EIC 501:ADVANCED INSTRUMENTATION 3-0-0

MODULE I

Generalized Configurations, Functional description & performance characteristics of measuring Instruments: Functional Elements of an instrument; active & passive transducers; analog & digital modes of operation; null & deflection methods; I/O configuration of measuring instruments & instrument system – methods of correction for interfering & modifying inputs. Generalized performance characteristics of Instruments: Static characteristics and static calibration- Meaning of static calibration, measured value versus true value,

MODULE II

Motion and Dimensional measurement: Fundamental standards, relative displacements-translational and rotational, Calibration, Resistive potentiometers, differential transformers, variable inductance & variable reluctance pickups, capacitance pickup, Piezo-electric transducers, digital displacement transducers, Mechanical revolution counters and timers.

MODULE III

Force, Torque, Shaft Power and Pressure measurement: Standards & calibration; basic methods of force measurement; characteristics of elastic force transducer- strain gauge, differential transformer, Piezo electric transducer, variable reluctance/FM-oscillator, digital systems. Loading effects; Torque measurement on rotating shafts, shaft power measurement (dynamometers). Methods of pressure measurement; gauges & manometer.

MODULE IV

Flow measurement: Local flow velocity, magnitude and direction. Flow visualization. Velocity magnitude from pilot static tube. Velocity direction from yaw tube, pivoted vane, servoed sphere, dynamic wind vector indicator. Hot wire and hot film anemometer. Hot-film shock-tube velocity sensor. Laser Doppler anemo-meter; gross volume flow rate: calibration and standards.. Metering pumps. Electromagnetic flow meters.

MODULE V

Temperature measurement: Standards & calibration; thermal expansion methods- bimetallic thermometers, pressure thermometers; thermoelectric sensor (thermocouple) – common thermocouple, Radiation Methods – radiation fundamentals, radiation detectors thermal and photon.

Text Books: E. DOEBELIN and D. N. Manik, “Measurement systems application and design”, 5th Ed., TMH, 2007, New Delhi.

EIC 503: ADNANCED CONTROL THEORY **3-0-0 (3 credits)**

MODULE I

Non linear systems, Modelling Quasi-linearisation, stability of non-linear systems, phase plane methods, describing function methods, deriving describing function from FFT.

MODULE II

Popov's circle criterion, stability analysis using Lyapunov method, parameter plane analysis. Modal control, Pole allocation by SV and output feedback. Order reduction of linear system

MODULE III

CONVENTIONAL DESIGN METHODS

Design specifications- PID controllers and compensators- Root locus based design-Bode based design-Design examples

MODULE IV

DESIGN IN DISCRETE DOMAIN

Sample and Hold-Digital equivalents-Impulse and step invariant transformations- Methods of discretisation-Effect of sampling- Direct discrete design – discrete root locus Design examples

MODULE V

Linear Optimal Control with quadratic performance index Formulation, matrix Riccati equation, special cases, Lyapunovs's equation, LQR problem with prescribed degree of stability (Anderson formulation).

Suggested Books;

1. Tan,J.-Modern Control Theory, Mc. Grawhill.
2. Gibson, J.E.- Non linear system , Mc. Grawhill.
3. Alhems M and Falb P.L-Optimal Control, Mc. Grawhill.
4. Anderson and Moore- Optimal Control,PH
5. Bryon and Ho – Applied Optimal Control, John Wiley.
6. Thomson and Stevant- Nonlinear and dynamics and control,Wiley.
7. Vidyasagar- Nonlinear system analysis,PH
8. Atherton,- Nonlinear Control Engineering, Van Nostrand

EIC 505: OPTIMAL CONTROL THEORY 3-0-0 (3 Credits)

MODULE I

INTRODUCTION Statement of optimal control problem – Problem formulation and forms of optimal Control– Selection of performance measures. Necessary conditions for optimal control – Pontryagin's minimum principle – State inequality constraints – Minimum time problem.

