown to the transmitter - Water-pouring principle – Capacity calculation – SIMO - MISO - Ergodic capacity - Outage capacity – Influence of fading Correlation on MIMO capacity - Influence of LOS on MIMO capacity.

**UNIT II**
Delay diversity scheme- Alamouti space-time code - Maximum likelihood decoding - Maximum ratio combining – Transmit diversity - Space-time block codes - STBC for real signal constellations - Decoding of STBC-OSTBC - Capacity of OSTBC channels - Space-time code Word design criteria – Multiplexing architecture - VBLAST architecture.

**UNIT III**
Data transmission over multipath channels - Single carrier approach - Multicarrier approach - OFDM - OFDM generation - Cyclic prefix - Performance of space - Time coding on frequency-Selective fading channels- Capacity of MIMO – OFDM systems - Performance analysis of MIMO-OFDM systems; Case study – MIMO signal detection using machine learning

**Textbook(s)**
1. Mohinder Janakiram, “Space-time Processing and MIMO systems”, Artech House, First Edition, 2004.
2. Arogyaswami Paulraj, Rohit Nabar, Dhananjay Gore, “Introduction to Space-Time Wireless Communications”,
Cambridge University Press, 2008.

**Reference(s)**

1. Hamid Jafarkhani, “Space-Time coding-Theory and Practice”, Cambridge University Press, First Edition, 2005.
2. David Tse, Pramod Viswanath, “Fundamentals of Wireless Communication”, Cambridge University Press, 2005.
3. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung-Gu Kang, “MIMO-OFDM Wireless Communications
with MATLAB”, Wiley, 2010

# 3. Information Theory and Coding

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the fundamental concepts of Information theory
**CO2:** apply the concepts of source entropy and efficient encoding of information
**CO3:** understand channel models and determine the channel capacity
**CO4:** understand error control coding schemes

**Course Content:**

**UNIT I**

Modeling of Information Sources – Measure of information- Entropy- Mutual Information- Source Coding - Prefix Codes-Kraft inequality- Shannon Fano Encoding Algorithm-Huffman algorithm- Arithmetic coding- Lempel Ziv coding.

**UNIT II**

Channel Models- Channel Matrix, Joint probability Matrix-System Entropies, Channel Capacity, Channel coding theorem-Shannon-Hartley's law.

**UNIT III**

Error Correction Codes – Introduction to Galois fields, polynomial arithmetic, linear block codes for error correction -Decoding – Standard array decoding and Syndrome decoding. Cyclic Codes – Introduction to Convolutional codes- distance properties – Trellis codes, Viterbi decoder. Case study - Machine learning based encoding and decoding.

**Textbook(s)**

1. Ranjan Bose, "Information Theory, Coding and Cryptography", Tata McGraw Hill, 2nd edition.
2. P.S. Satyanarayana, "Concepts of Information Theory and Coding", Dynaram Publication, 2005.

**Reference(s)**

1. Richard B. Wells, "Applied Coding and Information Theory for Engineers" Pearson Education, LPE 2004.
2. Shu Lin and Daniel Castello, "Error Control Coding – Fundamentals and Applications", second edition 2004.

# 4.Modeling and Simulation of Communication Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the system level aspects of communication systems
**CO2:** use modelling and simulation tools for performance analysis
**CO3:** understand tradeoffs of various system parameters
**CO4:** design communication systems for specific applications

**Course Content:**

**UNIT I**
Introduction-challenges in design and optimization– Overview of deterministic and stochastic simulations– Tractable and intractable systems– Role of simulations for link budgeting Behavior predictions; role of ML in behavior prediction.

**UNIT II**
Simulation methodology—Simulation errors due to sampling and quantization–Baseband representation of band pass signals and systems– Time varying systems—Modeling of system building blocks - filters, amplifiers with internal noise-Modeling oscillator phase noise.

**Unit III**
Simulation of random process and noise sources—Post processing– Eye-diagrams– Spectrum and scatter plots—BER simulations using Monte-Carlo techniques—Introduction to simulation of nonlinear and time varying systems—Models of waveform channels– Guided and unguided channels, Radio channels, Multipath and fading channel—Introduction to discrete channel model; Case studies- Digital predistortion of amplifier using Machine learning.

**Textbook(s)**

1. W. H. Tranter, K. S. Shanmugan, T. S. Rappaport and K. L. Kosbar, Principles of Communication Systems Simulation with Wireless Applications, Prentice Hall, 2003.

**Reference(s)**
1. G. Rubino and B. Tuffin, Rare Event Simulation Using Monte Carlo Methods, John Wiley and Sons, 2009.
2. M. Schiff, Introduction to Communication Systems Simulation, Artech House, 2006.
*3.* C. B. Rorabaugh, Simulating Wireless Communication Systems: Practical Models in C, Prentice Hall, 2004

# 5. Orthogonal Frequency Division Multiplexing

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes:**

At the end of the course, the students should be able to
**CO1:** understand the architecture of OFDM transceiver
**CO2:** apply different synchronization techniques to handle the effect of ISI and CSI
**CO3: u**nderstand pilot structures and channel estimation techniques
**CO4: u**nderstand the effect of PAPR and reduction techniques

**Course Content:**

**UNIT I**
Introduction to OFDM-Single-Carrier vs. Multi-Carrier Transmission, Basic Principle of OFDM, OFDM Modulation and Demodulation, OFDM Guard Interval, BER of OFDM Scheme, Coded OFDM, OFDMA: Multiple Access Extensions of OFDM, Resource Allocation.

**UNIT II**
Synchronization for OFDM - Effect/estimation of symbol-time offset(STO),Effect/estimation of carrier-frequency offset (CFO), Effect/compensation of sampling clock offset (SCO).

**UNIT III**
Channel Estimation- Pilot Structure, Training Symbol-Based Channel Estimation, DFT-Based Channel Estimation, Decision-Directed Channel Estimation-Introduction to PAPR- PAPR and oversampling, PAPR Reduction Techniques; AI/ML role in channel estimation or resource allocation.

**Textbook(s)**
1. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung-Gu Kang, " MIMO-OFDM Wireless Communications with MATLAB", Wiley, 2010, ISBN: 978-0-470-82561-7

**Reference(s)**

1. Y. Li. G. Stuber, " OFDM for Wireless Communication", Springer, 2006.
2. R. Prasad, " OFDM for Wireless Communication", Artech House, 2006.

# 6.Signal Estimation and Detection

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the principles of optimal estimation and detection.
**CO2**:model specific problems in communication systems as standard estimation and detection problems
**CO3**: apply appropriate solution techniques
**CO4**: analyze the performance of estimation and detection techniques

**Course Content:**

**UNIT I**

Review of probability and random processes; Applications of statistical estimation and detection techniques in communication systems; Classical estimation – Bias and variance, Cramer Rao lower bound, Sufficient statistic, MVUE,Fischer Neyman factorization theorem, Rao-Blackwell theorem.

**UNIT II**

Maximum Likelihood (ML) estimation; Linear models – BLUE; Least Squares – consistency, efficiency and asymptotics; Bayesian estimation – MMSE and MAP estimation, Kalman and Weiner filtering; Introduction to channel and spectrum estimation.

**UNIT III**

Detection theory - Bayesian and Neyman-Pearson detection, Minimax Detection, Composite hypothesis testing, GLRT, Sequential detection, Performance analysis by Monte Carl method, Signal detection in continuous time, Karhunen Loève(KL) theorem, Detection of random signals in Gaussian noise; ML role in channel estimation.

**Textbook(s)**

1.S.M. Kay, “Fundamentals of Statistical Signal Processing”, Volume I and II, Prentice Hall Inc., 1998.

**Reference(s)**

1. H. V. Poor, “An Introduction to Signal Detection and Estimation”, 2nd Ed., Springer-Verlag, 1994.
2. H. L. Van Trees, “Detection, Estimation and Modulation Theory”, Part 1, 2nd Ed., John Wiley, 2013.
3. M. D. Srinath, P. K. Rajasekaran and R. Vishwanathan, “An Introduction to Statistical Signal Processing with Applications”, Prentice-Hall, 1996.

# 7.Satellite Communication

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the basic concepts of satellite communication
CO2: design link budget for satellite communication system
CO3: understand the various subsystems in satellite communication systems
CO4: apply appropriate multiple access schemes for specific applications

**Course Content:**

**UNIT I**
Review of Microwave Communications - Overview of satellite communications - Satellite orbits - Orbital mechanics and effects - Kepler's laws - Configurations of various orbits - Orbital elements - Elevation and azimuth angles - Doppler effect- Effect of the sun and moon - Sun transit outage. Satellite link models and design - Satellite system parameters - Link budget design.

**UNIT II**
Satellite subsystems – AOCS - TTC&M - Power and communication subsystems - Computations and controlling by processors - Satellite multiple access schemes – FDMA - TDMA and CDMA - Spread spectrum concepts - Comparison of multiple access schemes.

**UNIT III**
Satellite applications – VSAT - DTH television principles - Direct broadcast radios - Principles of navigation – GPS - Satellites and launch vehicles – INSAT - IRS satellites PSLVs – GSLVs, AI/ML role in satellite communication and satellite based navigation.

**Textbook(s)**
1. T.Pratt, C.W.Bostain and J.E.Allnut, "Satellite Communications", John Wiley and Sons, Second Edition, 2003.
2. Dennis Roddy, "Satellite Communications", McGraw-Hill Publishing Company, Fourth Edition, 2006.

**Reference(s)**
1. Wilbur L. Pritchard, Hendri G. Suyderhoud, Robert A. Nelson, "Satellite Communication Systems Engineering", Prentice Hall/Pearson, 2007.
2. M. Richharia, "Satellite Communication Design Principles", McGraw-Hill Publishing Company, Second Edition.

# 8.Optical Communication Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes:**

At the end of the course, the student should be able to
**CO1:** understand the signal propagation through optical fibers.
CO2: analyze the effect of various design parameters on the performance of optical detectors
CO3: design optical links for effective end-end communication
CO4: understand the concepts of measurements in fiber optic systems

**Course Content:**

**UNIT I**
Introduction – Ray theory transmission – Electromagnetic mode theory for optical propagation – Cylindrical fibers – Single mode fibers – Attenuation – Material absorption losses in silica glass fibers – Linear and nonlinear scattering losses Fiber bend losses– Chromatic and intermodal dispersion.

**UNIT II**
Optical detectors: Introduction – Device types – Optical detection principles Absorption Quantum efficiency – Responsively –Long- wavelength cutoff – Semiconductor photodiodes with and without internal gain.

**UNIT III**
Link design – System degradation and power penalty – Measurements on fiber optic systems – SONET – EDFA – WDM components and networks; Case Study-End to End deep learning for system optimization.

**Textbook(s)**
1. John M Senior, “Optical Fiber Communication, Principles and Practice”, Third Edition, Prentice Hall, 2009.
**Reference(s)**
1. Gerd Keiser, “Optical Fiber Communication”, Fourth Edition, MGH, 2008.
2. Joseph c. Palais, “Fiber Optic Communications”, Fourth Edition, Pearson Education, 2004.
3. C. Siva Ram Murthy and Mohan Gurusamy, “WDM Optical Networks: Concepts, Design, and Algorithms” Prentice-
Hall, 2002.

# 9.Wireless Local Area Networks

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the working of wireless local area networks
**CO2**: analyze the performance of wireless local area networks
**CO3**: understand techniques for optimization of its performance
**CO4**: understand research literature on specific topics

**Course Content**:

**UNIT I**
Overview of the IEEE 802.11; MAC Layer – Network Architecture, Frame Types and Formats, Distributed Channel Access, Medium Access Rules, Hidden Node Problem, EDCA, PCF, HCCA, AP Discovery, Connection Establishment and Termination, Fragmentation and Aggregation, Block ACK, Power Save Methods, PSMP, Interoperability, Roaming, AP Channel Switching.

**UNIT II**
PHY Layer – OFDM, MIMO basics, High Throughput (HT), VHT, 802.11b, 802.11a, 802.11g, 802.11n, 802.11ac; Wi-Fi 6– EHT, 802.11ax, OFDMA, Multiuser Operation, TWT, Ppatial Reuse; Implementation Issues – Hardware, Software, Algorithms, Regulatory Requirements, Introduction to Wi-Fi 6E and 802.11be.

**UNIT III**
Applications and Case Studies – Intelligent techniques (AI/ML) to optimize Channel Access, Rate Adaptation, Frame Aggregation, PHY parameters, Beamforming, Multiuser Communication, Spatial Reuse, Channel Bonding, Multiuser MIMO, and Network Management.

**Textbook(s)**
1. Perahia, E., and Stacey, R., “Next generation wireless LANs: 802.11n and 802.11ac”, Cambridge university press, Second Edition, 2013.
2. Gulasekaran, S.R., and Sankaran, S.G., “Wi-Fi 6: Protocol and Network”, Artech House, 2021.
**Reference(s)**
Selected Research papers.

# 10 Performance Evaluation of Networks and Computing Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the necessary mathematical foundations.
**CO2**: apply mathematical tools to model and analyze networks and computing systems
**CO3**: carry out discrete event simulations of networks and computing systems

**CO4**: understand research literature on specific topics

**Course Content:**

**UNIT I**
Introduction – networks and computing systems as discrete event systems, mathematical and simulation tools for modeling and analysis, performance metrics; Selected Topics in Random Variables and Processes with applications to modeling of networks and computing systems – memoryless property, moment generating function; Laplace-Stieljes transform (LST), stationary- and independent-increment processes, Bernoulli, Poisson, Gaussian and Markov processes, discrete- and continuous-time Markov chains, renewal processes.

**UNIT II**
Queueing Theory – Little's Law, PASTA, common queueing models (M/M/1, M/M/1/K, M/M/K/K, M/G/1, M/G/1/K, M/G/∞), multiclass queueing models, networks of queues, Discrete-Event Simulation of Queueing Systems.

**UNIT III**
Applications to Computing Systems – availability analysis of web servers, CPU and I/O job scheduling in computing systems, shared and cache memories, multiprogramming and multiprocessor systems; Applications to Computer Networks– statistical multiplexing in links, packet buffering and queue overflows, Chernoff bound, dynamic channel allocation in circuit switched networks, throughput analysis of Wi-Fi MAC layer, coverage analysis in wireless sensor networks. ML based job scheduling.

