ELE744 Instrumentation
Course Outline

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Course Description

This is a one-semester course in electronic instrumentation. Along with an overview of instrumentation princibles, the physical principles and electrical characteristics for several common instrument transducers are studied. The electronic signal-conditioning circuits required to convert the electrical changes in the transducers to signal which can be interpreted accurately by a microprocessor or embedded controller, are analyzed and designed. A complete topic list is shown below.

The laboratory is project oriented with each student required to design and implement weather station instrumentation. The weather station will measure and display atmospheric parameters such as humidity, temperature, and barometric pressure. An embedded controller, the Motorola HC11, is constructed and programmed by each student. The laboratory is completely described in a separate *ELE744 Lab Outline* document.

Hours	3 hrs lecture, 3 hrs laboratory per week
Prerequisites	Third year electrical or computer engineering.
Corequisites	None

Objectives

- Understand the concept of an instrumentation system: *to support accurate measurements*
- Understand the concepts *accuracy* and *precision*
- Build, program, calibrate and use a microprocessor-based instrumentation system
- Be able to analyse and design an instrumentation system, dealing with the concepts of dynamic range, signal-noise ratio, and error budget
- Control noise, either intrinsic or external (interference).
- Read an operational amplifier spec sheet and use the specifications to construct an error budget for a high-gain amplifier
- Understand the operation of various instrumentation transducers
- Select and apply A/D conversion techniques such as successive-approximation, dual slope conversion, voltage-frequency conversion.
- Understand on a theoretical level *carrier signal* and *signal averaging* methods for extracting a signal from noise.

Course Evaluation

Lecture Component		60 %
	Quiz I	5 %
	Quiz II	5 %
	Midterm Test	15 %
	Final Exam	35 %
Laboratory Component		40 %
Total		100 %

In order to achieve at least a minimum passing grade in this course, the student is required to gain at least a 50% overall mark in the lecture component as well as at least a 50% overall mark in the laboratory component.

Course Topics

This listing of course topics should be regarded as provisional, since the course is being taught for the first time by Professor Hiscocks and it has been substantially reorganized, with a change in emphasis on the topics. However, the dates of the two quizzes and mid term will not change without agreement from the class.

Week #	Week of	Topic
1	Sept 2	• Course Overview • Lab Overview • **The Instrumentation System** • Application Domains • The Importance of Engineering Design • Precision and Accuracy • Calibration • Dynamic range: Noise floor to saturation, decibels • The 'signal plan' diagram for an amplifier system • Signal to noise ratio • Measurements that are affected by the instrument: measuring a marshmallow with calipers.
2	Sept 9	• **The need for signal conditioning** • Amplification • Noise control • Bandwidth limiting (to limit noise) • Distortion (of waveshape), harmonic generation • Linearity and signal compression • A-D converter step size • Impedance buffering • What are *small* voltages and currents? • What are *high* impedances?
3	Sept 16	• **Noise: The rogue's gallery** • Noise limits the smallest measureable signal • Thermal noise • Noise voltage and current in op-amps • Noise calculation example • Noise measurement: an AC voltmeter won't do.
4	Sept 23	• **Operational Amplifier Imperfections** • Offset voltage and drift • Bias current • Offset current • Power Supply Rejection Ratio • Common Mode Rejection Ratio • Reading the op-amp spec sheet • Design example: the error budget

Week #	Week of	Topic
5	Sept 30	• **The transducer and its conditioning circuits: 1** • Thermistor: sensitive but non-linear • Thermocouple: small signal, linear, wide range • Semiconductor: medium signal, linear • **Quiz 1**
6	Oct 7	• **The transducer and its conditioning circuits: 2** • Air pressure transducer (strain-guage) • Humidity sensor (variable capacitance) • The V-F (charge balancing) converter • Photodetector (matching and bandwidth) • **Quiz 1 returned**
7	Oct 14	• **At the Microprocessor: Inputs and Outputs** • Sampling and digital conversion artifacts • R-2R Digital-Analog Converter • Successive approximation A/D converter. • Dual slope A/D Converter • Grounding to an A/D converter. • **Mid-term test**
8	Oct 21	• **Grounding, Decoupling, Shielding and PCB Layout** • Magnetic and electrostatic coupling and shielding • Current-voltage transformations to improve noise immunity • How a 'ground' introduces noise into a system. • The 'guard' connection • Differential inputs, floating source to reduce noise • The noise sniffer • Oscilloscope measurements of a noise problem • Local power supplies • Grounding management in a mixed analog and digital system. • Rules for PCB layout in a mixed system. • **Mid-term returned**

Week #	Week of	Topic
9	Oct 28	• **Other noise control techniques** • Opto-coupling to separate ground systems. • Transformer coupling • Digital buffering to improve noise isolation • Quiet-timing a measurement • Inductive vs capacitive filtering • The dangers of a switching power supply
10	Oct 28	• **Carrier Signal Techniques** • Chopper stabilized op-amp • Lock-in amplifier technique • Correlation • Adaptive filtering • **Quiz 2**
11	Nov 4	• **Signal Averaging Techniques** • The basic idea • Analog averaging • Digital averaging • Example • **Quiz 2 returned**
12	Nov 11	• **Catchup and Review**
13	Nov 18	• **Catchup and Review**

References

There is no specific assigned textbook for this course. Some notes will be distributed in class, some notes will be made available in the course directory, some notes will be available by download from a manufacture's site on the Web, and some information will be available in textbooks. Students are encouraged, where they think it would be useful, to ask the instructor to identify a source of reference material.

Operational Amplifier Circuits, Theory and Applications
E. J. Kennedy,
Holt Rinehart and Winston Inc.
This text is out of print. Selected pages may be made available to students.

The Weather Station Project: An Exercise in Analog and Microprocessor System Design
Peter Hiscocks, 2001
A comprehensive manual on electronics meterological instruments.
This will be on line in the course directory.

M68HC11 Reference Manual
Motorola Document M68HC11RM/AD REV 3, 1991
The authoritative source of information about the 68HC11 microprocessor.

68HC11 Microcontroller, Construction and Technical Manual
Peter Hiscocks, 2001
Supplementary technical information on the MPP Board which is applications oriented. Information on programming and interfacing the MPP Board used at Ryerson and elsewhere. Available from Active Electronics in Willowdale.

M68HC11: An Introduction, Software and Hardware Interfacing
Han-Way Huang
Delmar Thompson, 2001
A basic text on the 68HC11 microprocessor.