MODULE II

LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING Linear optimal regulator problem – Matrix Riccatti equation and solution method –Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation.

MODULE III

NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL Numerical solution of 2-point boundary value problem by steepest descent and Fletcher.Powell method solution of Ricatti equation by negative exponential and interactive methods.

MODULE IV

FILTERING AND ESTIMATION Filtering – Linear system and estimation – System noise smoothing and prediction –Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation – Least square estimation – Recursive estimation.

MODULE V

KALMAN FILTER AND PROPERTIES Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter.

Suggested Books:

1. KiRk D.E., 'Optimal Control Theory – An introduction', Prentice hall, N.J., 1970.
2. Sage, A.P., 'Optimum System Control', Prentice Hall N.H., 1968.
3. Anderson, BD.O. and Moore J.B., 'Optimal Filtering', Prentice hall Inc., N.J.,1979.
4. S.M. Bozic, "Digital and Kalman Filtering", Edward Arnould, London, 1979.
5. Astrom, K.J., "Introduction to Stochastic Control Theory", Academic Press, Inc, N.Y., 1970.

EIC 531ADVANCE INSTRUMENTATION & CONTROL LAB 0-0-3 (2 Credits)

1. NI's LabVIEW and ELVIS simulation based practices.
2. MATLAB simulation based practices.
3. PSPICE based practices.

List of Equipment

Instrumentation tutor comprising of various sensor modules like thermocouple, RTD, Thermistor, Tachogenerator, Inductive pick-up, Capacitive pick-up, strain Gauge, LVDT, Piezoelectric pickup, Magnetic pick-up, Photo electric pick up, LDR vibrating beam pick up etc with display and calibrating facilities. Sensor modules with input modulation and output display, Recording facilities: Strain gauge, Thermocouple and other temperature sensors, LVDT, Level, Displacements, Acceleration, Load cells, etc.

AD 590, Thermocouples. Shaft encoders Synchros: transmitters, Control transformers, Differential transmitter, Pressure transducer. Variable Power supply, CRO. Photodetectors.

1. Design and simulation of Linearised models using MATLAB/PSPICE.
2. Simulation and analysis of State space models for continuous time and discrete time systems using MATLAB/PSPICE.
3. Design and Simulation of LTI models of Feedback Control System using MATLAB/PSPICE.
4. Simulation and analysis of Digital Control System using MATLAB/PSPICE.
5. Simulation and Stability analysis of control system with common non-linearities using MATLAB/PSPICE.
6. Familiarization and use of MATLAB command associated with Robust Control Systems.
7. Familiarization and use of PSIM software.

EIC 603: ADVANCE PROCESS CONTROL **3-0-0 (3 Credits)**

MODULE I

PROCESS DYNAMICS :- Introduction to process control-objective of modeling-models of industrial process hydraulic tanks-fluid flow systems-mixing process-chemical reactions-thermal systems heat exchangers and distillation column.

MODULE II

CONTROL ACTIONS AND CONTROLLER TUNING :- Basic control actions-on/off, P, P+I, P+I+D, floating control-pneumatic and electronic controllers- controller tuning-time response and frequency response methods- non-linear controllers.

MODULE III COMPLEX CONTROL TECHNIQUES :-Feed forward-ratio-cascade-split range-inferential-predictive-adaptive and multivariable control.

MODULE IV

PROGRAMMABLE LOGIC CONTROLLERS :- Evolution of PLC – Sequential and Programmable controllers – Architecture – Programming of PLC – Relay logic and Ladder logic – Functional blocks – Communication Networks for PLC.

MODULE V

COMPUTER CONTROL OF PROCESSESS :- PLC based control of processes Computer control of liquid level system – heat exchanger – Smart sensors and Field bus.