**Textbook(s)**
1. Vidyadhar G. Kulkarni, Modeling and Analysis of Stochastic Systems. CRC Press, 2016.
2. Kishore S. Trivedi, Probability and Statistics with Reliability, Queuing, and Computer Science Applications,
Second Edition, John Wiley and Sons, 2016.
3. Anurag Kumar, D. Manjunath, Joy Kuri, Communication Networking: An Analytical Approach, Morgan
Kauffmann Publishers, 2004.

.

**Reference(s)**

  Selected Research papers.

1. Dimitri P. Bertsekas, and Robert G. Gallager, Data Networks. Prentice-Hall International, 1987

## 9.Performance Evaluation of Networks and Computing Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the necessary mathematical foundations.
**CO2**: apply mathematical tools to model and analyze networks and computing systems
**CO3**: carry out discrete event simulations of networks and computing systems

**Course Content:**

**UNIT I**
Introduction – networks and computing systems as discrete event systems, mathematical and simulation tools for modeling and analysis, performance metrics; Selected Topics in Random Variables and Processes with applications to modeling of networks and computing systems – memoryless property, moment generating function; Laplace-Stieljes transform (LST),stationary- and independent-increment processes, Bernoulli, Poisson, Gaussian and Markov processes, discrete- and continuous-time Markov chains, renewal processes.

**UNIT II**
Queueing Theory – Little's Law, PASTA, common queueing models (M/M/1, M/M/1/K, M/M/K/K, M/G/1, M/G/1/K, M/G/∞), multiclass queueing models, networks of queues, Discrete-Event Simulation of Queueing Systems.

**UNIT III**
Applications to Computing Systems – availability analysis of web servers, CPU and I/O job scheduling in computing systems, shared and cache memories, multiprogramming and multiprocessor systems; Applications to Computer Networks– statistical multiplexing in links, packet buffering and queue overflows, Chernoff bound, dynamic channel allocation in circuit switched networks, throughput analysis of Wi-Fi MAC layer, coverage analysis in wireless sensor networks. ML based job scheduling.

**Textbook(s)**
1. Vidyadhar G. Kulkarni, Modeling and Analysis of Stochastic Systems. CRC Press, 2016.
2. Kishore S. Trivedi, Probability and Statistics with Reliability, Queuing, and Computer Science Applications,
Second Edition, John Wiley and Sons, 2016.

3. Anurag Kumar, D. Manjunath, Joy Kuri, Communication Networking: An Analytical Approach, Morgan
Kauffmann Publishers, 2004.

.

**Reference(s):**

  Selected Research papers.

1. Dimitri P. Bertsekas, and Robert G. Gallager, Data Networks. Prentice-Hall International, 1987

# 10.Molecular Communication

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the basic concepts of Molecular communication
**CO2**: understand the mechanism of transmission of information

**CO3:** understand the information theoretic foundations
**CO4:** understand the applications in various fields

**Course Content:**

**UNIT I**
Introduction to Molecular communication- Need for molecular communication-Examples to demonstrate the usage and to introduce the basic issues related to designing a molecular communication system - History of molecular communication-Early history and theoretical research- More recent theoretical research- Implementational aspects- Contemporary research - Applications areas-Biological engineering - Medical and healthcare applications-Industrial applications-Environmental applications -Information and communication technology applications.

**UNIT II**
Molecular communication paradigm-Molecular communication model-General characteristics -Transmission of information molecules- Information representation -Slow speed and limited range -Stochastic communication- massive parallelization- Energy efficiency-Biocompatibility, Detection and estimation in molecular communication.

**UNIT III**
Information theory concepts in molecular communication, Application areas of molecular communication- Drug delivery -Example: Cooperative drug delivery- Intracellular therapy, Tissue Engineering-Example: Tissue structure formation, Labon-a-chip technology- Examples-Bio-inspired lab-on-a-chip, Smart dust biosensor- Unconventional computation-
Examples- Reaction diffusion computation - Artificial neural networks-Combinatorial optimizers.

**Textbook(s)**
1. Pierobon, Massimiliano, and Ian F. Akyildiz. "Fundamentals of diffusion-based molecular communication in
nanonetworks." Foundations and Trends in Networking 8.1-2 (2014): 1-147.
2. Nakano, T., Eckford, A., and Haraguchi, T., "Molecular Communication". Cambridge: Cambridge University Press 2013. doi:10.1017/CBO9781139149693

# Professional Elective-II

# 1.Quantum Information Theory

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1:** understand the extension of Shannon theory to quantum domain
**CO2:** understand the mathematical tools used for measurement and analysis
**CO3:** understand resources used in quantum communication
**CO4:** understand tradeoffs among the resources

## Course Content

**UNIT I**
Review of Quantum theory: state vectors- qubits-Pauli matrices- unitary transformations-measurement- composite systems and tensor products- quantum gates and circuits-entanglement-and Bell inequalities, Noisy quantum states: ensembles and density matrices-POVMs and generalized measurements- separability and entanglement- Kraus maps and quantum instruments- noisy quantum channels- purifications. Unit quantum protocols: entanglement distribution- elementary encoding- superdense coding- quantum teleportation-Resource inequalities.

**UNIT II**
Tools of Quantum Shannon Theory: distance measures- classical information and entropies-quantum information and entropies, Classical typicality: typical sets, typical sequences, Shannon compression, weak and strong typicality, joint typicality, conditional typicality. Quantum typicality: typical subspaces, bipartite and multipartite states, conditional quantum typicality, weak and strong quantum typicality, joint and conditional quantum typicality. Schumacher compression.

**UNIT III**
Classical communication over noisy quantum channels: Holevo information, and classical capacity, Examples of quantum channels, Super additivity of classical capacity, Classical communication over entanglement-assisted quantum channels.Capacity theorem. Coherent communication with noisy resources: entanglement-assisted quantum communication, private classical communication, Quantum communication, The quantum capacity theorem, Resource trade-offs and trade-off coding, Non-additivity and other open problems. Introduction to quantum machine learning (QML).

**Textbook(s)**
1. Wilde, M. (2017). Quantum Information Theory (2nd ed.). Cambridge: Cambridge University Press.doi:10.1017/9781316809976

**Reference(s)**

1. Nielsen, Michael A.; Chuang, Isaac L. (2000). Quantum Computation and Quantum Information (1sted.). Cambridge University Press.

2. Watrous, J. (2018), The Theory of Quantum Information. Cambridge: Cambridge University Press. doi:10.1017/9781316848142

# 2.Analog IC Design

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to

**CO1**: analyze the basic characteristics of single and multi-stage amplifier configurations.
**CO2**: analyze the design of multi-stage amplifiers.
**CO3**: evaluate and apply the different principles in amplifier design.
**CO4**: analyze the design of feedback systems for amplifiers

**Course Content:**

**UNIT I**
Common Source - Single pole amplifiers, frequency and step response, input pole, input capacitance, active load. Common Gate and Source Follower Review – Single-ended Differential Pair – Active Current Mirrors - Widlar Current Source – Low Current Bias Circuit - Cascode self-biased source.

**UNIT II**
MOS Op-amp - Single stage op-amp review. Two-stage op-amp frequency response-Feedback, Stability, Compensation, Common mode and differential gain. RHP zero from Cc - RHP zero- Current mirror pole/zero doublet - Supply-independent biasing.

**UNIT III**
Telescopic and Folded cascode – Folded Cascode Biasing - Switched capacitors- ADCs, DACS, Programmable Gain Amplifiers . MOS switch regulators - StrongArm latch - Charge injection - rail-to-rail input and output - Ri, Ro and feedback noise; Circuit synthesis using AI/ML Techniques.

**Textbook(s)**
1. B. Razavi, “Design of Analog CMOS Integrated Circuits”, McGraw Hill, 2017.
2. P. Allen and D. Holberg, “CMOS Analog Circuit Design”, Oxford University Press, Second Edition, 2012.

**Reference(s)**
1. Sedra/Smith, “Microelectronic circuits”, 7th edition, Oxford University Press, 2015.
2. P. Gray, P. Hurst, S. Lewis, and R.G. Meyer, “Analysis and Design of Analog Integrated Circuits”, John Wiley and
Sons, Fourth Edition, 2001.

# 3. Digital IC Design

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to

**CO1**: realize the mixed logic building block and optimized logic function.
**CO2**: understand the optimizing concepts of arithmetic building blocks.
**CO3**: understand the basic testing of the combinational circuits.
**CO4**: analysis the synchronous sequential state machine

**Course Content:**

**UNIT I**
Mixed logic circuits - Entered variable K-map Minimization - Multiple output Minimization- Multilevel Minimization and Optimization - Resubstitution – Decomposition – Factorization - Adders -Carry Look Ahead adder - Carry Save adder.

**UNIT II**
Hazards- Propagation delay & Timing defects in combinational logic - Lumped Path Delay Diagram - Binary Decision Diagram (BDD)- Ordered BDD – LPDD – Testing: Fault Detection and Analysis in Combinational Systems: Path Sensitizing Method– Boolean Difference Method; Fault Detection and Analysis using AI/ML Techniques.

**UNIT III**
Static Timing Analysis (STA) design flow – STA Concepts – Standard Cell Library- Synchronous State Machines (FSM) -Design & analysis of simple state machines - state assignment - state reduction techniques - Asynchronous State Machine-Analysis of simple state machines - Detection and elimination of output races – glitches.

**Textbook(s)**

1. Richard F. Tinder, “Engineering Digital Design”, Academic Press, 2000.
2. Eugene Fabricius, “Modern Digital Design & Switching Theory”, CRC Press, 1992.

**Reference(s)**
1. Samuel C. Lee, “Digital Circuits and Logic Design”, Prentice Hall India Private Limited, 2006.
2. Zvi Kohavi and Niraj K Jha, “Switching and Finite Automata Theory”, Third Edition, Cambridge University, Press,
2009.

# 4.Functional Verification

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the process of functional verification and its different methodologies.
**CO2**: apply methodologies to design a verification environment using System Verilog.
**CO3**: analyze the device under test and to write test-benches using System Verilog.
**CO4**: analyze the verification process by use of assertion-based techniques.

**Course Content:**

**UNIT I**

HDL Review - Need for Functional Verification - ASIC Verification Concepts - Verification Tasks - Verification Plan -Linear Test Bench - Linear Random Test Bench – Self-Checking Test Benches - Test Coverage - System Verilog for Design- Data Types and Literals - Procedures and Procedural Statements - Operators - User-Defined Data Types - Hierarchy and Connectivity.

**UNIT II**

System Verilog for Verification - Tasks - Functions - Interfaces - Verification Blocks Transaction Level Modeling – System Verilog Classes - Random Stimulus - Class-Based Randomization - Functional Coverage - Queues - Dynamic Arrays - Inter-ProcessSynchronization - System Verilog Assertions (SVA) - Assertion-Based Verification (ABV) - Boolean Expressions- Single and Multiple Clock Definitions - Implication Operators - System functions - Nested Implications – Immediate Assertions - Concurrent Assertions - Boolean Assertions - Sequences - Sequence Composition.

**UNIT III**

Building a Test bench with Threads and Inter-Process Communication - Functional Coverage Strategies – Parameterized Cover Groups - Coverage Data Analysis - Coverage Statistics Measurement - Complete System Verilog Test Bench Design- FSM Modeling with System Verilog - Verification of a Four Port Router: Case Study - Opportunities for AI-Powered Verification and Machine Learning in Formal Verification.

**Textbook(s)**

1. Chris Spear, “SystemVerilog for Verification: A Guide to Learning the TestBench Language Features,” Third Edition, Springer, 2012.

2. Sutherland, Stuart, Davidmann, Simon, Flake, Peter, "SystemVerilog for Design: A Guide to Using SystemVerilog for Hardware Design and Modeling", Second Edition, Springer Science & Business Media, 2006.

**Reference(s)**

1. Faisal Haque, Jonathan Michelson, Khizar Khan, "The Art of Verification with System Verilog Assertions", First Edition, Verification Central, 2006.
2. S Halsoun and T Sasao, "Logic Synthesis and Verification", Kluwer Academic publishers, 2002.

# 5.Physical Design of ICs

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the steps by step process involved in the Physical design cycle.
**CO2**: analyze the different partitioning and floor planning methodologies used in the physical design of ICs.
**CO3**: analyze the different placement and routing methodologies used in the physical design of ICs.
**CO4**: generation of GDS II file after RC extraction.

**Course content:**

**UNIT I**

Physical IC Design–Objectives–VLSI Physical Design Cycle-Layout and design rules- basic algorithmic concepts for physical design- physical design processes and complexities. Partition: Kernigham- Lin's algorithm and Fiduccia Mattheyes algorithm - multilevel partition techniques; Optimal Partitioning using AI/ML Techniques.

**Unit II**

Floor-Planning: Hierarchical design - wire length estimation-slicing and non-slicing floor plan-polar graph representation and operator concept. Stockmeyer algorithm for floor planning. Placement: Design types – ASICs – SoC – microprocessor RLM. Placement Techniques: Simulated annealing-partition-based-analytical- Hall's quadratic- Timing and congestion considerations.

**Unit III**

Routing: Detailed- global and specialized routing- channel ordering- channel Routing problems and constraint graphsrouting algorithms- Yoshimura and Kuh's method-zone scanning and net merging- boundary terminal problem- minimum density spanning forest problem- topological routing- cluster graph representation. Parasitic Extraction (RC Extraction)–Chip Finishing Overview–Final Validation– Net List Output–GDS2 Output.

**Textbook(s)**
1. Naveed Sherwani, ―Algorithms for VLSI physical design Automation‖, 2nd Edition, Kluwer Academic Publisher,1999.
2. Christophn Meinel and Thorsten Theobold, ―Algorithm and Data Structures for VLSI Design‖, KAP, 2002.
3. Sarrafzadeh, M. and Wong, C.K., "An Introduction to VLSI Physical Design", 4th Ed., McGraw-Hill. 1996

**Reference(s)**

1. Wolf, W., "Modern VLSI Design System on Silicon", 2nd Ed., Pearson Education. 2000.
2. Sait, S.M. and Youssef, H., "VLSI Physical Design Automation: Theory and Practice", World Scientific. 1999
3. Sherwani, N.A., "Algorithm for VLSI Physical Design Automation", 2nd Ed., Kluwer.1999
4. Lim, S.K., "Practical Problems in VLSI Physical Design Automation", Springer. 2008

# 6.Mixed Signal IC Design

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1**: develop a comprehensive understanding of electrical noise.
**CO2**: understand the design considerations of different data converters.
**CO3**: gain proficiency in designing mixed-signal circuits.
**CO4**: develop the skills to use switched-capacitor CMFB for op-amp design

## Course content:

**UNIT I**
Feedback and Topologies Review; Introduction to electrical noise- noise measurements, thermal noise, simulating MOSFET noise, noise equivalent bandwidth, kT/C noise, signal-to-noise ratio (SNR), noise figure (NF), white noise, shot noise, flicker noise, noise and feedback, op-amp noise modeling.

