University of Macau
Department of Electromechanical Engineering
MECH483－Measurement Technique & Data Processing
Syllabus
1st Semester 2012/2013
Part A – Course Outline

Required elective course in Electromechanical Engineering

Course description:

The aim of this course is to introduce knowledge of engineering measurement, sensors, signal conditioning circuits, data acquisition, signal sampling, hardware and software of computerized data-acquisition systems, time series analysis of experimental data, correlation analysis, regression analysis, spectral analysis, and discrete Fourier Transform. Application of instruments and measuring works, and the establishment of modern Computer Aided Testing Systems.

Prerequisite:

None

Textbook:

- Anthony J. Wheeler and Ahmad R. Ganji, ***Introduction to Engineering Experimentation,* 3**rd Edition, Prentice Hall, 2010
- Edward W. Kamen and Bonnie S. Heck, ***Fundamentals of Signals and Systems Using the Web and MATLAB***, 3rd Edition, Pearson Prentice Hall, 2007

References:

- Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard V, *Mechanical Measurements*, 5th Edition, Addison-Wesley, 1993
- Ernest O. Doebelin, *Measurement Systems: Application and Design*, 4th Edition, McGraw-Hill, 1990
- Richard S. Figliola and Donald E. Beasley, *Theory and Design for Mechanical Measurements*, John Wiley & Sons, 1991
- John P. Bentley, *Principles of Measurement Systems*, 4th Edition, Longman Scientific & Technical, 1995
- Waldemar Nawrocki, *Measurement Systems and Sensors*, Artech House, 2005
- Edward W. Kamen and Bonnie S. Heck, *Signals and Systems*, 3rd Edition, Pearson Prentice Hall, 2007
- John G. Proakis and Dimitris G. Manolakis, *Digital Signal Processing*, 4th Edition, Pearson Prentice Hall, 2007
- James D. Hamilton, *Time Series Analysis*, Princeton, 1994

Course objectives:

1. Introduce to students the fundamental principles of measurements, instrumentation methodology, and experimental design to the solution of practical problems related to experimental measurement and data analysis. [k, l]
2. Introduce to students a working knowledge of the theoretical basis for operation of instruments, sensors, and associated equipment by analyzing practical problems dealing with the use of such instruments, sensors, and equipment. [a, b, e]
3. Familiarize students with the operation of various instruments by hand-on application in the laboratory. [c, g]

Topics covered:

1. **Introduction -** Review of Syllabus; Introduction to Measurement & Experiment; Applications; Dimensions and units
2. **Characteristics of Measurement Systems -** Measurement error analysis; Systematic errors & random errors; Range, span, accuracy, precision, hysteresis, resolution, repeatability, linearity, zero offset, sensitivity, drift; Static calibration; Sequential calibration procedure