Suggested Books

1. George Stephanopolus, "Chemical Process Control", Prentice Hall India
2. Harriot P., “Process Control”, Tata McGraw-Hill, New Delhi, 1991.
3. Norman A Anderson,” Instrumentation for Process Measurement and Control” CRC Press LLC, Florida, 1998.
4. Dale E. Seborg, Thomas F Edgar, Duncan A Mellichamp, “Process dynamics and control”, Wiley John and Sons, 1989.
5. Marlin T.E., “Process Control”, Second Edition McGraw hill, New York, 2000.
6. Balchan J.G. and Mumme G., “Process Control Structures and Applications”, Van Nostrand Renhold Co., New York,1988.
7. Lucas M.P, “Distributed Control System”, Van Nostrand Reinhold Co. NY 1986
8. Pertrezeulla, “Programmable Controllers”, McGraw-Hill, 1989
9. Chidambarm. M, “ Computer control of processes”, Narosa Publications, 2002.

EIC 504:BIOMEDICAL INSTRUMENTATION 3-0-0 (3 Credits)

MODULE I

Introduction to the physiology of cardiac, nervous and muscular and respiratory systems. Transducers and Electrodes : Different types of transducers and their selection for Biomedical applications, Electrode theory, Different types of electrode Hydrogen Calomel, Ag-Agcl, Ph, Po2 Pco2 electrodes, selection criteria of electrodes.

MODULE II

Cardiovascular measurement: The heart and other cardio vascular systems, Measurement of Blood pressure, Blood flow, Cardiac output and cardiac rate, Electrocardiography, Phonocardio-graphy, Ballistocardiography, Plethysmography, Magnet-Cardiography, Cardiac pace-maker, Computer applications. Measurement of electrical Activities in Muscles and Brain: Electromyography, Electroencephalograph and their interpretation.

MODULE III

Respiratory system measurement: Respiratory mechanism, Measurement of gas volume, flow rate carbon dioxide & oxygen concentration in inhaled air, Respiratory controller. Instrumentation for clinical laboratory: Measurement of pH value of blood. ESR Measurement, Haemoglobin Measurement, oxygen & carbon dioxide concentration in blood, GSR Measurement,

MODULE IV

Medical Imaging: Ultra sound Imaging, Radiography, MRI, Electrical tomography & applications.

MODULE V

Biotelemetry: Transmission and reception aspects of biological signals via long distances. Aspects of patient care monitoring

Ref. Books:

1. Webster J S –Medical instrumentation-Application & Design.
2. Cromwell L Biomedical instrumentation, PHI
3. Khandpur R S Hand book on Biomedical instrumentation,TMH,N.Delhi1991.
4. Astor B R introduction to Biomedical instrumentation & measurement, McMillan.

EIC 506: TRANSDUCERS & SENSORS **3-0-0 (3 Credits)**

MODULE I

Evolution and Trends in Instrumentation Evolution: Kelvinian Concept of Measurement, Instrumentation - Many Facets, Sensors – Techniques and Technology. Signal Conditioning & Signal Processing, Signal Transmission, End Devices and Interfacing. The Trends: Taking up new challenges, Smart and Intelligent Sensors, Introduction to Image Based Instrumentation.

MODULE II

Classification of Instrumentation Transducer_Analog/digital, Active/passive, Force balance, Variable Resistance Transducers, Potentiometers, Strain Gauges, Resistance Thermometers, Thermistors, Hotwire Anemometers, Ac and Dc Bridges and Half bridges.

MODULE III

Concepts based on Natural Human Reasoning Fuzzy Logic Based Instrumentation, Artificial Neural Networks and Expert Systems.

MODULE IV

Concepts based on Statistical Analysis. Estimation and Correlation Techniques, Concept of Conventional Filtering and Estimators.

MODULE V

Electrical Sensors in Instrumentation. Introduction, Active Sensors: Thermocouple, Piezoelectric Sensors, pH Sensors. Passive Sensors: Inductance Sensors, Capacitance Sensors. Optical Sensors: Classification based on signal acquisition techniques and coherency of optical sources.