**UNIT II**
Data converter fundamentals - DAC architectures: resistor string, R-2R, and current steering topologies. Cyclic and pipeline DACs. ADC architectures including flash and two-step - successive approximation (charge redistribution) ADCs -segmentation, calibrating DAC offsets and gains, topologies without an op-amp, op-amps in data converters - bottom-plate sampling - S/H and Cyclic (algorithmic) converter - pipeline ADC.

**UNIT III**
Fully-differential output op-amps - biasing for power and speed - diff-amps and CMFB - op-amp design for mixed-signal circuits - switched-capacitor CMFB - Op-Amp Design Using Switched-Capacitor CMFB; Circuit Optimization using AL/ML techniques.

**Textbook(s)**
1. R. Jacob Baker, “CMOS Circuit Design, Layout and Simulation”, Wiley India Pvt. Ltd, Third Edition.
2. B. Razavi, “Principles of Data Conversion System Design”, John Wiley and Sons, 1995

**Reference(s)**
1. R. Jacob Baker, “CMOS Mixed Signal Circuit Design”, Wiley India Pvt. Ltd, 2008
2. B. Razavi, “Design of Analog CMOS Integrated Circuits”, McGraw Hill, 2001.
3. B. Razavi, “RF Microelectronics”, Prentice Hall, 2011

# 7.VLSI Testing and Testability

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes:**

At the end of the course, the student should be able to
**CO1**: understand the fault equivalence and dominance collapsing for digital circuits
**CO2**: analyse the given fault as detectable or not using logic and fault simulation algorithms.
**CO3**: generate the test vector using combinational ATPG algorithms.
**CO4**: understand the scan and logic BIST architectures

**Course content**

**UNIT I**
Introduction to VLSI Testing- Need for VLSI Testing - Fault Modelling – Defects, Errors and Faults- Functional Vs Structural Testing- Levels of Fault Models - Glossary of fault models - Single stuck-at fault – Equivalence and Dominance - Checkpoint theorem.

**UNIT II**
Logic and fault simulation – Simulation for Design Verification and Test Evaluation - Modeling circuits for simulation - Algorithms for true value simulation and fault simulation - Combinational ATPG Algorithms- Redundancy Identification -Roth's D-algorithm – PODEM Algorithm; Fault detection using AI/ML Techniques.

**UNIT III**
Design for Testability– Digital DFT and Scan Design – Ad-Hoc DFT methods – Scan Design – Logic BIST- Test patterngeneration – Exhaustive Testing – Pseudo Random Testing Pseudo Exhaustive Testing – Output Response Analysis –Signature Analysis- Logic BIST architecture.

**Textbook(s)**
1. Vishwani D. Agrawal and Michael L. Bushnell, "Essentials of Electronic Testing for Digital Memory and Mixed Signal VLSI Circuits", Kluwer Academic Publishers, 2005.
2. Parag K. Lala, "An Introduction to Logic Circuit Testing", Morgan &Claypool Publishers,2009.

**Reference(s)**
1. LaungTerng Wang, Cheng Wen Wu and Xiaoqing Wen, "VLSI Test Principles and Architectures – Design for Testability", First Edition, Morgan Kaufmann Publishers, 2006.
**2.** Parag K. Lala, "Digital Circuit Testing and Testability", Academic Press, 1997.

# 8.System on Chip

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the concept of ARM System on a chip.
**CO2**: understand the interconnect topologies in ARM SoC.
**CO3**: understand the basic concepts of SystemC.
**CO4**: understand the basics of electronic system transaction Level Modelling

**Course content :**

**UNIT I**
Digital System and VLSI Design-Why design Integrated Circuits-Integrated Circuit design Techniques-IP based Desgin-Introduction to System-on-Chip-Socs Design Flow-Soc Technology- Soc I/O blocks- Processor, Memory and IP blocks.

**UNIT II**
Soc InterConnect- Interconnect Requirements- Basic Interconnect Topologies- Simple Packet-Switched Interconnect-Network-on-Chip- Advanced Interconnect Topologies- Interconnect Building Blocks- Long-distance Interconnects-Serialiser and Deserialiser: SERDES-Automatic Topology Synthesis.

**Unit III**
Electronic System-Level Modelling- Modelling Abstractions- Interconnect Modelling-SystemC Modelling Library-Transaction-level Modelling- Processor Modelling with Different Levels of Abstraction- ESL Modelling of Power,Performance and Area; Optimal SoC design using AI/ML Techniques.

**Textbook(s)**
1. Wayne Wolf, “Modern VLSI Design: SOC Design,-IP based design” Pearson Education, 2002.
2. Prakash Rashnikar, Peter Paterson and Lenna Singh, “System On a Chip Verification Methodology & Techniques,”Kluwer Academics Publishers, 2001.

**Reference(s)**
1. Farzad Nekoogar and Faranak Nekoogar, “From ASICs to SOCs: A Practical Approach,” Prentice Hall, 2003.
2. David J. Greaves” Modern System-on-Chip Design on Arm” , Arm education media
1. Modern Grant Martin and Henry Chang, “Winning the SOC Revolution: Experiences in Real Design,” Kluwer Academic Publishers, 2003.
2. Jerraya and W. Wolf, “Multiprocessor Systems On Chips,” Morgan Kaufmann, 2004.
3. G. De Micheli, R. Ernst, and W. Wolf, “Readings in Hardware/Software Co-Design,” Morgan Kaufmann, 2000

# 9.VLSI Fabrication Technology

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the wafer preparation and impurities doping mechanisms and its importance.
**CO2**: understand the growth of oxide and lithography process to pattern microdevices.
**CO3**: understand the lithography and pattering process of microdevices.
**CO4**: understand the different methods of film deposition and wet and dry etching processes.

**Course content :**

**UNIT I**
Brief History of Semiconductor technology. Scaling Trends and Scaling Methodologies - Scaling Challenges, ITRS Roadmap. Silicon structure and properties- Czochralski and Float Zone crystal growth, dopant distribution, and wafer preparation, Crystalline defects and their effects. Basic fabrication steps and their importance- Concepts of Clean room and safety requirements- Concepts of Wafer cleaning processes.

**UNIT II**
Diffusion and ion implantation- Types of diffusion- Ficks laws, junction depth, stopping mechanisms, Gaussian implantation profile, variations to predicted distribution, implantation damage, and annealing. Oxidation technologies- Plasma and Rapid Thermal Processing. Characterization of oxide films- High and low k dielectrics. Lithography. Photolithography, E-beam lithography and minimum resolvable feature sizes, UV sources, photoresists.

**UNIT III**
Deposition requirements and techniques – Physical- Evaporation and sputtering techniques. Failure mechanisms in metal interconnect - multilevel metallization schemes. Chemical Vapor Deposition- CVD techniques for deposition of polysilicon- silicon dioxide, silicon nitride and metal films. Epitaxial growth of silicon- PECVD.Etching - wet chemical etching techniques. Plasma etching and RIE techniques- Chemical Mechanical Polishing, Process integration and characterization techniques.

**Textbook(s)**
1. Plummer, J. "Silicon VLSI Technology: Fundamentals, Practice and Modeling", 3rd Ed., Prentice Hall, 2000.
2. Gandhi, S. K., "VLSI Fabrication Principles: Silicon and 1996 Gallium Arsenide", John Wiley and Sons,2003.
3. S. M. Sze, VLSI Technology, TATA, McGraw-Hill, 1999.

**Reference(s)**

1. Peter Van Zant, “Microchip Fabrication: A Practical Guide to Semiconductor Processing”, McGraw- Hill Professional, Sixth Edition, 2014.
2. Chang, C.Y. and Sze, S.M., “ULSI Technology”, McGraw Hill, 1999.
3. Campbell, S.A., “The Science and Engineering of Microelectronic Fabrication”, 4th Ed., Oxford University Press, 1999.

# 10.Semiconductor Memories

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be
**CO1:** understand the SRAM cell structures with its advantages & disadvantages.
**CO2:** understand the variations in DRAM with its advantages & disadvantages.
**CO3:** understand other types of semiconductor memories to implement EEPROM and Flash memories etc.
**CO4:** understand MRAMs and FRAMs types of memories

**Course Content:**

**UNIT I**
Random Access Memory Technologies: SRAM Cell structures, MOS SRAM Architecture, Advanced SRAM architecturesand technologies, Application specific SRAMs.

**UNIT II**
CMOS DRAM, DRAM cell theory and cell structures, BICMOS DRAM, DDR, Non-volatile Memories: Masked ROMs,High density ROM, PROM, CMOS PROMS, EPROM, Floating gate EPROM cell, One-time programmable EPROM,EEPROM, Flash Memories, Advanced Flash memory architecture- RAM fault modeling - BIST techniques for memory.

**UNIT III**
Radiation effects, Single Event Phenomenon (SEP), Radiation Hardening Process and Design Issues, FRAMs, GaAs FRAMs, Magneto resistive RAMs (MRAMs), Memory MCM testing and reliability issues, Memory cards, High Density Memory Packaging; Optimal memory cell design, detection and classification of defects using AI/ML techniques.

**Text Book(s)**
1. Ashok K. Sharma, "Semiconductor Memories: Technology, Testing, and Reliability", Wiley, 2013.
2. Betty Prince, "Emerging Memories: Technologies and Trends ", Kluwer Academic, 2002.
3. Tegze P Haraszti, "CMOS Memory Circuits", Kluwer Academic, 2001.
4. Brent Keeth and R Jacob Baker, "DRAM Circuit Design: A Tutorial", Wiley – IEEE Press, 2000.

**Reference(s)**
1. Kevin Zhang, "Embedded Memories for Nano- Scale VLSIs", Springer, 2009
2. Santosh K. Kurinec and Krzysztof Iniewski, "Nanoscale Semiconductor Memories: Technology and Applications"CRC press, 2013.
3. Koichi Ishibashi and Kenichi Osada, "Low Power and Reliable SRAM Memory Cell and Array Design", Springer,2011.
4. Saraju P. Mohanty and Ashok Srivastava, "Nano-CMOS and Post-CMOS Electronics: Circuits and Design", Vol2., (IET) The institution of Engineering and Technology, 2015

# Jharkhand University of Technology
# Ranchi, 834010

**SCHEME OF INSTRUCTION AND SYLLABUS**
**For B.Tech. Program in**
**Electronics and Communication Engineering**
**(Effective from 2024-25)**

## SEMESTER VI

# PCC-I -Wireless Communication & Networks

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1**: characterize wireless channels
**CO2**: apply techniques to improve performance in fading channels
**CO3**: understand multiple access techniques in wireless networks
**CO4**: understand working principles of modern wireless networks

**Course content :**

**UNIT I**
Introduction: Wireless communication, importance and requirements, types and classifications; Block diagram, brief function of major blocks; Wireless channels- characterization of wireless channel, Communication link, propagation phenomenon, LoS, NLoS; Mobile wireless channel-multipath propagation, ISI, fading, large scale-Friss free-space pathloss model, ray tracing model, two-ray tracing model, shadowing, small scale multipath measurements; Rayleigh, Rician model, Fading parameters like power-delay profile, coherence bandwidth, delay spread, etc., Passband representation of received signal; Channel capacity –AWGN, fading channel capacity, outage capacity, BER performance.

**Unit II**
Performance improvement techniques: Equalization-adaptive, DFE; Diversity techniques-types, receive diversity, transmit diversity, MIMO, MIMO-Channel, capacity, data rate; receiver architecture – combiners, rake receiver. Chanel Coding –Parity, block codes, convolution codes, interleaving, randomizer. Multicarrier communication – Frequency selective channels, OFDM, Single-carrier vs multi-carrier. Multiple access- techniques, TDMA, FDMA, CDMA, space division.

**Unit III**
Introduction to Wireless networks: Wireless Local Area Networks, 802.11n; Cellular mobile communication architecture, 2G network, evolution of cellular mobile communication 1G-5G;

**Textbook(s)**
1. Andrea Goldsmith, "Wireless Communication", Cambridge University Press, 2005.
2. David Tse and Pramod Viswanath, "Fundamentals of wireless communication", 2005

**Reference(s)**
1. William C Y Lee, "Wireless and Cellular Communications", Tata McGraw Hill Publishing Company Limited, Third Edition, 2006.

# PCC-II  IOT &Embedded Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the fundamentals of IoT technology
**CO2**: visualize and appreciate the business opportunity and applications
**CO3**: understand the technology and standard for IoT
**CO4**: develop and design IoT networks for identified applications

**Course Content:**

**UNIT I**
Introduction- IoT definition, use-cases and business Opportunities; IoT Architecture: Objects Layer, Object Abstraction Layer, Service Management Layer, Application Layer, Business Layer

**UNIT II**
IoT Elements- Identification, Sensing, Communication, Computation, Services, Semantics; IoT Common standards: ZigBee, BLE, WiFi, LoRa, LPWAN, IPV6, AMPQ, MQTT; Support to the IoT: Big Data Analytics, Cloud computing, and Fog computing;

**Unit III**
QoS Criteria: Reliability, Mobility, Performance, Scalability, Management, Interoperability; Security and Privacy in IoT: Confidentiality, Integrity, Availability, Privacy; IoT Applications: smart city, smart health, smart farming, smart manufacturer.

**Unit IV**
Introduction to Embedded Computing: Characteristics of Embedding Computing  Applications, Concept of Real time Systems, Challenges in Embedded System Design, Design Process. Embedded System Architecture: Instruction Set Architecture, CISC and RISC instruction set architecture, Basic Embedded Processor/Microcontroller Architecture (ATOM processor, Introduction to Tiva family etc.)

**Unit V**

Designing Embedded Computing Platform: Bus Protocols, Bus Organization, Memory Devices and their Characteristics, Memory mapped I/O, I/O Devices, I/O mapped I/O, Timers and Counters, Watchdog Timers, Interrupt Controllers, Interrupt programming, GPIO control, Sensors, Actuators, A/D and D/A Converters, Need of low power for embedded systems, Mixed Signals Processing.