3. **Measurement Systems with Signal Conditioners -** Signal conditioners; Amplification; Attenuation; Filtering; Differentiation; Integration; Gain; Frequency response; Phase angle; Bode diagrams; Loading effects; Circuit analysis of amplifier with OP-AMP; DC gain, corner frequency, roll-off rate, phase angle
4. **Computerized Data-Acquisition Systems -** Computer systems for data acquisition; Components; Representing numbers; Converting of different numbers; Multiplexers; A/D converters; D/A converters; Simultaneous sample-and-hold subsystems; Number of bits, input range, speed; Binary output codes and conversion; Quantizing error; Successive-approximations converter; Hardware & software of DAS
5. **Frequency-Domain Data Analysis -** Trigonometric Fourier series; Even & odd functions; Trigonometric form vs. complex exponential form; Fourier transform; Rectangular form & polar form; Inverse FT; Discrete-time Fourier transform (DTFT); Inverse DTFT; Discrete Fourier transform (DFT); Inverse DFT; Sinusoidal form of IDFT; DFT vs. DTFT; FFT and its applications in data analysis; Sampling-rate theorem; Frequency aliases; Lowest aliasing frequency determination; Spectral analysis; Selection of sampling rate & filtering; Corner frequency; Attenuation rate; Filter order; MATLAB programming for frequency-domain data analysis
6. **Time-Domain Data Analysis -** General statistical concepts and definitions; Measures of central tendency; Measures of dispersion; Probability distribution functions; Probability mass function; Probability density function; Cumulative distribution function; Normal distribution calculation; Parameter estimation of mean; Confidence interval, level; Central limit theorem; Two-sided/one-sided confidence interval; Small sample cases; Correlation of experimental data; Correlation efficient; Least-squares linear fit; Measure of adequacy of regression model; Outliers in x-y data sets; MATLAB programming for time-domain data analysis
7. **Measurement of Solid-Mechanical Quantities -** Measuring strain; Uniaxial stress; Biaxial stress; Strain gage signal conditioning; Wheatstone bridge; Measuring displacement; Potentiometer; LVDT; Capacitive displacement sensor; Measuring linear velocity; LVT; Doppler radar; Using displacement and acceleration sensors; Measuring acceleration & vibration; Piezoelectric accelerometers; Strain-gage accelerometers; Servo accelerometer; Vibrometer; Measuring force; Wheatstone full bridge
8. **Dynamic Behavior of Measurement Systems -** Order of dynamic measuring systems; Typical systems; Zero-order systems; First-order systems; Time constant; Step input, ramp input, sinusoidal input; Second-order systems; Spring-mass-damper system; Step input, ramp input, sinusoidal input; Natural frequency & damping ratio; Accelerometer & vibrometer

Class schedule and credits:

Timetabled work in hours per week			No of teaching weeks	Total hours	Total credits	No / Duration of exam papers
Lecture	Tutorial	Practice				
2	0	2	14	56	3	1 / 3hrs

Topic Outline:

Week No.	No. of hours	Topics
1	2	**Introduction** Review of Syllabus; Introduction to Measurement & Experiment; Applications; Dimensions and units
2	4	**Characteristics of Measurement Systems** Measurement error analysis; Systematic errors & random errors; Range, span, accuracy, precision, hysteresis, resolution, repeatability, linearity, zero offset, sensitivity, drift; Static calibration; Sequential calibration procedure
3	4	**Measurement Systems with Signal Conditioners** Signal conditioners; Amplification; Attenuation; Filtering; Differentiation; Integration; Gain; Frequency response; Phase angle; Bode diagrams; Loading effects; Circuit analysis of amplifier with OP-AMP; DC gain, corner frequency, roll-off rate, phase angle
4	4	**Computerized Data-Acquisition Systems** Computer systems for data acquisition; Components; Representing numbers; Converting of different numbers; Multiplexers; A/D converters; D/A converters; Simultaneous sample-and-hold subsystems; Number of bits, input range, speed; Binary output codes and conversion; Quantizing error; Successive-

		approximations converter; Hardware & software of DAS
5, 6, 7	12	**Frequency-Domain Data Analysis** Trigonometric Fourier series; Even & odd functions; Trigonometric form vs. complex exponential form; Fourier transform; Rectangular form & polar form; Inverse FT; Discrete-time Fourier transform (DTFT); Inverse DTFT; Discrete Fourier transform (DFT); Inverse DFT; Sinusoidal form of IDFT; DFT vs. DTFT; FFT and its applications in data analysis; Sampling-rate theorem; Frequency aliases; Lowest aliasing frequency determination; Spectral analysis; Selection of sampling rate & filtering; Corner frequency; Attenuation rate; Filter order; MATLAB programming for frequency-domain data analysis
8, 9, 10	10	**Mid-term Exam;** **Time-Domain Data Analysis** General statistical concepts and definitions; Measures of central tendency; Measures of dispersion; Probability distribution functions; Probability mass function; Probability density function; Cumulative distribution function; Normal distribution calculation; Parameter estimation of mean; Confidence interval, level; Central limit theorem; Two-sided/one-sided confidence interval; Small sample cases; Correlation of experimental data; Correlation efficient; Least-squares linear fit; Measure of adequacy of regression model; Outliers in x-y data sets; MATLAB programming for time-domain data analysis **Laboratory Experiment** Data acquisition systems; A/D converters; D/A converters
11, 12	8	**Measurement of Solid-Mechanical Quantities** Measuring strain; Uniaxial stress; Biaxial stress; Strain gage signal conditioning; Wheatstone bridge; Measuring displacement; Potentiometer; LVDT; Capacitive displacement sensor; Measuring linear velocity; LVT; Doppler radar; Using displacement and acceleration sensors; Measuring acceleration & vibration; Piezoelectric accelerometers; Strain-gage accelerometers; Servo accelerometer; Vibrometer; Measuring force; Wheatstone full bridge **Laboratory Experiment** Data acquisition systems; A/D converters; D/A converters; PZT actuators; Capacitive sensors
13	4	**Dynamic Behavior of Measurement Systems** Order of dynamic measuring systems; Typical systems; Zero-order systems; First-order systems; Time constant; Step input, ramp input, sinusoidal input; Second-order systems; Spring-mass-damper system; Step input, ramp input, sinusoidal input; Natural frequency & damping ratio; Accelerometer & vibrometer
14	4	**Course Review** Review of major points gained from this course; Fundamental methods of measurement for experimentations; Sensors for measuring solid-mechanical quantities and signal conditioning circuits; Frequency-domain and time-domain data analysis techniques; Applications of instruments and computer aided-testing systems