Text Books:

1. Herman K p Neubert, "Instrument Transducers-An introduction to their performance and design", Oxford University Press 2nd Edition, 12th Impression 2011.
2. M K Ghosh, S Sen & S Mukhopadhyay, "Measurement & Instrumentation-Trends & Applications", Ane Books Pvt. Ltd. (2009 Reprint)

Reference Books:

3. Doeblin, E.O. – Measurement Systems: Application and Design, Mc Graw Hill International.
4. Patranabis, D – Sensors and Transducers, Wheeler Pub., New Delhi.
5. B C Nakra & K K Chaudhary, "Instrumentation, Mesurement and Analysis" Tata Mc Graw Hill. Fourt Reprint 2005.
6. Murthy, D.V.S., Transducers and Instrumentation, PHI, New Delhi.
7. Alexander D Khazan, "Transducers and their elements – Design and application", PTR Prentice Hall, 1994.

EIC 601:DIGITAL INSTRUMENTATION **3-1-0 (4 Credits)**

MODULE I

DAS:- Overview of A/D converter, types and characteristics – Sampling , Errors. Objective – Building blocks of Automation systems –Counters – Modes of operation- Frequency, Period, Time interval measurements, Prescaler, Heterodyne converter for frequency measurement, Single and Multi channel Data Acquisition systems.

MODULE II

INTERFACING AND DATA TRANSMISSION Data transmission systems – 8086 Microprocessor based system design – Peripheral Interfaces – Time Division Multiplexing (TDM) – Digital Modulation – Pulse Modulation – Pulse Code Format – Interface systems and standards – Communications.

MODULE III

INSTRUMENTATION BUS Introduction, Modem standards, Basic requirements of Instrument Busstandards, Bus communication, interrupt and data handshaking, Interoperability, interchangeability for RS-232, USB, RS-422, RS-485

MODULE IV

PARALLEL PORT BUSES Field bus, Mod bus, GPIB, IEEE-488, VME, VXI, Network buses – Ethernet – TCP/IP protocols; CAN bus- basics, Message transfer, Fault confinement.

MODULE V

CASE STUDIES PC based DAS, Data loggers, PC based industrial process measurements like flow, temperature, pressure and level development system, CRT interface and controller with monochrome and color video display.

Suggested Books:-

1. A.J. Bouwens, “Digital Instrumentation” , TATA McGraw-Hill Edition, 1998.
2. N. Mathivanan, “Microprocessors, PC Hardware and Interfacing”, Prentice-Hall India, 2005.
3. H S Kalsi, “Electronic Instrumentation” Second Edition, Tata McGraw-Hill,2006.
4. Joseph J. Carr, “Elements of Electronic Instrumentation and Measurement” Third Edition, Pearson Education, 2003.
5. Buchanan, “Computer busses”, Arnold, London, 2000.
6. Jonathan W Valvano, “Embedded Microcomputer systems”, Asia Pvt. Ltd., Brooks/Cole, Thomson, 2001.

EIC 502: ROBUST & ADAPTIVE CONTROL **3-0-0 (3 credits)**

MODULE I

System identification, Problem statement, classical stochastic approach, Kalman filters, structure of on line parameter identifiers.

MODULE II

Adaptive control. Need for adaptation, parameter plane analysis, limitation of gain-schedule, structure of self adaptive and auto tuned control systems, stability of adaptive controller.

MODULE III

Multivariable Frequency domain approach for linear systems. Characteristics loci, Nyquist arrays, stability criteria, decoupling and compensation.

MODULE IV

Robust Control. Definition and problem statement, the H(n) norm, $H\propto$ norm, frequency domain formulation, state space formulation robust stabilization H2 optimal control, $H\propto$ control.

Ref. book:

1. Astrom, - Adaptive Control Techniques, Pearson.
2. Sastry, S. and Bodson - Adaptive Control (Stability, Convergence and robustness).
3. Peter Dorato - Robust Control.
4. Morari and Zafirious - Robust Process Control.