**Unit VI**

Programming Embedded Systems: Basic Features of an Operating System, Kernel Features, Real-time Kernels, Processes and Threads, Context Switching, Scheduling, Shared Memory

Communication, Message-Based Communication, Real-time Memory Management, Dynamic Allocation, Device Drivers, Real-time Transactions and Files, Real-time OS (VxWorks, RT-Linux, Psos).

**Unit VII**

Network Based Embedded Applications: Embedded Networking Fundamentals, Layers and Protocols, Distributed Embedded Architectures, Internet-Enabled Systems, IoT overview and architecture, Interfacing Protocols (like UART, SPI, I2C, GPIB, FIREWIRE, USB,). Various wireless protocols and its applications: NFC, Zig Bee, Bluetooth, Bluetooth Low Energy, Wi-Fi. CAN. Overview of wireless sensor networks and design examples
Case studies: Programming in Embedded C, Embedded system design using Arduino, ATOM processors, Galileo and Tiva based embedded system applications

**Textbooks and References**

1. Hersent, O., Boswarthick, D. and Elloumi, O., 2011. The internet of things: Key applications and protocols. John
Wiley & Sons.
2. Burbank, J.L., Andrusenko, J., Everett, J.S. and Kasch, W.T., 2013. Wireless networking: Understanding
internetworking challenges. John Wiley & Sons

3.Wayne Wolf, "Computers as Components- Principles of Embedded Computing System Design", Morgan Kaufmann Publishers, Second edition, 2008

4. Barry Crowley, "Modern Embedded Computing", Morgan Kaufmann Publishers, 2012

# Professional Elective -III

# 1.FPGA based System Design

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** design digital circuits using programmable logic devices.
**CO2**: understand the architectures and features of various technology-based FPGAs.
**CO3**: comprehend the different phases of FPGA design flow and timing constraints

**CO4**: understand advanced architectures of FPGA.

**Course content :**

**Unit I**

Programmable Logic Devices - PROM - PAL - PLA - CPLD - Gate Arrays – MPGA. Introduction to FPGAs – Design flow– Circuit Fabrics – LUTs and IO Blocks. FPGA Technology overview – Digital Design for FPGAs, FPGA ProgrammingTechnologies – Antifuse - EPROM - EEPROM - FLASH – SRAM. FPGA Fabric - Configurable Logic Block - LUT - Slice– Slicem. Programmable Interconnects - Input Output Blocks - Keeper Circuit - Xilinx 7 Series Architecture.

**Unit II**

FPGA Design Flow and Abstraction Levels - Verilog Design for Synthesis - One Hot Encoding - Memory Blocks – Block Memory Generator (BRAM/BROM) - Single Port Memory - Dual Port Memory - FIFO - Distributed RAM – Synthesis Pitfalls - Latch Inference - Static Timing Analysis - Speed Performance - Timing Constraints - Clock Management – Clock Buffers - Clock Tree Routing.

**Unit III**

Introduction to SoC Design - Hard Macros - Multipliers - DSP Block - Hard Core Processors - Interface Circuits - Configuration Chain - JTAG Interface - Zynq7000 Architecture**;** Case Study: FPGA implementation of AI/ML algorithms.

**Textbook(s)**

1. Wayne Wolf, “FPGA-Based System Design”, Prentice Hall India Pvt. Ltd., 2005.
2. Amano, Hideharu, “Principles and Structures of FPGAs”, First Edition, Springer, 2018.
3. Readler, Blaine C.,” Verilog by example: a concise introduction for FPGA design”, Full Arc Press, 2011.

**Reference(s)**

1. Zainalabedin Navabi, “Embedded Core Design with FPGAs, First Edition”, McGraw Hill, 2008.
2. Xilinx Inc, “Vivado Design Suite User Guide, 2021.
3. Michael D. Ciletti, “Advanced Digital Design with Verilog HDL”, Second Edition, Pearson Higher Education,
2011.

# 2.Hardware Security and Trust

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand typical hardware security vulnerabilities at various phases of VLSI Design flow
**CO2:** understand fundamental approaches used in Trojan insertion
**CO3**: understand different approaches for Trojan and Piracy detection and analysis

**CO4**: analyze the ways in which trust can be incorporated in VLSI Design flow

**Course Content :**

**Unit I**
Review of VLSI Design Flow - Hardware Trojan –Trojan taxonomy - Case study - Trojan detection – Classification of
Trojan detection - Challenges in Trojan detection.

**Unit II**
Design for hardware trust – Delay-based methods – Shadow registers – Ring oscillators - Dummy scan Flip-Flop insertion- Trojan activation time analysis - Trojan detection and isolation flow – Architectural approaches; AI-based Hardware Trojan detection techniques

**Unit III**
Security and testing – Scan-based testing – Scan-based attacks and countermeasures - System-on-chip test infrastructure -
Emerging areas of test security. Trojan prevention: Built-in self-authentication - BISA structure and insertion flow -Analysing BISA structure - Trusted design in FPGAs.

**Textbook(s)**
1. Mohammad Tehranipoor and Cliff Wang (Eds.), "Introduction to Hardware Security and Trust", Springer, New
York, 2012.
2. Mohammad Tehranipoor, Hassan Salmani and Xuehui Zhang, "Integrated Circuit Authentication - Hardware
Trojans and Counterfeit Detection", Springer International Publishing, Switzerland 2014.

**Reference(s)**

1. Nicolas Sklavos, Ricardo Chaves, Giorgio De Natale, Francesco Regazzoni (Eds), "Hardware Security and Trust:
Design and Deployment of Integrated Circuits in a Threatened Environment", Springer, 2017.

2. Prabhat Mishra, Swarup Bhunia, Mark Teharanipoor (Eds), “Hardware IP Security and Trust”, Springer, 2017.

# 3.VLSI System Design

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the basic constructs of Verilog.
**CO2**: design digital blocks using Gate level and Data flow modeling style of Verilog.

**CO3**: design digital blocks using behavioral modeling and also synthesizable constructs in the same.
**CO4:** analyze the working and designing of standard VLSI System building blocks.

**Course Content :**

**Unit I**
Review of VLSI Design Flow - Introduction to HDLs - Verilog modeling styles – Gate Level, Structural - Dataflow -Register Transfer Level (RTL) abstraction for HDL-Based Design Flow.

**Unit II**
Behavioral Verilog Modeling of Combinational and Sequential Subsystems: Multiplexer – Decoder – Encoder – adders –Multipliers – Counters - Shift Registers - State Machines.

**Unit III**
Logic Synthesis with Verilog HDL and their constructs, Impact of Logic Synthesis, Basics of Timing - Speed of a Digital system - Design Case Studies - Simple Processor – FIFO Circular Buffer - DSP Blocks – LFSR; Case Study: Design the AI/ML algorithms using Verilog.

**Textbook(s)**

1. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", Second Edition, Pearson, 2003.
2. Michael D Ciletti, "Advanced Digital Design with the Verilog HDL", Second Edition, Pearson, 2017.

**Reference(s)**
1. T. R. Padmanabhan and B. Bala Tripura Sundari, "Design through the Verilog HDL", First Edition, Wiley
Interscience, 2004

# 4.Design of ICs for Optical Communication

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the design challenges in transmission of random binary data in optical communication system
**CO2**: design optical communication related circuits and systems
**CO3**: analyze and characterize optical communication related circuits and systems
**CO4**: carry out the performance evaluation of an optical communication system

**Course Content:**

**Unit I**

Optical Communication System: General Optical System – Design Challenges – State of the Art Random Binary Data – Properties – Generation – Data Formats – Effect of Bandwidth Limitation – Effect of noise – Phase noise and jitter – Transmission Lines; Optical Devices: Laser Diodes – Optical Fibers - Photodiodes – Optical Systems

**Unit II**

Transimpedance Amplifiers: General Considerations – Open Loop TIA – Feedback TIA – Supply Rejection – Differential TIA – High Performance Techniques – Automatic Gain Control – Development in TIA Design with case studies; Limiting Amplifiers and Output Buffers: General Considerations – Broadband Techniques - Output Buffers – Distributed Amplification, Oscillators: Ring Oscillators - LC Oscillators – Inductors – Varactors – Quadrature Oscillator – Distributed Oscillator - Voltage Controlled Oscillators

**Unit III**

PLL - Charge-Pump PLLs - Nonideal Effects in PLLs - Delay-Locked Loops, Clock and Data Recovery: General Considerations - Phase Detectors for Random Data - Frequency Detectors for Random Data - CDR Architectures - Jitter in CDR Circuits, Multiplexers and Laser Drivers: Multiplexers - Frequency Dividers - Laser and Modulator Drivers – Design Principles - Laser Driver Design, Burst-Mode Circuits: Burst-Mode TIAs - Burst-Mode CDR Circuits; Design optimization of high-speed laser driver IC using support vector regression (SVR), Deep Neural Network for anomaly detection in highspeed laser driver circuits.

**Textbook(s)**


1. Behzad Razavi, "Design of Integrated Circuits for Optical Communications", 2nd Edition, Wiley, 2012.
2. Behzad Razavi, "Design of CMOS Phase Locked Loops", Cambridge University Press, 2020

**Reference(s)**

1. Eduard Säckinger, “Analysis and Design of Transimpedance Amplifiers for Optical Receivers” Wiley, 2017.
2. Ofer Aluf, “Advance Elements of Laser Circuits and Systems: Nonlinear Applications in Engineering”, 1st Edition,
2021.

# 5.Optoelectronic Integrated Circuit Design

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the working principle of the optical devices

**CO2**: use the optical materials for different applications
**CO3**: design simple optoelectronics device
**CO4**: understand the behavioral characteristics of optical devices

## Course Content:

**Unit I**

Introduction -Optical mechanism in semiconductors, E-H pair generation and recombination, absorption and radiation in semiconductor, deep level transitions, Auger recombination, luminescence and time resolved photoluminescence, optical properties of photonic band-gap materials; Junction photodiode: PIN, heterojunction and avalanche photodiode; Comparisons of various photodetectors, measurement techniques for output pulse.

**Unit II**

Photovoltaic effect, V-I characteristics and spectral response of solar cells, heterojunction and cascaded solar cells, Schottky barrier and thin film solar cells, design of solar cell, Generative Adversial Network (GAN) to optimize nanostructure design for solar cells. Modulated barrier, MS and MSM photodiodes; Wavelength selective detection, coherent detection;Microcavity photodiode, Support Vector Regression (SVR) and particle swarm optimization (PSO) algorithms to optimize design parameters of microcavity photodiode.

**Unit III**

Dynamic effects of MOS capacitor, basic structure and frequency response of charge coupled devices, buried channel charge coupled devices. Electroluminescent process, choice of light emitting diode (LED) material, device configuration and efficiency; LED: Principle of operation, LED structure, frequency response, defects, and reliability.

**Textbook(s)**

1. Horst Zimmermann "Silicon Optoelectronic Integrated Circuits" 2nd edition, Volume 13, Springer Series in
Advanced Microelectronics
2. Jianjun Gao "Optoelectronic Integrated Circuit Design" 1st edition, 2011, Wiley


**Reference(s)**

1. O. Wada "Optoelectronic Integration: Physics, Technology and Applications" 1994
2. Ginés Lifante "Integrated Photonics Fundamentals" 2003. Wiley

# 6.Radio Frequency Integrated Circuits

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand RF CMOS device characteristics and its importance in RF ICs
**CO2**: apply RF computational techniques to design actively loaded RF amplifiers
**CO3**: design and analyze two port networks
**CO4**: evaluate the characteristics of RF CMOS sub blocks from top-level specifications and to model circuits using circuit simulators

**Course Content:**

**Unit I**

Introduction- Review of RF and communication systems concepts, Basic Concepts in RF Design - General Considerations, Effects of Nonlinearity, Noise, and Sensitivity and Dynamic Range. RF systems – basic architectures, Parallel RLC – Series RLC - Impedance Transformers - L-Pi-T-Type. Higher Order Matching - Transmission Lines - Driving Point Impedance. Small Signal RF CMOS Model - Noise Sources Transceiver Architectures- Basic and Modern Heterodyne Receivers, Direct- Conversion Receivers. Low-IF Receivers and Heterodyne Transmitters. Low-Noise Amplifiers- General Considerations, Problem of Input Matching, and LNA Topologies

**Unit II**

Mixers- General Considerations, Passive Down conversion Mixers, Active Down conversion Mixers, and Active Mixers with High IP2, Up conversion Mixers. Two Port Network - S-Parameters - Maximum Stable Gain - Reflection Coefficients - Stability - Non-Linearity - 1-dB Gain Compression Point - Inter-Modulation -Receiver Architecture - Direct Conversion - Super Heterodyne - Hartley Architecture - CMOS sub blocks - Low Noise Amplifier - Inductive Source Degeneration - Cascode and Differential Configurations - Inductive Peaking - Current Reuse.

**Unit III**

Oscillators- Cross-Coupled Oscillator, Voltage-Controlled Oscillators, Low-Noise VCOs. Phase-Locked Loops- Type-I PLLs, Type-II PLLs, and PFD/CP Nonidealities. Power Amplifiers- Classification, High-Efficiency Power Amplifiers, Cascode Output Stages, and Basic Linearization Techniques. Doherty Power Amplifier, Polar Modulation, and Out phasing; ML based linearization techniques.

**Textbook(s)**

1. RF Microelectronics by Behzad Razavi. Second Edition, Pearson, 2012 (Indian Edition 2013 by Dorling
Kindersley).
2. The Design of CMOS Radio-Frequency Integrated Circuits by Thomas H. Lee. Cambridge University Press, 2004.

**Reference(s)**

1. SorinVoinigescu, High-Frequency Integrated Circuits, Cambridge University Press, 2013, South Asian Paperback
edition of 2018.
2. Michael Steer, Microwave and RF Design - A Systems Approach, SciTech Publishing, 2010, Indian Reprint by
Yesdee Publishing, 2012.

# 7.Microwave Circuits for Wireless Communications

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes:

At the end of the course, the student should be able to
**CO1:** understand and apply the principles of electromagnetics and transmission lines
**CO2:** analyze microwave networks and determine the network parameters and characteristics
**CO3:** design and implement the matching networks and multisection matching transformers
**CO4:** design and analyze microwave amplifiers

## Course Content:

### Unit I

**Review of electromagnetics:** Maxwell's equations, plane wave solutions, transmission lines; types of transmission lines and their properties, coaxial lines, rectangular waveguides, microstrip. Microwave Network analysis; scattering matrix, transmission matrix formulations. Flow graphs, Mason's rule.

