Module Information	
Module Title	**Biomedical Signal Processing**
Module Code	**AML502**

1. MODULE SUMMARY

Aims and Summary

The module prepares the students to model, simulate and process biomedical signals. Students will be taught biomedical signal processing operations, digital filters for removal of artefacts, event detection, and spectral analysis of biomedical signals. Concepts of segmentation and pattern classification applicable to biomedical signal processing will also be discussed along with case studies. Students will be trained on the usage of MATLAB/SIMULINK tools to design and build biomedical signal processing subsystems.

Module Size and Credits

Module size	Single
CATS points	12
ECTS credits	N/A
Open / restricted	Restricted
Availability on/off campus	On Campus/Off campus
Total student study hours	120
Number of weeks	4 weeks Full-time or 8 weeks Part-time.
Centre responsible	Centre for Biomedical Engineering / Department of Electronics and Communication Engineering
Academic Year	2009

Entry Requirements (pre-requisites and co-requisites)

Normally to be qualified for entry to the Postgraduate Engineering Programme

Excluded Combinations

None

Composition of Module Mark (including weighting of components)

Full-time / Part-time : 50% Written Examination and 50 % Assignment

Pass Requirements

A minimum of 40 % marks in the written examination and a minimum of 40% marks in the assignment are required for a pass and overall 40% marks

Special Features

80% attendance in theory and 80% attendance in laboratory are required.
It is likely that considerable time will be spent in School facilities outside of normal timetabled class time.

Courses for which this module is mandatory

M.Sc. [Engg] in Advanced Medical Electronics

Courses for which this module is a core option

None

2. TEACHING, LEARNING AND ASSESSMENT

Intended Module Learning Outcomes

After undergoing this module, students will be able to:

1. Describe and distinguish the various biomedical signals
2. Apply the signal processing concepts to design, simulate and analyze digital filters for removal of artefacts, event detection, and spectral analysis of biomedical signals
3. Analyse, segment and classify the biomedical signal features
4. Proficiently use MATLAB/SIMULINK tools to design biomedical signal processing subsystems, as well as model and analyse the biomedical signals

Indicative Content

Class Room Lectures

1. **Introduction to Biomedical Signals -** Nature of biomedical signals, Biomedical signals- Action potentials, Electroneurogram, Electromyogram, Electrocardiogram, Electroencephalogram, Phonocardiogram, Carotid pulse and speech signal, Objectives and difficulties in biomedical signaling system, Computer aided diagnosis.
2. **Review of DSP -** Sampling basics, Sampling Theory and Finite Data Considerations, Conversion requirements for biomedical signals, Signal conversion circuits, Noise, Ensemble Averaging, Data Functions and Transforms, Convolution, Correlation, and Covariance, The z-transform, transfer functions, z-plane pole-zero plots.
3. **Filtering for removal of artifacts -** Random noise, Structured noise, Physiological interference, Stationary versus non-stationary processes. Illustration of the problem with case-studies – Noise in event-related potentials, High frequency noise, Motion artifact, Powerline interference in ECG, Maternal interference in fetal ECG, Time-domain filters – FIR, IIR filters, Synchronized Averaging, Moving-average filters, Derivative based operators to remove low frequency artifacts, Frequency-domain filters, Removal of high frequency noise - Btterworth lowpass filters, Removal of low frequency noise - Butterworth highpass filters, Removal of periodic artifacts - notch and comb filters, Optimal filtering - Wiener filter, Adaptive filter for removal of interference - Adaptive noise canceller, the least-mean-squares adaptive filter, the recursive least-squares adaptive filter, Selecting an appropriate filter.
4. **Event detection -** Illustration of the problem with case-studies - The P, QRS and T waves in the ECG, First and second heart sounds, Dicrotic notch in the carotid pulse, EEG rhythms, Waves and transients, Detection of events and waves - Derivative based method for QRS detection, The Pan-Tompkins algorithm for QRS detection, Detection of the dicrotic notch, Correlation analysis of the EEG channels - Detection of EEG rhythms, Template matching for EEG spike-and-wave detection, Cross-spectral Techniques - coherence analysis of EEG channels, The Matched Filters - Detection of EEG spike-and-wave complexes, Detection of the P wave, Homomorphic Filtering - generalized linear filtering, Homomorphic deconvolution, Extraction of the vocal-tract response, Application - ECG Rhythm Analysis, Identification of Heart Sounds.
5. **Modeling Biomedical Systems -** Parametric System Modeling, Autoregressive or All-pole Modeling - Spectral matching and parameterization, Optimal model order, Relationship between AR and cepstral coefficients, Pole-zero Modeling - Sequential estimation of poles and zeros, Iterative system identification, Homomorphic prediction and modeling, Application - Heart-rate Variability.
6. **Frequency domain characterization -** Fourier spectrum, Estimation of Power Spectral Density Function - the periodogram, The need for averaging, Spectral resolution and leakage, Estimation of autocorrelation function, Synchronized averaging of PCG spectra, Measures Derived from PSDs - Moments of PSD functions, Spectral power ratios.
7. **Analysis of Non-stationary Signals -** Illustration of the problem with case-studies – Heart sounds and murmurs, EEG rhythms and waves, Articular cartilage damage and knee-joint vibrations, Time-variant systems - Characterization of non-stationary signals and dynamic systems, Fixed Segmentation - The short-time Fourier transform, Considerations in short-time analysis, Use of Adaptive filters for Segmentation - Monitoring the RLS filter, The RLS lattice filter, Applications - adaptive segmentation of EEG signals, Time-varying Analysis of Heart-rate Variability.
8. **Pattern Classification and Diagnostic Decision -** Illustration of the problem with case-studies – Diagnosis of bundle-branch block, Normal or ectopic ECG beat, Is there an alpha rhythm? Presence of murmur, Pattern Classification, Supervised Pattern Classification - Discriminant and decision functions, Distance functions, The nearest-neighbor rule, Unsupervised Pattern Classification - Cluster-seeking methods, Probabilistic Models and Statistical Decision - Likelihood functions and statistical decision, Bayes classifier for normal patterns, Logistic Regression Analysis, The Training and Test steps – the leave-one-out method, Measures of Diagnostic Accuracy and Cost – Receiver