EIC 605: DIGITAL & NON LINEAR CONTROL 3-0-0 (3 credits)

MODULE I

PHASE PLANE ANALYSIS Concepts of phase plane analysis- Phase portraits- singular points-Symmetry in phase plane portraits-Constructing Phase Portraits- Phase plane Analysis of Linear and Nonlinear Systems- Existence of Limit Cycles. Describing Function Fundamentals-Definitions-Assumptions-Computing Describing
Functions-Common Nonlinearities and its Describing Functions-Nyquist Criterion and its Extension-Existence of Limit Cycles-Stability of limit Cycles.

MODULE II

LYAPUNOV THEORY Nonlinear Systems and Equilibrium Points-Concepts of Stability-Linearization and Local Stability-Lyapunov's Direct Method-Positive definite Functions and Lyapunov Functions- Equilibrium Point Theorems-Invariant Set Theorems-LTI System Analysis based on Lyapunov's Direct Method-Krasovski's Method-Variable Gradient Method-Physically Control Design based on Lyapunov's Direct Method.

MODULE III

FEEDBACK LINEARIZATION Feedback Linearization and the Canonical Form-Mathematical Tools-Input-State Linearization of SISO Systems- input-Output Linearization of SISO Systems-Generating a Linear Input-Output Relation-Normal Forms-The Zero-Dynamics-Stabilization and Tracking-Inverse Dynamics and Non-Minimum-Phase Systems-Feedback Linearization of MIMO Systems Zero-Dynamics and Control Design.

MODULE IV

SLIDING MODE CONTROL

Sliding Surfaces- Continuous approximations of Switching Control laws-The Modeling/Performance Trade-Offs-MIMO Systems.

MODULE V

Review of Z-transform. Computation of time response of Discrete Data system. Billnear Transformation. W-plane, prewarping, inverse transformation. Design of discrete controllers. Z-domain compensation, w-plane compensation, state variable feedback deadbeat controller, sampled data version of PID controllers. Effect of Data Digitization. Effect of finite word size, limit cycle determination. State Variable Analysis of Digital Control Systems.

Suggested Books

1. J A E Slotine and W Li, Applied Nonlinear control, PHI, 1991.
2. Hasan Khalil, "Nonlinear systems and control", Prentice Hall.
3. S H Zak, "Systems and control", Oxford University Press, 2003.
4. Torkel Glad and Lennart Ljung, "Control Theory – Multivariable and Nonlinear Methods", Taylor & Francis, 2002.
5. G. J. Thaler, "Automatic control systems", Jaico publishers, 1993.
6. P.Albertos, A. Sala," Multivariable Control System", Springer, 2004
7. Gopal, M. – Digital Control Engineering, New Age International. New Delhi.
8. Kuo, B. C. – Digital Control Systems , Oxford University Press.
9. Kuo, B. C. – Analysis and Synthesis of sampled-data control system, PHI
10. Houpies, C. H. - Digital Control Systems (Hardware and Software).
11. Philips and Nagle – Digital Control System Analysis and Design.

1. **STUDY AND MEASUREMENT OF BIO-MEDICAL SIGNALS**

1. Vernier Bioinstrumentation Sensor Kit

- **EKG Sensor**
  - Offset: ~1.00 V (±0.3 V)
  - Gain: 1 mV body potential / 1 V sensor output

- **Hand Grip Heart Rate Monitor Specifications**
  - Receiver range: 80–100 cm
  - Transmitter transmission frequency:5 kHz ±10%
  - Receiver current consumption: 30–55 µA
  - Transmitter operating temperature: 0–60 ˚C

- **Hand Dynamometer Specifications**
  - Accuracy: ±0.6 N
  - Power: 7 mA @ 5VDC
  - Resolution: 0.2141 N
  - Safety range (maximum force without damage done to sensor): 0 to 850 N
  - Operational range: 0 to 600 N

