ACADEMIC AFFAIRS OFFICE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

No. Acd./2373/IAPC-114 Dated: December 22, 2021

Head, Department of Electronics and Communication Engineering

The IAPC in its 114th meeting held on 01.12.2021 vide Item No. 114.2.2 considered and approved the proposal of Department of Electronics and Communication Engineering to introduce the following PECs with minor modifications:

1. ECN-347: Introduction to Microwave Semiconductor Device Modelling Techniques
2. ECN-634: Low Voltage CMOS Circuit Operation
3. ECN-635: Magnetic Random Access Memory

The modified syllabus of above courses is attached as **Appendix-A**.

Assistant Registrar (Curriculum)

Encl: as above

Copy to (through e mail):-

1. All faculty
2. Head of all Departments / Centres
3. Dean, Academic Affairs
4. Associate Dean of Academic Affairs (Curriculum)
5. Channel i/ Acad portal/ Academic webpage of iitr.ac.in

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-347 **Course Title**: Introduction to Microwave Semiconductor Device Modelling Techniques
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of operating principles of Electronic Devices.
9. **Objective:** To introduce methods for modelling of semiconductor devices for RF/Microwave applications.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** General RF circuit terminology and operations, Noise, diode and transistor based RF circuits- Switches, attenuators, amplifiers, frequency multipliers and phase shifter circuits, Device parasitic, thermal behavior and device nonlinearities.	7
2.	**Device parameter extraction technique:** Extrinsic and intrinsic parameter extraction- Open, short, thru, open-short-thru, Multiport de-embedding, examples of de-embedding, Load pull techniques.	6
3.	**Modelling of Diodes:** Conventional PN junction diode modelling, PIN diode modelling- lumped element modelling, equivalent circuit models, integral based model, reverse bias modelling, forward and reverse bias distortions, time domain models, modelling of varactor and schottkey diodes, modelling of Tunnel diode, modelling of Gunn diode	6
4.	**Modelling of MESFET/MOSFET and HEMT Devices:** Bulk MESFET/MOSFET technology, MESFET/MOSFET capacitance characteristics, HEMT technology, MESFET/MOSFET and HEMT device characteristics, HBT device characteristics, SPICE modelling, Angelov and ASM HEMT models, HBT noise model, MESFET/MOSFET and HEMT noise model	8
5.	**Switched RF Circuits:** Basic Transmit/receive (T/R) switches, Specific T/R switches-two device SPDT switch, 4 device SPDT switches, tunes $\lambda/4$ transmission line SPDT T/R switches, switched passive elements for tuning and matching, RF attenuators, RF limiters and phase shifters	8
6.	**Transistor based RF Circuits:** Small and large signal transistor based circuits, design of single stage amplifier using HBT/MESFET/HEMT/MOSFET, Frequency multipliers	7
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	R. H. Caverly, "Microwave and RF Semiconductor Control Device Modelling", Artech House	2016
2.	S. M. Sze and K. K. Ng, "Physics of Semiconductor Devices", John Wiley & Sons	2007
3.	K. Chang, I. Bahl and V. Nair, "RF and Microwave Circuit and Component Design for Wireless Systems", John Wiley & Sons	2002
4.	G. D Vendelin, A. M. Pavio and U. L. Rohde, "Microwave Circuit Design using Linear and Nonlinear Techniques", John Wiley & Sons	2005
5.	E. Camargo, "Design of FET Frequency Multipliers and Harmonic Oscillators", Artech House	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-634 **Course Title**: Low Voltage CMOS Circuit Operation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of digital and analog VLSI circuit design/analysis, MOS device physics.
9. **Objective:** To understand essential aspects of low voltage operation of MOSFETs and CMOS circuits comprehensively and to learn to design such circuits.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Metrics for evaluating application performance, evaluating, and summarizing performance, energy management approaches (e.g., DVFS).	1