operating characteristics, McNemar's test of symmetry, Reliability of Classifiers and Decisions, Application - Normal versus Ectopic ECG Beats.

Laboratory Practice

Design and simulate the following signal processing operations using MATLAB/SIMULINK:

1. Quantization and sampling of ECG, EEG and speech.
2. Filtering for removal of artifacts (Time-domain, Frequency-domain, Wiener filter and Adaptive filter).
3. Detection of events and waves for various biomedical signals.
4. Matched Filters for ECG and EEG.
5. Homomorphic Filtering
6. Biomedical system modelling for Heart-rate Variability
7. Adaptive segmentation of EEG signals, time-varying Analysis of Hear-rate Variability.
8. Pattern Classification for ECG signals.

Teaching and Learning Methods

1. Theoretical Knowledge [~30% of module time]
    a. Face to face lectures from a module leader- 30 hours
    b. Case study teaching and discussion from a practicing engineer- 6 hours

36 hours

2. Laboratory Practice (Skills) [~ 25% of module time]

30 hours

3. Application Orientation and Problem Solving [45% of module time]
    a. Reading
    b. Research
    c. Written Examination
    d. Assignment Solving and Documentation

54 hours

Method of Assessment

Part-A

Written Examination [50% Weightage]

At the end of the module, normally on the last day of the last week of the module, written examination is conducted to test students' understanding of taught theoretical concepts. The question paper will comprise either or a combination of the following:

- 6 questions, out of which 5 questions need to be answered
- Practical laboratory work
- Presentations
- Field work
- Creation of a physical model

The marks scored by the student will be scale down to 50% weight.

Part –B

Assignment [50% Weightage]

Students are required to submit word processed assignment report on formally announced last day of the module. Assignment tests students' problem solving skills based on taught concepts. The assignment is assessed for 100 marks but scored marks is scaled down to 50%

Assessment				
Learning Outcomes	**1**	**2**	**3**	**4**
Part A	**X**	**X**	**X**	**X**
Part B	**X**	**X**	**X**	**X**

Both written examination scripts and assignment reports will be double marked/valued

Re-assessment

A minimum of 40 % marks in the written examination and a minimum of 40% marks in the assignment are required for a pass in the module.
A student failing in any one of the components or both is considered as FAIL in the module. A failed student is required to retake the module at the next opportunity. A maximum of 3 attempts including the original are allowed.

Date of Last Amendment

May 2009

3. MODULE RESOURCES

Essential Reading

1. Module Notes

Recommended Reading

Books

1. Willis J. Tompkins, *Biomedical Digital Signal Processing*, Prentice Hall of India, 2001
2. Rangaraj M. Rangayyan, *Biomedical Signal Analysis: A Case-Study Approach*, Wiley-IEEE Press, 2001
3. Emmanuel C. Ifeachar and Barrie W. Jervis, *Digital Signal Processing-A practical approach*, Pearson Education, 2002
4. Sanjit K. Mitra, *Digital Signal Processing- A computer based approach*, 2^{nd} edition, Tata McGraw-Hill, 2001
5. John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, 3rd edition, Prentice Hall, 1996
6. Alan V. Oppenheim and Ronald Schafer, *Discrete-Time Signal Processing*, 2nd edition, Prentice Hall, 1999
7. John L. Semmlow, *Biosignal and Biomedical Image Processing: MATLAB-Based Applications*, Marcel Dekker, 2004

Journals

1. IEEE Transactions on Signal Processing
2. IEEE Transactions on Biomedical Engineering

Magazines

1. IEEE Signal Processing Magazine

Internet Sites

1. www.eg3.com/dsp
2. www.dspguide.com/
3. www.dsptutor.freeuk.com
4. www.dspguru.com/
5. www.mathworks.com/applications/dsp_comm/

Laboratory

Hardware: PCs

Software: MATLAB/SIMULINK

Software Manual: MATLAB User Manual

4. MODULE ORGANISATION

Module Leader

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Date and Time of Examination

As per time table

Subject Quality and Approval Information

Subject Quality Group / Subject Board	Electronics and Communication Engineering
Subject Assessment Board	Postgraduate Engineering Programmes
Shortened title	BSP
Date of approval by MARP	May 2009