- **O_2 Gas Sensor Specifications**
  - Measurement Range: 0–27% (0-270 ppt)
  - Accuracy (@ Standard Pressure 760 mmHg): +/- 1% volume O2
  - Resolution: 0.01%
  - Output Signal Range: 0 to 4.8 VDC; 2.7 to 3.8 VDC @ 21% O2
  - Output Impedance: 1 KΩ
  - Input Voltage: 5 VDC +/–0.25 VDC

- **Surface Temperature sensor Specifications**
  - Temperature range: –25 to 125°C (–13 to 257°F)
  - Maximum temperature that the sensor can tolerate without damage: 150°C
  - Temperature sensor: 20 kΩ NTC Thermistor
  - Accuracy: ±0.2°C at 0°C, ±0.5°C at 100°C

- **Blood Pressure sensor Specifications**
  - Pressure range: 0 mm Hg to 250 mm Hg
  - Maximum pressure without permanent damage: 1030 mm Hg
  - Typical accuracy: ± 3 mm Hg
  - Temperature Compensated: 0 °C to 50 °C
  - Sensing element: SenSym SDX05D4
  - Combined linearity and hysteresis: typical ±0.2% full scale
  - Response time: 100 microseconds

- **Spirometer Specifications**

- Flow rate: ±10 L/s
- Dead Space: 93 mL
- Nominal Output: 60 µV/[L/s]
- Detachable Flow Head
- Dimensions: 80.5 mm (diameter) × 101.5 mm (length)
- Mass: 80 g
- Construction: Clear acrylic plastic
- Dimensions: 127 mm × 23 mm × 35 mm
- Mass: 85 g
- Construction: Black ABS plastic
- Cable length: 1.5 meters
- Default Sampling Rate:
- Computer: 100 samples/s
- TI Calculator: 50 samples/s

- **Analog Proto Board Connector Specification**
  - 0 – 5 volt raw signal.

Experimental Panel :-

- Automation of Brain-Wave Experiments in the Neurophysiology Laboratory, using NI LabVIEW.
- Implement of Simple EKG.
- Implementation of Filters
- Designing Bioinstrumentation Amplifier to Record ECG Signals.
- Design of ECG Analysis System.

- Complete working manual should contain theory including range and rating of required equipments & essential formulae, experimental procedure, circuit details, calculations, discussion on results (theoretical versus practical) and Questions for further work.

- **Myolectric Kit**
- Integrate an isolated EMG amplifier and PWM-controlled servo motor to explore prosthetic control
- Build student intuition by working through the steps involved in acquiring an actual EMG signal
- Measure and implement real-time signal processing and control using the same software platform
- Save time with comprehensive curriculum that enables a deep understanding of engineering principles

Myoelectric Sensor

- Analog output +/-5 V
- Servo
- Operating range 4.8-6.0 V
- Stall torque 0.294 N.m
- Dimensions 2.9x1.3x3.0 cm
- Weight 21.9 g

Experimental Panel :-

- Introduction to NI LabVIEW and Data Acquisition.

- Acquisition of Biopotentials using NI LabVIEW.
- Analysis of ECG and EEG Signals.
- Build an ECG based on an Instrumentation Amplifer.
- To conduct ECG measurement
- To conduct EMG/EEG measurement.
- To measure electrical signal produced during muscle contraction.
- To determine person's heart rate, while mobile or stationery (performed with wireless hand grips.)
- To measure systolic and diastolic blood pressure utilizing oscillometric technique.
- To perform variety of tests for air flow and lung volume.
- To measure oxygen concentration in Air.
- To measure grip strength and perform muscle fatigue studies (Strain Gauge Based)
- To measure FFT and perform Digital Filtering.
- Complete working manual should contain theory including range and rating of required equipments & essential formulae, experimental procedure, circuit details, calculations, discussion on results (theoretical versus practical) and Questions for further work.

2.	**National Instruments LabView Development System** **(10 Users)**	**National Instruments LabView Development System** **(10 Users)**