2.	MOSFET operation in weak inversion: Inversion/depletion charge, I-V characteristics, C-V characteristics and device capacitances, short channel effects. 1/f/white/flicker noise.	10
3.	Near-threshold digital CMOS circuits: Transistor sizing in combinational and sequential circuits, warning flip-flops, CMOS memory design and noise margins, dynamic circuits, resilient circuits, PVT variations	8
4.	Low voltage analog circuits: Building blocks of OPAMP, OPAMP design, voltage/current references, switched capacitor circuits. Coping with PVT variations. Noise in circuits.	8
5.	Low voltage mixed-signal circuits: Building blocks for PLLs, PLLs, building blocks for ADCs, ADCs, filters.	9
6.	FinFETs: I-V/C-V in weak inversion, device capacitances, noise, digital, analog circuits.	6
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Sub-Threshold Design for Ultra Low-Power Systems, A. Wang, B. H. Calhoun, and A. P. Chandrakashan, Springer	2006
2.	Low voltage CMOS VLSI Circuits, by J. B. Kuo and J.H Lou, Wiley	1999
3.	Charge-based MOS transistor Modelling The EKV Model for Low-Power and RF IC Design By C.C. Enz and E.A. Vittoz, Wiley	2006
4.	Design of Low-Voltage CMOS switched-Opamp switched-capacitor Systems by V.S.L. Cheung and H.C. Luong, Kluwer Academic Publishers	2003
5.	Low Voltage CMOS Operational Amplifiers (Theory, Design, and Implementation) by S. Sakurai and M. Ismail, Springer	1995
6.	Digital Integrated Circuits, A Design Prospective by J.M. Rabaey, Prentice Hall	2002
7.	Circuit Techniques for Low-voltage and high-speed A/D converters by M.E. Waltari and K.A.I. Halonen, Kluwer Academic Publishers	2002
8.	CMOS Mixed Signal Circuit Design by R.J. Baker, Wiley	2003
9.	Analog Integrated Circuit Design by Tony Chan Carusone, David A. Johns and Kenneth W. Martin, Wiley	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-635 **Course Title**: Magnetic Random Access Memory
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Vector algebra, Basic electromagnetics
9. **Objective:** To introduce the concepts required to understand the emerging magnetic memory and logic devices.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Introduction: Memory organization, requirements for next-generation of memory, magnetic random access memory - history and timeline	2
2.	Fundamentals of magnetism: Origin of magnetism, types of magnetic materials, temperature dependence, magnetic hysteresis, magnetostatics, magnetic anisotropy	6
3.	Micromagnetic modeling: Continuum approach to describe magnetization, energy minimization and equilibrium configurations, magnetization dynamics – Landau-Lifshitz-Gilbert (LLG) equation of motion, Stoner-Wohlfarth model, finite temperature effects, Fokker-Planck equation, domain walls	10
4.	Spin-transfer-torque magnetic random access memory (STT-MRAM): Read and write mechanism, magnetic tunnel junction, magnetoresistance, spin-transfer-torque induced switching, threshold current and switching probabilities, thermal stability and retention times, reliability issues, comparison with other types of memories	10
5.	Experimental techniques: Growth of magnetic multilayers - epitaxy, sputtering, fabrication process, characterization techniques	8
6.	Related concepts and emerging applications: Current-driven domain wall motion, spin-orbit-torque, topological insulators, voltage-controlled-magnetic anisotropy, Dzyaloshinskii–Moriya interaction, antiferromagnetic memory, applications - cache memory, embedded-memory, neuromorphic hardware etc.	6
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	A. Aharoni, "Introduction to the Theory of Ferromagnetism", Oxford Science Publications	2000
2.	J.M.D. Coey, "Magnetism and Magnetic Materials", Cambridge University Press	2010
3.	B. Dieny, R.B. Goldfarb, K-J Lee, "Introduction to Magnetic Random Access Memory", IEEE Press, Wiley	2017
4.	Evgeny Y. Tsymbal, Igor Zutic, "Handbook of Spin Transport and Magnetism", Taylor and Francis	2011
5.	Denny D. Tang, Yuan-Jen Lee, "Magnetic Memory Fundamentals and Technology", Cambridge University Press	2010
6.	Ralph Skomski, "Simple Models of Magnetism", Oxford University Press	2008
7.	B. D. Cullity, C. D. Graham, "Introduction to Magnetic Materials", Wiley-IEEE Press	2010