Contribution of course to meet the professional component:

This course prepares students to work professionally in the area of **mechanical measurement & data processing**.

Relationship to EME Programme objectives and outcomes:

This course primarily contributes to Electromechanical Engineering Programme outcomes that develop student abilities to:

(a) an ability to apply knowledge of mathematics, science, and engineering.
(e) an ability to identify, formulate, and solve engineering problems.
(g) an ability to communicate effectively.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The course secondarily contributes to Electromechanical Engineering Programme outcomes that develop student abilities to:
(b) an ability to design and conduct experiments, as well as to analyze and interpret data.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
(l) an ability to use the computer/IT tools relevant to the discipline along with an understanding of their processes and limitations.

Course content:

Maths	Basic Science	Engineering Science	Engineering Design and Synthesis	Complementary Studies	Computer Studies	Total 100%
20	0	50	20	0	10	100

Persons who prepared this description:

Dr. Qingsong Xu

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Part B – General Course Information and Policies

1st Semester 2012/2013

Instructor: Dr. Qingsong Xu
Office Hour: By appointment
Email: qsxu@umac.mo
Office: B1-A710
Phone: (853) 8397-8462

Time/Venue:

Every Monday, 3:30 p.m. - 5:30 p.m., Room U101
Every Friday, 8:30 a.m. - 10:30 a.m., Room U107

Assessment:

Final assessment will be determined on the basis of:

Attendance and in-class Performance:	5%
Homework:	20%
Experiments:	15%
Mid-term:	30%
Final Exam (Comprehensive):	30%

Grading System:

The credit is earned by the achievement of a grade from 'A' to 'D'; 'F' carries zero credit.

Grades are awarded according to the following system:

Letter Grades	Grade Points	Percentage
A	4.0 (Excellent)	93-100
A-	3.7 (Very good)	88-92
B+	3.3	83-87
B	3.0 (Good)	78-82
B-	2.7	73-77
C+	2.3	68-72
C	2.0 (Average)	63-67
C-	1.7	58-62
D+	1.3	53-57
D	1.0 (Pass)	50-52
F	0 (Fail)	Below 50

Homework Policy:

The completion and correction of homework is a powerful learning experience; therefore:

- There will be approximately 6 homework assignments.
- Homework is due one week after assignment unless otherwise noted, no late homework is accepted.
- Possible revision of homework grades may be discussed with the grader within one week from the return of the marked homework.
- The homework grade will be based on the average of the assignment grades.

Quizzes/Mid-terms Exams:

One mid-term exam will be held during the semester. There will be 1-2 lab experiments during the semester.

Note:

- Attendance is strongly recommended.
- Check UMMoodle (webcourse.umac.mo) for announcement, homework and lectures. Report any mistake on your grades within one week after posting.
- No make-up exam is give except for CLEAR medical proof.