### Unit II

Matching networks: lumped element designs and limitations, single and double stub tuned designs. Quarter-wavelength transformers, multisection matching transformers; Active microwave circuit design, characteristics of microwave diodes and transistors. Linear and nonlinear behavior and models; Filter Synthesis by Using Artificial Intelligence Techniques-Neural Network Modeling, Experimental Design and Data Acquisition.

### Unit III

**Amplifier design**: gain and stability, design for noise figure. Noise in microwave circuits; dynamic range and noise sources, equivalent noise temperature, system noise figure considerations.

### Textbook(s)

1. David M. Pozar, Microwave Engineering, 4th. ed., John Wiley & Sons, 2012.

### Reference(s)

1. Guillermo Gonzalez, Microwave Transistor Amplifiers, 2nd. ed., Prentice-Hall, 1997.

# 8.Design of Millimeter-Wave Circuits and Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the mmWave IC technology, its capabilities and limitations
**CO2**: analyze and optimize radio link budgets for wireless communication systems
**CO3**: design mmWave ICs
**CO4**: analyze the system-level requirements and trade-offs associated with various mmWave applications

**Course Content:**

**Unit I**

Introduction to mmWave: Physics, Technology - Active components: SiGe BiCMOS Technology - SOI CMOS Technology - Passive components: transmission lines, Capacitor / Inductor / Transformer, Hybrid couplers.

**Unit II**

Millimeter-wave Communication Links and Budgets - Phased-Array: Beamforming, Architecture, ML techniques for beamforming; Metrics - Building Block: Low Noise Amplifier design and Power Amplifier design, layout and verification - mmWave Phase Shifters: Active and Passive.

**Unit III**

Transmit/Receive switches and their use in systems - mmWave Transceivers: Architecture - mmWave Mixers, Active and Passive - mmWave multipliers – Voltage Controlled Oscillators - High-Speed circuits & dividers for LO networks (CML) - Phased-Array Systems - Radar Fundamentals - Radar Transceiver System-on-chip.

**Textbook(s)**

Sorin Voinigescu, High-Frequency Integrated Circuits, 1st ed., Cambridge, 2013

**Reference(s)**

1. Hubregt J. Visser, Array and Phased Array Antenna Basics, Wiley, 1st ed., 2005.
2. David Pozar, Microwave Engineering, Wiley, 4th ed., 2011.
3. Merrill Skolnik, Introduction to Radar Systems, McGraw-Hill, 3rd ed., 2002.

# 9.IC Design for Sensor Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the concepts of design and calibration of sensor interface circuits and sensor interface system
**CO2**: apply the design principles on precision instrumentation amplifiers and dedicated sensor systems
**CO3**: analyze CMOS based sensor circuits and their characteristics
**CO4**: evaluate the performance of MOS based sensor interface circuits and systems using simulation tools

**Course Content:**

**Unit I**

**Sensor Interface Circuits** – Sensor Signal Normalization – Analog Data Acquisition Circuits in Integrated Sensing System – Integrated Interface Circuits for Capacitive Micromechanical Sensors – Interfaces for Microsensor Systems – Sensor Interface Systems – Smart Sensor Systems – Smart Sensor Design – Calibration and Self-Calibration of Smart Sensors

**Unit II**

**Precision Instrumentation Amplifiers** – Three- OpAmp Instrumentation Amplifier, Current-Feedback Instrumentation Amplifiers -Auto-Zero OpAmps and InstAmps - Chopper OpAmps and InstAmps - Chopper Stabilized OpAmps and InstAmps - Chopper Stabilized and AZ-Chopper OpAmps and InstAmps, Dedicated Impedance-Sensor Systems - Capacitive-Sensor Interfaces using Square-Wave Excitation Signals - Dedicated Measurement Systems – Detection of Microorganisms – Water Content Meaurements– Blood Impedance Characterization

**Unit III**

**CMOS Based Sensors** – DNA Microarrays –Functionalization – Electrochemical Readout Techniques - Image Sensors – Impact of CMOS Scaling – CMOS Pixel Architectures – Photon Shot Noise – A/D Converters for CMOS Image Sensors – Light Sensitivity – Dynamic Range – Global Shutter Circuit Platforms for Smart Sensors – mm Scale Sensor Platform for future IOT Applications – Deep Neural Networks and Reinforcement Learning to optimize design of sensor system for power consumption and data accuracy-Smart Sensor Microsystem-Decision Trees and Genetic Algorithm to optimize design of smart sensor microsystem for performance and power consumption; Application-Dependent Design and Integration Approaches – Energy Efficient RRAM Crossbar-based Approximate Computing for Smart Cameras - NVRAM-Assisted Optimization Techniques for Flash Memory Management in Embedded Sensor Nodes

**Textbook(s)**

Gerard Meijer, Michiel Pertijs, Kofi Makinwa “Smart Sensor Systems: Emerging Systems and Applications” 1st edition,
Wiley, 2014

**Reference(s)**

1. Chong-Min Kyung, Hirrota Yassura, “Smart Sensors and Systems” Springer, 2017
3. Willy Sansen, Johan H Huijsing “Analog Circuit Design Mixed A/D Circuit Design, Sensor Interface Circuits and
Communication Circuits” Springer Science, 1999

# 9.Microelectromechanical Devices

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1**: understand the MEMS devices and MEMS materials used in fabrication
**CO2**: understand the different MEMS micro sensor principles and micro actuators mechanism
**CO3**: understand the engineering science of microsystem
**CO4**: understand the mechanism and fabrication process of microsystem and packaging

## Course Content:

### Unit I

Overview of MEMS and Microsystem, MEMS Materials: Silicon, Polymer: Polymers in MEMS– Polimide, SU-8, Liquid Crystal Polymer (LCP), PDMS, PMMA, Parylene; Microsensor-Working principles of different microsensors-acoustic, BioMEMS, Chemicals, Optical, Pressure, and Thermal, Flow and Tactile sensors- Optical MEMS – Lenses and Mirrors. Micro-actuators-different actuations mechanisms- Thermal force, Shape memory alloy, Piezoelectric materials, Electrostatic force, Applications of micro actuators.

### Unit II

Engineering science for microsystem design: Engg. Mechanics of microsystem: Design-static bending of thin plates, mechanical vibration, thermomechanical, fracture mechanics, thin film mechanics, and finite element analysis, thermofluidic and microsystem design- characteristic of moving fluid, continuity and momentum equations, Laminar fluid flow, and heat conduction, miniaturization laws

### Unit III

Microsystem fabrication process-photolithography, ion-implantation, diffusion, oxidation, thin films deposition methodschemicalvapor deposition, physical vapor deposition, epitaxy deposition, Etching- Anisotropic Wet Etching – Dry Etching of Silicon – Plasma Etching – Deep Reactive Ion Etching (DRIE) – Isotropic Wet Etching- Gas Phase Etchants; Micromanufacturing: Bulk micromachining, surface micromachining, and LIGA process; Assembly of 3D MEMS, Microsystems packaging and materials- Artificial Intelligence applications for MEMS Sensors and actuators and applications of MEMS devices.

### Textbook(s)

1. Tai-Ran Hsu, MEMS and Micro systems Design and Manufacture, Tata McGraw Hill, 2002.
2. Chang Liu, Foundation of MEMS, International Edition, 2nd edition, 2006.
3. GK Anantha Suresh, et. al, Micro and Smart Systems, Wiley-India, 2010.

### Reference(s)

1. Stephen D Senturia, Microsystem Design, Springer Publication, 2000.
2. Julian W.Gardner, Vijay K Varadhan, "Microsensors, MEMS and Smart devices", John Wiley & sons, 2001.

## 10.Energy Harvesting Technologies and Circuits

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand various energy sources available in the environment
**CO2**: understand the fundamentals of energy harvesting technologies and methods
**CO3**: understand about the low power and high-power energy harvesting technologies and their model
**CO4**: understand different conditional circuits used for energy harvesting devices

**Course Content :**

**Unit I**

Introduction-Energy sources, energy harvesting based sensor networks, photovoltaic cell technologies, generation of electric power in semiconductor PV cells, Thermoelectric energy harvesting- design and effecinecy, piezoelectric energy harvesting, types of Piezoelectric materials, Transducers. Micro scale harvesting, Strategy for Enhancing the generated power.

**Unit II**

Piezoelectric Electromechanical modeling of Lumped parameter model and coupled distributed parameter models and closed from solution. Performance Evalution, Electromagnetic-Basic priciple, micro fabricated coils and magnetic materials, scaling, power maximization, micro and macro scale implementations. Non-linear techniques, vibration control & steady state cases. Power sources for WSN, Power generation, conversion, examples – case studies.

**Unit III**

Harvesting circuits- Schottky diode, MOSFET as a diode, PWM and transistor switching, Interface/power conditioning circuit: linear DC-DC converters, Buck-boost Convertor, AC-DC boots rectifiers, Voltage Multipliers, and LT Spice Analysis of Power Conditioning Circuit; Role and application of AI/ML in energy systems.

**Textbook(s)**
1. Carlos Manuel Ferreira Carvalho, Nuno Filipe Silva Veríssimo Paulino, “CMOS Indoor Light Energy Harvesting
System for Wireless Sensing Applications", springer, 2016.
2. Shashank Priya, “Energy Harvesting Technologies, “Springer, 2009.

**Reference(s)**
1. Danick Briand, Eric Yeatman, Shad Roundy, “Micro Energy Harvesting”, 2015

# Professional Elective- IV

# 1.FinFET Technology

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** know the challenges of MOSFET scaling, oxide defects, and importance of FinFET
**CO2:** understand the MOS System, region of operation, physical effect of FinFET Technology
**CO3:** understand the different types of leakages and parasitic resistances in FinFET
**CO4:** know the fabrication materials, process and various fabrication challenges

**Course Outcome:**

**Unit I**

Introduction-Moore's Law, MOSFET Scaling, Challenges, and Physics-Leakage Current, Variability, FinFET- Single and Multigate, Multigate MOS Capacitor, Oxide Charges, Effect of Oxide Charges on Energy Band, Multigate MOS Capacitor Systems, Fin-FET-Operation, Basic Features, Drain Current Formulation-Derivation of Electrostatic Potential, Continuous Drain Current, Equation, Regional Drain Current Equations.

**Unit II**

Physical Effect and Leakage and Parasitic- Short Channel Effect on Threshold, Quantum Mechanical Effect, Surface Mobility, Subthreshold, Gate induced Drain and Source, Gate induced Source, Source Drain P-N Junction leakages, and Gate Oxide Tunneling leakages, Impact Ionization Current, Source-Drain Parasitic Resistance, Gate Resistance, Source Drain-P-N Junction Capacitances

**Unit III**
FinFET-Fabrication-material, well formation, Fin pattering, Alternative well formation, Gate Definition, Source-Drain Extension, Raised Source-Drain, replacement metal gate formation, Challenges to FinFET Process-Lithography, Process Integration, Dopant Implantation, and Etching, Device Technology and FinFET circuit Design Challenges; Role of Al/ML in FinFET optimization and fabrication.

**Textbook(s)**
1. Samar K. Saha, "FinFET Devices for VLSI Circuit and Systems," CRC Press, 2021.
2. Yogesh Singh Chauhan, "FinFET Modelling for IC Design and Simulation, Academic Press, 2015.

**Reference(s)**
Jean-Pierre Colinge, "FinFETs and Other Multi-gate Transistors," Springer, 2008

# 2.Nano Electronics

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
CO1: understand the deep sub-micron effects and limits of scaling on nano-electronic devices
CO2: use of wave – particle analysis in the development of transport properties
CO3: use mathematical methods for advanced nanomaterial studies
CO4: develop spice compatible models

## Course Content:

### Unit I

Deep Submicron Devices Limits to Scaling –Nano Devices – Quantum Effects– Atomic Scale Parameter Fluctuation – Nanoscale MOSFET –FINFETS –Vertical MOSFETS - Tunnel FETS - The Schrödinger Equation –Electrons in a Crystal Lattice – Quantum Well– Wire and Dot Devices - Scattering Rates and Lifetimes in Electronic Devices - CVD and Other Processes in Fabrication of Nano Devices.

### Unit II

Band-Structure and Transport Resonant Tunneling Transistors –Single Electron Transistors – and Spintronics Devices - Atoms–up Approaches – Transport in Molecular Structures – Molecular Systems as Schrodingers equation – Nanoscale and Quantum Devices –Single Electron Transistor – Quantum Wires - Quantum Dot Cellular Automata.

### Unit III

Alternatives to Conventional Electronics – Drift Diffusion– Ballistic Transport –NEGF – Molecular Interconnects – Graphene–Carbon Nanotubes and Silicon Nanowire, Technology Devices and Circuits - 1 D transport - Reflection, Transmission and the non-equilibrium Green Function Formalism (NEGF) - Contacting the schodinger - Density of states – Hamiltonian - and Spice compatible modeling of carbon-based advanced nanomaterial channels for MOSFET devices.

**Textbook(s)**

1. S. Datta, “Lessons from Nanoelectronics”, World Scientific, 2012.
2. S. Datta, “Quantum Transport: Atom to Transistor”, Cambridge University Press, 2005.

**Reference(s)**

1. Gerhard Klimeck, “Nanoelectronics Modeling: From Quantum Mechanics and Atoms to Realistic Devices”,

https://nanohub.org/resources/8086, 2010.
2. Waser Ranier, "Nano Electronics and Information Technology: Advanced Electronic Materials and Novel Devices"
Wiley VCH, 2003.

# 3.Energy Materials

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
CO1: understand the applications of different solar cells
CO2: understand the new generation energy harvesting materials
CO3: know the different synthesis methods of materials
CO4: understand various methods to analyze and characterize the materials

**Course Content:**

**Unit I**

Solar and Energy Harvesting Materials**-** First generation solar cell materials; single and polycrystalline Silicon, amorphous silicon, contact materials. Second generation solar cell materials: CdSe, CdTe, Copper Indium Gallium Selenide (CIGS), Gallium Arsenide for applications in photovoltaics, Materials for thin film solar cells, thin film processing, and properties. Contact materials for second generation solar cells. Third generation solar cell materials; Quantum Dots, Organic materials, Composites, Dyes, Perovskites and their synthesis, characterization and properties, Interface energetics, photoactive layers and their materials. Piezoelectric, Pyroelectric and Thermo-electrics materials, Electrostatic (capacitive) Energy Harvesting and materials, energy from Magnetic Induction, Metamaterial, energy from atmospheric pressure changes, electroactive polymers (EAPs); Use of Machine Learning and Artificial Intelligence for Energy Materials.

**Unit II**

Energy Storage Materials-Electrochemistry and electro-chemical Battery materials, Hydrogen Storage materials for fuel cells: Metal hybrids, Nanostructured metal hydrides, Non-metal hydrides, Carbohydrates, Synthesis of hydrocarbons, Aluminum, Liquid organic hydrogen carriers (LOHC), Ammonia, Amine borane complexes, Nano borohydrides and nano catalyst doping, imidazolium ionic liquids, phosphonium borate, Carbonite substances, Metal Organic frameworks, Activated Carbons, Carbon nanotubes, Clathrate hydrates, Glass capillary arrays; Physical Materials Synthesis Methods**:** Vacuum Evaporation, Electron beam evaporation Sputtering, Cathodic Arc Deposition, Chemical Vapour Deposition, Atomic Layer Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Lithography and their types; Al/Ml in material Process and manufacturing.

**Unit III**

Physical Materials Synthesis Methods**:** Sol-Gel technique, self-assembly, colloidal method, hydro-thermal method, coprecipitation method, solid state synthesis, microwave method, micro-emulsion method; **Materials** Characterization Methods**:** Electron beam instruments: Transmission electron and scanning electron microscopes, Auger electron spectroscope, x-ray spectrometers, Analysis of micrographs in TEM, SEM, and HRTEM, Interpretation of analytical data: EDS, WDS, Auger, EELS, ESCA, SIMS. Bulk averaging techniques: Thermal analysis, DTA, DSC, TGA, resistivity/conductivity. Optical spectroscopy: atomic absorption spectroscopy, infrared spectroscopy and Raman spectroscopy; Scanning Tunneling and Atomic Force Microscopy.

**Textbook(s)**

1. Advanced Energy Materials, Ashutosh Tiwari & Sergiy Valyukh, J. Wiley & Sons, 2014.
2. Eco- and Renewable Energy Materials, Young Zho, Springer, 2013.

**Reference(s)**

Materials and Energy (Book Series), Leonard C Feldman (Ed. In Chief), World Scientific

# 4.Thin Electronic Films

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
CO1: understand the structure and fabrication of thin film materials used in electronics applications
CO2: understand the physics and technology behind electronic thin films materials used in engineering applications
CO3: understand the dependence of the electronic properties and characteristics on various parameters
CO4: understand the principles behind designing, and engineering of thin film materials for electronic applications

**Course Content:**

**Unit I**

Introduction - Bonding and crystal structure of electronic materials, thin film vs bulk material considerations, thin film formation and structure – Physical Vapor Deposition, Chemical Vapor Deposition, Introduction to Artificial Intelligence for Thin film Manufacturing; Epitaxy; Nucleation and Kinetics; Structure of thin films; Electrical conduction in thin metal films, Skin Effect, Resistivity vs thickness, Interconnects in Microelectronics, Electromigration; Thin film diodes and transistors;
Role of Defects.

**Unit II**

Thin films for Dielectric and magnetic applications - Polarization Mechanisms in thin films, electric susceptivity and polarizability, Clausius Mossotti Equation, high and low K materials, frequency dependence, dielectric loss and Breakdown, Piezoelectric and Ferroelectric thin films; Magnetic properties of thin films, Hard and Soft magnetic materials, Anisotropic and Giant Magnetoresistance, Spintronics and magnetic sensors, Magnetic Recording, Superconducting thin films.

**Unit III**

Thin films for Optical and electromagnetic applications - Light Propagation in materials, Total Internal Reflection, Luminescence, Optical Anisotropy, LCDs, Optoelectronic devices – LEDs, LASERs, Solar Cells, Photodetectors, waveguides, Optical fibers; responses of materials to electromagnetic waves, metamaterials, materials for electromagnetic shielding, radars and antennas; smart materials, wide band gap materials.

**Textbooks/References**

1. Jianguo Zhu, Xiaohong Zhu, Hong Liu, Jie Xing, "*Thin Film Physics And Devices*: Fundamental Mechanism,
Materials And Applications For Thin Films", **World Scientific**, 2021 (First Edition).
2. Jaydeep Sarkar, "*Sputtering Materials for VLSI and Thin Film Devices*", **Elsevier (William Andrew)** Inc., First
Edition, 2014
3. S. O. Kasap, "*Principles of Electronic Materials and Devices*", Fourth Edition, **McGraw Hill Education**, 2018
4. L. Solymar, D. Walsh and R. R. A. Syms, "*Electrical Properties of Materials*", Ninth Edition, **Oxford**
**University Press**, 2014
5. Rolf. E Hummel, "*Electronic Properties of Materials*", Fourth Edition, **Springer**, 2012

# 5.Operating Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
CO1: understand the architecture and functionalities of modern OS.
CO2: understand and apply the algorithms for scheduling.
CO3: understand and apply the algorithms for resource management
CO4: apply semaphores and monitors for classical and real-world synchronization scenarios

**Course Content:**

**Unit I**

Introduction to Operating Systems: Overview - Types of systems - Computer system operations - Hardware Protection - ;Operating systems services - System calls - System structure - Virtual machines. Process Management: Process concepts - Process scheduling - Operations on Process - Cooperating process – Inter-process communication - Multithreading models - Threading issues - Thread types - CPU scheduling –scheduling algorithms.

**Unit II**

Process Synchronization: Critical section problem - synchronization hardware – Semaphores - Classical problems of synchronization - Critical regions – Monitors – Deadlocks - Deadlock characterization - Methods of handling deadlocks - Deadlock prevention – Avoidance - Detection and recovery.

**Unit III**

Storage Management: Memory management – Swapping - Contiguous memory allocation. Paging – Segmentation - Segmentation with Paging - Virtual memory - Demand paging - Process creation – page replacement - Thrashing. File Systems: Directory structure - Directory implementation - Disk scheduling. Case study: Threading concepts in Operating systems, Kernel structures.

**Textbook(s)**

*1.* Silberschatz and Galvin, "Operating System Concepts", Ninth Edition, John Wiley and Sons, 2012.

**Reference(s)**

1. Deitel. Deitel and Choffnes, "Operating System", Third edition, Prentice Hall, 2003.
2. Tannenbaum A S, "Modern Operating Systems", Third edition, Prentice Hall, 2007.
3. Stevens W R and Rago S A, "Advanced Programming in the Unix Environment", Second Edition, Addison-Wesley, 2008.

4. Gary Nutt, “Operating Systems”, Third Edition, Addison Wesley, 2009.

# 6. Real-Time Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the foundations of real time systems
**CO2**: apply the concept of real time task-scheduling, and resource sharing
**CO3**: perform real time communication using real time operating systems
**CO4**: develop real time systems using real time operating systems

**Course Content:**

**Unit I**

Introduction**:** Real-time and real time system, applications, models of real-time systems (RTS), characteristics, safety and reliability, types, timing constraints, examples of RTSs.; Global Times**:** time and order, time measurement, dense time vs sparse time, internal clock synchronization, external clock synchronization**; Real-time model:** components and messages, component state, gateway component, linking interface specification, component integration.

**Unit II**

Temporal relations**:** real-time entities, observations (untimed, indirect, state and event), real-time images and objects, temporal accuracy, permanence and idempotency, determinism; Real-time task scheduling: types of real-time tasks, task scheduling, concepts and classification, algorithms – clock driven scheduling, hybrid schedulers, event driven scheduling, EDF scheduling, rate monotonic algorithm, multiprocessor task allocation, dynamic allocation of tasks.
**Resource sharing and Dependencies:** resource sharing, priority inversion, basic concepts of faults, errors, failures, anomaly detection, fault tolerance, robustness.

**Unit III**

Real-time communication**:** requirements, design issues, communication model, flow control, event triggered communication, rate constrained communication, time-triggered communication; Real-time operating **systems:** features, inter-component communication, task management, time as data, inter-task interactions, Process I/O, error detection, Unix as a RTOS, POSIX, Contemporary RTOSs like PSOS, RT Linux et, benchmarking real time systems.

**Textbook(s)**

Kopetz H. Real-time Systems: Design Principles for Distributed Embedded Applications. Springer Science &
Business Media; 2011 Apr 15.

**Reference(s)**

1. Rajib Mall. Real-Time Systems: Theory and Practice, Pearson, First Edition; 2006.
2. Laplante PA. Real-time Systems Design and Analysis: An Engineer's Handbook. Wiley-IEEE Press; 1996 Nov 1.
3. Real-Time Systems - Course (nptel.ac.in)
4. Real Time Systems (iitpkd.ac.in)

# 6.MIPS Architecture

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
CO1: describe the MIPS architecture and its components
CO2: write basic MIPS assembly language programs
CO3: analyze and debug MIPS assembly language programs
CO4: design and implement simple embedded systems using the MIPS architecture

## Course Content:

### Unit I

Introduction-Introduction to Computer Architecture, MIPS Architecture Overview, MIPS Instruction Set, MIPS Assembly Language Programming, Data Types and Addressing Modes

### Unit II

MIPS Processor Design- MIPS Processor Architecture, MIPS Pipeline Design, MIPS Memory Hierarchy, Cache Memory and Virtual Memory, MIPS I/O System

### Unit III

Advanced Topics in MIPS Architecture- Multithreading and Multicore Processing, Exception and Interrupt, Handling, MIPS Performance Analysis and Optimization, MIPS SIMD Architecture, MIPS Future and Emerging Trends.

### Textbook(s)

1. Computer Organization and Design MIPS Edition: The Hardware/Software Interface (5th Edition) by David A. Patterson and John L. Hennessy
2. Advanced Computer Architecture: Parallelism, Scalability, Programmability (2nd Edition) by Hesham El-Rewini and Mostafa Abd-El-Barr

### Reference(s)

1. MIPS Assembly Language Programming by Robert Britton
2. Computer Organization and Design: The Hardware/Software Interface, ARM Edition (1st Edition) by David A. Patterson and John L. Hennessy
3. Computer Architecture, Fifth Edition: A Quantitative Approach by John L. Hennessy and David A. Patterson

# 7.Parallel and Pipelined based Computer Architecture

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
CO1: interpret the performance of a processor based on different metrics
CO2: predict the challenges of realizing different kinds of and leverage them for performance advancement.
CO3: apply the concept of memory hierarchy for efficient memory design and virtual memory to overcome the memory
wall
CO4: explore emerging computing trends, computing platforms, and design trade-offs

**Course Content**:

**Unit I**

Design Space Exploration and Optimizations: Performance metrics and performance enhancement techniques, Basic concepts of parallel processing and pipelining, Power dissipation in processors, power metrics, and low-power design techniques. Instruction set architecture design: Instruction set design, implementation and performance perspectives, relative advantages of RISC and CISC instruction set, Data Path Design

**Unit II**

Instruction-level parallelism (ILP): Pipeline data-path, data-dependence. Challenges in ILP realization. Pipeline hazards and their solutions, out-of-order execution, branch prediction, and dynamic scheduling. VLIW and superscalar processors.

**Unit III**

Memory systems: Overview of memory hierarchy, Cache design considerations, instruction vs. data caches, write-policy and replacement policy, analysis of cache performance, and cache design for performance enhancement. Brief overview of memory technologies (SRAM, DRAM, and flash). Data Level Parallelism: Flynn Processor classification, SIMD, MIMD, GPU architectures, IO: types, models, protocols, Sockets, ISR.

**Textbook(s)**

1. J.L.Hennessy, D.A.Patterson, Computer Architecture: a quantitative approach, Morgan Kaufmann, 5th edition,
2011, ISBN: 978-1558605961.
2. William Stallings, Computer Organization and Architecture, Prentice Hall, 10th edition, 2015, ISBN-10:
013293633X, ISBN-13: 978-0132936330

3. Kai Hwang, Advanced Computer Architecture: Parallelism, Scalability, Programmability, McGraw-Hill, 3rd Ed,
2015

**Reference(s)**

1. Andrew S. Tanenbaum, Structured Computer Organization, Prentice Hall, 6th edition, 2012, ISBN: 978-
0132916523.
2. Patterson, J.L. Hennessy, Computer Organization and Design: The Hardware/Software Interface, Morgan
Kaufmann, 5th edition, 2013, ISBN-13:9780124078864

# 8.Parallel Computing

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand significance of shared and distributed memory for parallel computing
**CO2:** understand parallel communication among the cores for carrying out the parallel computation
**CO3:** understand and analyze the parallel codes, and parallel I/O algorithms
**CO4:** develop efficient the parallel codes, and parallel I/O algorithms

**Course Content:**

**Unit I**

Introduction: Parallel computing, Shared memory and distributed memory parallelism, Amdahl's law, speedup and efficiency, supercomputers. Message passing: MPI basics, point-to-point communication, collective communication, synchronous/asynchronous send/receive, algorithms for gather, scatter, broadcast, reduce.

**Unit II**

Parallel communication: Network topologies, network evaluation metrics, communication cost, routing interconnection networks, static and adaptive routing, process-to-processor mapping. Performance: Scalability, benchmarking, performance modeling, impact of network topologies, parallel code analysis and profiling.

**Unit III**

Designing parallel codes: Domain decomposition, communication-to-computation ratio, load balancing, adaptivity, AI/ML role in load balancing; case studies: weather and material simulation codes. Parallel I/O: MPI I/O algorithms, contemporary large-scale I/O architecture, I/O bottlenecks Job scheduling, RDMA, one-sided communication, NVM, extreme scale computing: issues and trends.

**Textbook(s)**

1.Peter S Pacheco, "An Introduction to Parallel Programming," Morgan Kaufmann, 2011.

2. DE Culler, A Gupta and JP Singh, Parallel Computer Architecture: A Hardware/Software Approach MorganKaufmann, 1998.

3. A Grama, A Gupta, G Karypis, and V Kumar, Introduction to Parallel Computing. 2nd Ed., Addison-Wesley,
2003.

**Reference(s)**

1. Marc Snir, Steve W. Otto, Steven Huss-Lederman, David W. Walker and Jack Dongarra, “MPI - The Complete Reference, Second Edition,” Volume 1, The MPI Core.