- No exam is given if you are 15 minutes late in the midterm exams and 30 minutes late in the final exam. Even if you are late in the exam, you must turn in at the due time.
- Cheating is absolutely prohibited by the university.

Appendix - Rubric for Programme Outcomes

Rubric for (a)	5 (Excellent)	3 (Average)	1 (Poor)
Understand the theoretic background	Students understand theoretic background and the limitations of the respective applications.	Students have some confusion on some background or do not understand theoretic background completely	Students do not understand the background or do not study at all
Use a correct model and formulation correctly	Students choose a model correctly and properly apply correct techniques	Students choose a wrong model sometime, use a wrong formula, or a different technique	Students use a wrong model and wrong formula, or do not know how to model
Compute the problem correctly	Students use correct techniques, analyze the problems, and compute them correctly	Students sometime solve problem mistakenly using wrong techniques	Students do not know how to solve problems or use wrong techniques completely

Rubric for (b)	5 (Excellent)	3 (Average)	1 (Poor)
Conduct experiments	Student successfully completes the experiment, records the data, analyzes the experiment's main topics, and explains the experiment concisely and well.	Student successfully completes the experiment, records the data, and analyzes the experiment's main topics.	Student either does not complete the experiment successfully, or completes it successfully but does not record the correct data.
Design experiments	Student understands what needs to be tested and designs an appropriate experiment that takes into account the limitations of the equipment and measurement accuracy.	Student understands what needs to be tested and designs an appropriate experiment, but may not fully understand the limitations of the measurements.	Student does not understand what needs to be tested and/or does not design an appropriate experiment.

Rubric for (c)	5 (Excellent)	3 (Average)	1 (Poor)
Design capability and design constraints	Student understands very clearly what needs to be designed and the realistic design constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Student understands what needs to be designed and the design constraints, but may not fully understand the limitations of the design constraints	Student does not understand what needs to be designed and the design constraints.
Process to meet desired needs	Student understands very clearly the process of the design	Student understands what the needs of the process design, but may not fully understand the limitations of the design constraints	Student does not understand the process.

Rubric for (e)	5 (Excellent)	3 (Average)	1 (Poor)
Identify applications in engineering systems	Students understand problem and can identify fundamental formulation	Students understand problem but cannot apply formulation.	Students cannot identify correct terms for engineering applications
Modeling, problem formulation and problem solving	Students choose and properly apply the correct techniques	Students model correctly but cannot select proper technique or model incorrectly but solve correctly accordingly	Students at loss as to how to solve a problem

Rubric for (g)	5 (Excellent)	3 (Average)	1 (Poor)
Professional Impact	Student's/Team's/Group's document(s)/presentation(s) is/are considered to be of professional quality	Student's/Team's/Group's document(s)/presentation(s) is/are considered acceptable for college level work	Student's/Team's/Group's document(s)/presentation(s) is/are considered unacceptable for college level work
Written Component	Document is nearly error free with sophisticated use of vocabulary, formatted properly, with well developed concise sentences and paragraphs	Document contains some errors with a somewhat colloquial vocabulary, minor formatting issues, with some organizational issues that do not interfere with communication	Document contains many errors, very colloquial vocabulary, with severe organizational issues that interfere with communication. Document would be considered unacceptable.
Oral Component	Presentation is consistent, uniform, clear, direct, complete and captivating with very clear fonts and graphics with an excellent layout that clearly presents the technical content	Presentation is somewhat inconsistent between speakers, occasionally difficult to hear, with an acceptable layout containing acceptable fonts and graphics that adequately presents the technical content	Presentation is very inconsistent between speakers, difficult to hear with a poor layout containing illegible fonts and graphics that poorly presents the technical content. Would be considered unacceptable

Rubric for (k)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern hardware tools in engineering practice	Student uses the hardware to measure and/or build engineering systems/designs correctly, and understands the limitations of the hardware.	Student uses the hardware to measure and/or build engineering systems/designs correctly.	Student does not use the hardware correctly.

Rubric for (l)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern computer and software tools in engineering practice	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs, and understands the limitations of the software.	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs.	Student does not use the computer and software to correctly create engineering designs and/or does not correctly interpret the results.