2. William Gropp, Ewing Lusk, Anthony Skjellum, Using MPI: portable parallel programming with the messagepassing interface, 3rd Ed., Cambridge MIT Press, 2014

# 9.Embedded Systems for Robotics

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the concept of controllers in robotic systems
**CO2:** understand the different sensors and actuators required for robotic systems
**CO3**: analyse different types of robot designs
**CO4**: develop mobile robot application

**Course Content:**

**Unit I**
Robots and Embedded Systems-Robots and Controllers: Mobile Robots-Embedded Controllers-Interfaces-Operating System, Robot operating system (ROS), Sensors, Actuators in Robots - Control - On-Off Control, PID Control, Velocity Control and Position Control, Recent Trends in Robotics

**Unit II**
Mobile Robot Design: Driving Robots- Single Wheel Drive- Differential Drive- Tracked Robots- Synchro-Drive- Ackermann Steering- Drive Kinematics, Omni-Directional Robots, Balancing Robots, Walking Robots

**Unit III**
Mobile Robots, Concepts of Localization, and path planning, Maze Exploration, Map Generation

**Textbook(s)**

Thomas Bräunl, *"Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems",* Third
Edition, Springer-Verlag Berlin Heidelberg, 2008.

**Reference(s)**

1. R.K.Mittal and I.J.Nagrath, "Robotics and Control", Tata McGraw-Hill Publishing Company Ltd., New
Delhi, 2003.
2. John J. Craig, "Introduction to Robotics: Mechanics and Control", Fourth Edition, Pearson, 2018.
3. Anis Koubaa, "Robot Operating System (ROS) The Complete Reference", First Volume, Springer, 2016.
4. K.S. Fu, R.C. Gonzalez and C.S.G. Lee, "Robotics: Control, Sensing, Vision, and Intelligence", McGraw-Hill, New York, 1987

# 10.Multi-Core Architecture

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1:** analyze and evaluate the performance of multi-core architectures
**CO2:** design and develop software for multi-core architectures using parallel programming paradigms and techniques
**CO3:** apply the knowledge of multi-core architectures to solve real-world problems in embedded systems
**CO4:** develop applications using multi-core architecture

## Course Content:

**Unit I**

Introduction to Multi-Core Architectures - Introduction to parallel computing and multi-core architectures – Characteristics and design principles of multi-core architectures - Challenges and opportunities of multi-core architectures in embedded systems - Case studies of multi-core architectures in industry and research

**Unit II**

Programming Multi-Core Architectures - Parallel programming paradigms and models - Synchronization and communication mechanisms for multi-core architectures - Performance analysis and optimization of parallel programs - Tools and libraries for programming multi-core architectures.

**Unit III**

Applications of Multi-Core Architectures in Embedded Systems - Multi-core architectures for real-time and safety-critical systems - Multi-core architectures for multimedia and signal processing applications - Multi-core architectures for Internet of Things (IoT) and Cyber-Physical Systems (CPS) - Case studies of multi-core architectures in embedded systems.

**Textbook(s)**

1. "Multi-Core Embedded Systems" by Georgios Keramidas and Stamatis Vassiliadis
2. "Programming Multi-Core and Many-Core Computing Systems" by Sabri Pllana and Fatos Xhafa
3. "Multi-Core Technologies: Foundations and Applications" by Jan F. Broenink, Henk Corporaal, and Sander Stuijk

**Reference(s)**

1. "Multi-Core Embedded Systems" edited by Georgios Keramidas and Stamatis Vassiliadis
2. "Parallel Computing: Principles and Practice" by Michael J. Quinn
3. "Parallel Programming in C with MPI and OpenMP" by Michael J. Quinn

4. "OpenMP: Portable Shared Memory Parallel Programming" by Barbara Chapman, Gabriele Jost, and Ruud van

# Open Elective I

# 1.Sensor Networks

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** analyze and evaluate the performance of sensor networks based on various metrics
**CO2:** design and implement sensor networks using various hardware and software platforms
**CO3:** identify and solve the challenges and issues related to sensor network design
**CO4:** apply the knowledge and skills in sensor networks to real-world problems and applications

**Course Content:**

**Unit I**

Introduction to Sensor Networks- Introduction to sensor networks: definitions, applications, and characteristics; Sensor network architecture and components: sensors, microcontrollers, communication modules, and power sources; Communication protocols and standards for sensor networks: IEEE 802.15.4, ZigBee, and LoRaWAN; Energy-efficient design principles for sensor networks: power management, duty cycling, and sleep/wake scheduling: Data collection and processing in sensor networks: data aggregation, compression, and filtering.

**Unit II**

Sensor Network Design and Implementation - Sensor network topology and deployment: star, mesh, and tree topologies; Localization and tracking in sensor networks: triangulation, trilateration, and fingerprinting; Security and privacy in sensor networks: encryption, authentication, and key management; Programming and development tools for sensor networks: Arduino, Contiki, and TinyOS; Hands-on lab sessions: designing and implementing a sensor network using wireless sensor nodes and microcontrollers

**Unit III**

Advanced Topics in Sensor Networks- Emerging trends and applications in sensor networks: smart cities, precision agriculture, and healthcare; Big data analytics and machine learning for sensor networks: data mining, classification, and prediction; Cloud-based sensor networks: architecture, services, and platforms; Integration of sensor networks with other systems and technologies: Internet of Things (IoT), Cyber-Physical Systems (CPS), and Wireless Sensor-Actuator Networks (WSANs); Final project: developing a sensor network application for a specific domain or problem.

**Textbook(s)**

1. Feng Zhao and Leonidas Guibas, "Wireless Sensor Networks: An Information Processing Approach,
2. N. Sastry and S. Shakkottai, "Building Wireless Sensor Networks: Theoretical and Practical Perspective,
3. Chiara Buratti, Marco Stango, and Roberto Verdone "Sensor Networks with IEEE 802.15.4 Systems: Distributed Processing, MAC, and Connectivity"

**Reference(s)**

1. Wenbo Mao, Wei Li, and Sushil Jajodia, "Security in wireless sensor networks"
**2.** Ali H. Al-Bayatti, Azween Abdullah, and Mazin Abed Mohammed, "Machine learning for wireless sensor networks: A comprehensive survey"

# 2.Deep Learning

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1:** understand the mathematics behind the functioning of artificial neural networks
**CO2:** design deep learning models for sequential and image data
**CO3:** carry out design and implementation of deep learning models for signal processing applications
**CO4:** design and deploy simple TensorFlow-based deep learning solutions to classification problems

**Course Content:**

**Unit I**

Introduction to Deep Learning: Basics: Biological Neuron, Idea of computational units, McCulloch– Pitts unit and Thresholding logic, Linear Perceptron, Activation and Loss Functions, Perceptron Learning Algorithm, Linear separability. Convergence theorem for Perceptron Learning Algorithm. Building small functions using perceptron model, Feedforward Networks: Multilayer Perceptron, Gradient Descent, Backpropagation, regularization.

**Unit II**
Convolutional Neural Network: Building a convolutional neural network. Input Layers, Convolution Layers. Pooling Layers. Dense Layers. Backpropagation Through the Convolutional Layer. Filters and Feature Maps. Backpropagation Through the Pooling Layers. Dropout Layers and Regularization. Batch Normalization, Optimizers. LeNet, AlexNet. Visualisation of various layers in CNN- Image processing using CNN-examples and applications

**Unit III**
Embedding and Representation Learning: Autoencoder Architecture-Implementing an Autoencoder in TensorFlow - Denoising- Sparsity in Autoencoders. Models for Sequence Analysis - Recurrent Neural Networks- Vanishing Gradients- Long Short-Term Memory (LSTM) Units- TensorFlow Primitives for RNN Models -Augmenting Recurrent Networks with
Attention.

**Textbook(s)**
1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, “Deep Learning”, MIT Press, 2016.
2. Yoshua Bengio "Learning deep architectures for AI." Now publishers, 2009.

**Reference(s)**

1. N.D.Lewis, “Deep Learning Made Easy with R: A Gentle Introduction for Data Science”, Createspace Independent, 2016.
2. Nikhil Buduma, “Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms”, O’Reilly, 2022.

## 3.Reinforcement Learning

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the mathematics behind reinforcement learning algorithms
**CO2**: implement probabilistic reinforcement learning algorithms
**CO3**: implement model free Reinforcement learning techniques
**CO4**: understand function approximation and deep learning-based reinforcement learning solutions

**Course Content:**

**Unit I**
Introduction- Markov Decision Process: Markov property, Markov chains, Markov reward process (MRP). Bellman equations for MRPs, Introduction to Markov decision process (MDP), state and action value functions, Bellman expectation equations, optimality of value functions and policies, Bellman optimality equations, Overview of dynamic programing for MDP-principle of optimality, iterative policy evaluation, policy iteration

**Unit II**
Overview of Monte Carlo methods for model free RL, First visit and every visit Monte Carlo, Monte Carlo control, On policy and off policy learning, Importance sampling, Incremental Monte Carlo Methods for Model Free Prediction- TD(0), TD(1) and TD(λ), k-step estimators, unified view of DP, MC and TD evaluation methods, TD Control methods - SARSA, Q-Learning and their variants.

**Unit III**

Function approximation methods- Gradient MC and Semi-gradient TD(0) algorithms, Control with function approximation, Least squares, Experience replay in deep Q-Networks-Policy Gradient methods - Log-derivative trick, Naive REINFORCE algorithm, actor-critic methods-Introduction to deep reinforcement learning methods and multi-agent reinforcement learning.

**Textbook(s)**

1. Richard S. Sutton and Andrew G. Barto, Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2019
2. Wiering, Marco, and Martijn Van Otterlo. "Reinforcement learning. Adaptation, learning, and optimization 12", Springer 2012

**Reference(s)**

1. Russell, Stuart J., and Peter Norvig. "Artificial intelligence: a modern approach", Pearson Education Limited, 2016.

**2.** M. Wiering and M. van Otterlo, “Reinforcement Learning: State-of-the-Art”, Springer, 2012

# 4.Internet of Things

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the fundamentals of IoT technology
**CO2**: visualize and appreciate the business opportunity and applications
**CO3**: understand the technology and standard for IoT
**CO4**: develop and design IoT networks for identified applications

**Course Content:**

**Unit I**
Introduction- IoT definition, use-cases and business Opportunities; IoT Architecture: Objects Layer, Object Abstraction Layer, Service Management Layer, Application Layer, Business Layer.

**Unit II**
IoT Elements- Identification, Sensing, Communication, Computation, Services, Semantics; IoT Common standards: ZigBee, BLE, WiFi, LoRa, LPWAN, IPV6, AMPQ, MQTT; Support to he IoT: Big Data Analytics, Cloud computing, and Fog computing;

**Unit III**

QoS Criteria: Reliability, Mobility, Performance, Scalability, Management, Interoperability; Security and Privacy in IoT: Confidentiality, Integrity, Availability, Privacy; IoT Applications: smart city, smart health, smart farming, smart manufacturer.

**Textbooks and References**
1. Hersent, O., Boswarthick, D. and Elloumi, O., 2011. The internet of things: Key applications and protocols. JohnWiley & Sons.
2. Burbank, J.L., Andrusenko, J., Everett, J.S. and Kasch, W.T., 2013. Wireless networking: Understanding internetworking challenges. John Wiley & Sons

## 5.Blockchain Technology

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the fundamentals of blockchain technology
**CO2**: understand development and evolution of blockchain technology
**CO3**: understand the distributed technology and system and importance of blockchain
**CO4**: develop and design platform for blockchain for the specified applications

**Course Content:**

**Unit I**
Introduction- Blockchain, Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems; Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods.

**Unit II**
(Blockchain 1.0 and 2.0) – Concepts germane to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology; Blockchain 2.0 –blockchains with smart contracts and Turing complete blockchain scripting – issues of correctness and verifiability, Ethereum platform and its smart contract mechanism.

**Unit III**
Blockchain 3.0- Plug-and-play mechanisms for consensus and smart contract evaluation engines, Hyperledger fabric platform; Applications, limitation and research direction in blockchain.

**Textbooks and references**


1. Draft version of "S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, 'Blockchain Technology: Cryptocurrency and
Applications', Oxford University Press, 2019.
2. Josh Thompson, 'Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain
Programming', Create Space Independent Publishing Platform, 2017

## 6.Understanding ICT Standardization: Principles and Practices

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the purpose of ICT standards and SDOs process
**CO2**: understand landscape of national, regional and international standardization
**CO3**: understand and distinguish between formal and de facto standardization
**CO4**: learn the process of de facto standards get adopted by SDOs

**Course Content:**

**Unit I**
Introduction- Basic of standardization, standards in everyday life, formal standardization, standard development organization (SDO) standards, regulation; benefits and risks, standardization landscape, standardization process, standard development process, Characteristics of standard, standard development life cycle.

**Unit II**
Standard organizations-formal standardization and standrds development organizations, De facto standards, sonsortia and standardization, selecting relevant SDOs, identifying SDO documents, structure and formalism of the standards; standardization documents, classification and naming conventions.

**Unit III**

National, regional and international standardization – cooperation and coordination, geographical scope in standardization, guidance for the regional and national adoption of international standards; standards supporting regulation, legislation and policy.

**Textbooks and references**
3. Nizar Abdelkaf et al. “Understanding ICT Standardization: Principles and Practices. ETSI 2021.
4. https://standards.ieee.org/develop/

# 7.System Engineering

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: describe processes, methods, and practices of systems engineering
**CO2**: apply systems engineering practices and methods to relevant examples.
**CO3**: develop requirements, architectures, specifications, verifications, and tests.
**CO4:** analyze systems using systems engineering approaches to increase performance

**Course Content:**

**Unit I**
Introduction- System Engineering overview- origin, uses and applications of systems engineering, system of systems, value of system engineering; System Building Blocks and Interfaces- Systems Engineering through the System Life Cycle, The Systems Engineering Method, Testing throughout System Development, Managing System Development and Risks Organization of Systems Engineering

**Unit II**

Concept Development- Need analysis, Originating a New System, Operations Analysis, Functional Analysis, Feasibility Definition, Needs Validation, System Operational Requirements, Developing the System Requirements, Operational Requirements Analysis, Performance Requirements Formulation, Implementation of Concept Exploration, Performance Requirements Validation Process, System Modeling Languages: Unified Modeling Language (UML) and Systems Modeling Language (SysML), Model-Based Systems Engineering (MBSE), System Functional Specifications.

**Unit III**

Implementing the System Building Blocks, Requirements Analysis, Functional Analysis and Design, Component Design, Design Validation, Integration, testing and evaluating total system; Test planning and preparation, system integration, Developmental and operational test and evaluation, Engineering for production, transition from development to production, Production operations, Installation, maintenance and upgrading, Installation testing, In-service support, Upgrades and modernization.
**Textbooks and references**

1. Alexander Kossiakoff William N. Sweet Samuel J. Seymour Steven M. Biemer, System Engineering: Principles and Practices, 2nd Edition, John Wiley and Sons, 2010.

2. Cathleen Shamieh, System Engineering for Dummies, IBM limited edition, Joh Wiley and Sons, 2012

# 8.Software Defined Networks

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to

**CO1**: understand the principles of software defined networking

**CO2**: understand standard protocols and practices in the data and control plane.

**CO3**: understand the concept of network function virtualization and provide examples of its usage.

**CO4**: understand the application of SDN in various scenarios and the challenges involved

## Course Content:

**Unit I**

Introduction – Packet switching, switch architecture, forwarding tables; Evolution of Switches and Networking – Data and control planes, cost and other constraints- Data center architecture and requirements, orchestration, virtualization- Evolution towards SDN, How SDN Works – Characteristics, operation, SDN switches and controllers, SDN Applications.

**Unit II**

OpenFlow – Overview and basics, OpenFlow 1.1-1.5, interoperability, limitations, and drawbacks of SDN, SDN via APIs and overlays- Network Function Virtualization – OPNFV, NFV vs. SDN, in-line network functions, Open Daylight and ONOS controller.

**Unit III**

Applications and Use Cases – Applications in data centers, WANs, ISPs, campus networks, optical networks, and mobile networks, reactive vs. proactive applications, internal vs. external applications.

**Textbook(s)**

*1.* Goransson P, Black C, Culver T, "Software Defined Networks: A Comprehensive Approach", Morgan Kaufmann, Second Edition, 2017.

**Reference(s)**

1. Gray K, Nadeau TD, Amsterdam Boston Heidelberg, Morgan Kaufmann, "Network Function Virtualization" 2016.
2. Nadeau TD, Gray K. SDN: "Software Defined Networks: [an Authoritative Review of Network Programmability Technologies]", 1. ed. Beijing: O'Reilly; 2013.

# 9.Information Security

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: identify and analyze various Cryptographic algorithms used in Information Security
**CO2:** analyze the firewall design and firewall characteristics for system security
**CO3**: understand the concept related to various network layers security
**CO4**: understand the various features related to physical cryptographic platform

**Course outcome:**

**Unit I**

Cryptography - Introduction to Cryptography: OSI Security Architecture - Security Services, Security Attacks, Security Mechanism. Introduction to Classical Cryptography. Modern Cryptography: Secret key Cryptography - DES, AES. Public key Cryptography - Diffie-Hellman, RSA, ECC. Introduction to Hash Algorithm, Introduction to Digital Signature, Introduction to PKI.

**Unit II**

System and Network Security-Introduction - Access Control, Intrusion Detection and Prevention. Firewalls: Firewall Design Principles - Firewall Characteristics, Types of Firewalls. Trusted System. Malicious Soft wares: Virus, Trojan Horse, Ad ware/ Spy ware, Worms, Logic Bomb. Cyber Law and Forensics - IT ACT 2000, Cyber Forensics;
**Network Security** Introduction to Network Concepts, OSI Layers and Protocols, Network Devices, Network layer Security (IPSec) – IP Security Overview, IPSec Architecture, Authentication header, Encapsulating security Payload, Combining Security Associations, Key management. Transport Layer Security - SSL/TLS, SET. Application Layer Security – Authentication Applications, Kerberos, X. 509 Authentication Services. E-mail Security – PGP, S/MIME.

**Unit III**

Embedded Security **-I**ntroduction, Types of Security Features – Physical, Cryptographic, Platform. Kinds of Devices – CDC, CLDC. Embedded Security Design, Keep It Simple and Stupid Principle, Modularity Is Key, Important Rules in Protocol Design, Miniaturization of security, Wireless Security, Security in WSN

**Textbooks**

1. Cryptography and Network Security: Principles and Practice- William Stallings

2. Practical Embedded Security: Building Secure Resource Constrained Systems -Timothy Stapko, Publisher Newnes.

**Reference(S)**

1. Cryptography: Theory and Practice – 3rd Ed. SD Stinson, CRC Press.
2. Information Security for Technical Staff-SEI.
3. Guide to firewalls & network security: with intrusion detection & VPNs- HOLDEN, GREG.
4. CISSP: Certified Information Systems Security Professional Study Guide- Stewart, James Michael Et Al

# 10 Neuroengineering

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1**: understand aspects of neuroscience and bioengineering techniques for data-based modelling
**CO2**: adopt appropriate techniques to stimulate neural system
**CO3**: develop simple electronic for acquisition of brain signal
**CO4**: develop model for neuron and extracts the characteristics

## Course Content:

### Unit I

Introduction – Neuroscience and Brain Circuits - Brain, Spinal Cord, Pathways for Movement and Perception, Neurons, Synapses, Parts of the centra nervous systems, Nonlinearity of signals in the brain, Spikes, Synaptic potentials, Population signals, Local field potentials.

### Unit II

Neuro-recording methods – EEG, single unit recording, Near-infrared spectroscopy, Transcranial direct-current stimulation (TDCS), Transcranial magnetic stimulation (TMS), Functional magnetic resonance imaging (fMRI).

### Unit III

Mixed Signal Electronics in Neuroengineering - device-tissue interactions, bioelectronics recording/stimulation interface – experiments, hardware and methods; Computational Neuroscience – Membrane modelling, Single neurons, Excitatory and Inhibitory Synapses, Simple Neural circuits and models; Neuroscience to Artificial Intelligence – Models and circuits, Learning, Hebbian and backpropagation in biological circuits, reinforcement learning, Largescale models and abstractions.

**Textbook(s)**
1. Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., McNamara, J. O., & Williams, S. M. (Eds.). (2004). Neuroscience (3rd ed.). Sinauer Associates.
2. Akay M., Handbook of Neural Engineering, 2006, Wiley

**Reference(s)**
1. N. Aryan, Stimulation and Recording Electrodes for Neural Prostheses (2014), Springer, Available at https://link.springer.com/book/10.1007/978-3-319-10052-4
2. M. Nicolelis, Methods for Neural Ensemble Recordings (2008), CRC-Press
Available at https://www.semanticscholar.org/paper/Methods-for-NeuralEnsemble-Recordings-Nicolelis/f5199d649d17cfa34a27c6e42e276eb722b17798

3. E. Kandel et al. Principles of Neural Science, McGraw-Hill Education / Medical; 6th edition (5 April 2021

# 10.Robotic System Design

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the different terminology and mechanical subsystems
**CO2**: understand and analyze the controls involved in robotic system
**CO3**: use and apply necessary sensors and controls for robotic design
**CO4**: design a robot for a specific applications

**Course Content:**

Unit I

Introduction: Classification of robots, Three laws, Robot terminologies: work volume, Degree of Freedom, resolution, accuracy, repeatability, dexterity, compliance, payload capacity, speed of response, Wrist assembly, Joint notations, Selection criteria of any robot, Industrial applications of robot, Industrial robot system, Types, Centralized robotics system controllers, decentralized robotics system controller. Real time communication and timing; Futuristic robotics; Types of drives – Hydraulic, Pneumatic and Electric, Comparison of all such drives, DC servo motors, Stepper motors, AC servo motor – salient features and applications, pulse count calculations End effectors - Types of Grippers –Mechanical, Magnetic, vacuum, pneumatic and hydraulic, selection and design considerations.

Unit II

Need for sensors, types of sensors used in Robotics, classification and applications of sensors, Characteristics of sensing devices, Selections of sensors. Robot Vision setup (RVS), block diagram, components, working of RVS, Human vision Vs Robot Vision, Gradient calculations, Applications of RVS; Mathematical details-Spatial Descriptions: positions, orientations, and frame, mappings: changing description from frame to frame, Operators: translations, rotations and transformations, Homogeneous transformations, transformation arithmetic, compound Transformations, inverting a transform, transform equations, Euler Angles, Fixed Angles, Euler Parameters.

Unit III

Manipulator Kinematics, Link Description, Link to reference frame connections, Denavit-Hartenberg Approach, D-H Parameters, Position Representations, Forward Kinematics, Inverse Kinematics; Application specific robots.
Textbook/References

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014)
2. AsitavaGhoshal, Robotics: Fundamental concepts and analysis, Oxford University Press (2006)
3. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019)

4. S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, John Wiley & Sons Ltd., (2020)

## 11.Cyber Physical Systems

**Course Code-** **L:T:P-**

**Rationale**

**Course Outcomes**

At the end of the course, the student should be able to
**CO1**: understand the mathematical concepts of CPS
**CO2**: apply model based design to build CPS models
**CO3**: analyze the performance of simple CPS models
**CO4**: understand the role of networking, sensing, security and intelligent systems

**Course Content:**

Unit I

Introduction – Overview of CPS, characteristics, CPS in the real world, Computational vs. Physical Systems, Fundamental approach, CPS Genesis, Modeling, Design, Verification and Validation, Assembly and Deployment; trends and challenges of modern cyber-physical systems.

Unit II

Modeling Cyber-Physical Systems: Overview of Continuous, Discrete, and Hybrid Models, dynamics of a physical system; Properties of Systems - Causal Systems, Memoryless Systems, Linearity and Time Invariance, Stability; Feedback Control, Controller Design techniques, Logic based system specification; Discrete Systems - Discrete Signals, Modeling Actors as Functions; The Notion of State - Finite-State Machines, Transitions, When a Reaction Occurs, Update Functions, Software Tools Supporting FSMs, Moore Machines and Mealy Machines.

Unit III

Requirements and Design- Processors and Sensors: Sensors and CPS – trends, Sensors, CPS, and IoT, Actuators and servos, Embedded CPS architectures, Communications, Security, Processors; CPS design and analysis of their performance - Canonical Example: Stopping a car, Feedback, Reduced-gravity Drone; Trajectory Planning and examples, Aviation example, Typical requirements; Guidance techniques, Classical optimization and examples, Dynamic Programs, Automotive example.

**Textbook(s)**
1. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015
2. Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2011.

**References(s)**
**http://www.feron.org/Eric/OMSCS-CyberPhysicalSystems/page.html**
http://LeeSeshia.org

# 12.Physical Chemistry of Materials and Processes

**Course Code-** **L:T:P-**

## Rationale

## Course Outcomes

At the end of the course, the student should be able to
**CO1**: understand the physical properties of semiconductors
**CO2**: understand the impact of defects in semiconductors
**CO3**: understand growth of semiconductor materials
**CO4**: understand the processing of semiconductor materials

## Course Content:

### Unit I

Elemental and compound semiconductor materials, structural, electronic and optical properties, Defects in Semiconductors - Point Defects in Ionic Solids: Modelling the Electrical Conductivity of Ionic Solids by Point Defects, Mediated Charge Transfer, Point Defects and Impurities in Elemental Semiconductors, Vacancies and Self-Interstitials in Semiconductors with the Diamond Structure, Effect of Defect–Defect Interactions on Diffusivity: Trap-and-Pairing Limited Diffusion Processes, Light Impurities in Group IV Semiconductors: Hydrogen, Carbon, Nitrogen, Oxygen and Their Reactivity

### Unit II

Growth of Semiconductor Materials - Growth of Bulk Solids by Liquid Crystallization, Growth of Si-Ge Alloys, Single Crystal Growth from the Vapour Phase - Epitaxial Growth of Single Crystalline Layers of Elemental and Compound Semiconductors, Growth of Poly/Micro/Nano-Crystalline Thin Film Materials- Growth of Nanocrystalline/Microcrystalline Silicon, Growth of Silicon Nanowires

### Unit III

Semiconductor Materials Processing - Thermal Annealing Processes, Rapid thermal processing, Hydrogen Passivation Processes, Introduction to Gettering and Defect Engineering, Oxidation, Diffusion and ion implantation, Chemical and physical deposition methods, Wafer Bonding.

### Textbook(s)

1. Sergio Pizzini, Physical Chemistry of Semiconductor Materials and Processes, 2015, John Wiley & Sons.
2. S. Cambell, The Science & Engineering of Microelectronic Fabrication, Oxford, 1996.

### Reference(s)

1. S.P. Mauraka and M.C. Peckerar, Electronic Materials Science and Technology, Academic Press, 1989.

# 13.Leadership from the Ramayana

Introduction to Ramayana, the first Epic in the world – Influence of Ramayana on Indian values and culture –Storyline of Ramayana – Study of leading characters in Ramayana – Influence of Ramayana outside India – Relevance of Ramayana for modern times

## 14. **Strategic Lessons from the Mahabharata**

Introduction to Mahabharata, the largest Epic in the world – Influence of Mahabharata on Indian values and culture – Storyline of Mahabharata – Study of leading characters in Mahabharata – Kurukshetra War and its significance - Relevance of Mahabharata for modern times

## 15 .**Lessons from the Upanishads**

Introduction to the Upanishads: Sruti versus Smrti - Overview of the four Vedas and the ten Principal Upanishads - The central problems of the Upanishads – The Upanishads and Indian Culture – Relevance of Upanishads for modern times – A few Upanishad Personalities: Nachiketas, SatyakamaJabala, Aruni, Shvetaketu

## 16. **Message of the Bhagavad Gita**

Introduction to Bhagavad Gita – Brief storyline of Mahabharata - Context of Kurukshetra War – The anguish of Arjuna – Counsel by Sri. Krishna – Key teachings of the Bhagavad Gita – Karma Yoga, Jnana Yoga and Bhakti Yoga - Theory of Karma and Reincarnation – Concept of Dharma – Concept of Avatar - Relevance of Mahabharata for modern times.

## 17. **Life and Message of Swami Vivekananda**

Brief Sketch of Swami Vivekananda’s Life – Meeting with Guru – Disciplining of Narendra - Travel across India - Inspiring Life incidents – Address at the Parliament of Religions – Travel in United States and Europe – Return and reception India – Message from Swamiji’s life

## 18. **Life and Teachings of Spiritual Masters India**

Sri Rama, Sri Krishna, Sri Buddha, AdiShankaracharya, Sri Ramakrishna Paramahamsa, Swami Vivekananda, Sri RamanaMaharshi, Mata Amritanandamayi Devi.

## 19. **Insights into Indian Arts and Literature**

The aim of this course is to present the rich literature and culture of Ancient India and help students appreciate their deep influence on Indian Life - Vedic culture, primary source of Indian Culture – Brief introduction and appreciation of a few of the art forms of India - Arts, Music, Dance, Theatre

## 20. **Yoga and Meditation**

The objective of the course is to provide practical training in YOGA ASANAS with a sound theoretical base and theory classes on selected verses of Patanjali’s Yoga Sutra and Ashtanga Yoga. The coverage also includes the effect of yoga on integrated personality development.