

## Master Course Description for EE 436 (ABET sheet)

**Title:** Medical Instrumentation

**Credits:** 4 (3 lecture; 1 lab)

### UW Course Catalog Description

**Coordinator:** Robert Bruce Darling, Professor, Electrical and Computer Engineering

**Goals:** This course provides seniors and first year graduate students in electrical engineering and bioengineering with a theoretical and practical understanding of the instrumentation systems used in making human physiological measurements. Students will gain familiarity and experience with the transducers, signal conditioning circuits, and signal processing approaches that are used to obtain these physiological measurements through several design projects.

**Learning Objectives:** At the end of this course, students will be able to:

1. *Understand and apply* the principles of cell electrophysiology, biopotentials, and electrical interactions with tissue.
2. *Design* operational amplifier, instrumentation amplifier, and signal conditioning circuitry for measuring biopotentials and other physiological quantities.
3. *Understand and apply* the principles of electrical equivalent circuits for transducers to the design of measurement instrumentation.
4. *Design* accurate measurement circuits and data acquisition systems which minimize instrumentation system errors.
5. *Understand and be conversant* with the principles of clinical human physiological measurements, particularly those associated with circulation, respiration, and metabolism.
6. *Understand and apply* the principles of electrical safety for humans.
7. *Formulate and solve* open-ended human physiological measurement design problems.
8. *Write* formal project reports and design documentation.
9. *Demonstrate* awareness of contemporary issues and practices in the medical instrumentation field.

**Textbook:** J. G. Webster (ed.), *Medical Instrumentation: Applications and Design, 4th Ed.*, John Wiley & Sons, 2010. ISBN # 978-0-471-67600-3

**Reference Texts:**

1. R. K. Hobbie, *Intermediate Physics for Medicine and Biology*, 3rd Ed., Springer AIP Biological Physics Series, 1997. ISBN # 1-56396-458-9.
2. S. Silbernagl, *Color Atlas of Physiology*, 5th Ed., Georg Thieme Verlag, 2003. ISBN # 1-58890-061-4.
3. L. H. Opie, *Heart Physiology: From Cell to Circulation*, 4th Ed., Lippincott, Williams & Wilkins, 2004. ISBN # 0-7817-4278-1.
4. D. Dubin, *Rapid Interpretation of EKG's*, 6th Ed., Cover Publishing, Inc., 2003. ISBN # 0-912912-06-5.
5. ISBN # 0-912912-06-5.
6. A. Y. K. Chan, *Biomedical Device Technology: Principles and Design*, C. C. Thomas Publishers, 2008. ISBN # 978-0-398-07699-3.
7. J. D. Enderle and J. D. Bronzino, *Introduction to Biomedical Engineering*, 3rd Ed., Academic Press, 2012. ISBN # 978-0-12-374979-6.

#### **Prerequisites by Topic:**

1. Devices and Circuits II (EE-332),
2. Fundamentals of analog circuits and electrical measurement systems (covered in EE-331 and EE-332),
3. Characteristics and limitations of operational amplifiers (covered in EE-332), and
4. Elementary understanding of anatomy and physiology.

#### **Topics:** (approximately 1 week per topic)

1. Basic Concepts of Medical Instrumentation. (Ch. 1 of Webster)
2. Basic Sensors and Principles. (Ch. 2 of Webster)
3. Amplifiers and Signal Processing. (Ch. 3 of Webster)
4. The Origin of Biopotentials. (Ch. 4 of Webster)
5. Biopotential Electrodes. (Ch. 5 of Webster)
6. Biopotential Amplifiers. (Ch. 6 of Webster)
7. Blood Pressure and Sound. (Ch. 7 of Webster)
8. Measurement of Flow and Volume of Blood. (Ch. 8 of Webster)
9. Measurements of the Respiratory System. (Ch. 9 of Webster)
10. Therapeutic and Prosthetic Devices. (Ch. 13 of Webster)
11. Electrical Safety. (Ch. 14 of Webster)

**Course Structure:** The class meets three times a week for 50 minute lectures. Homework problems are assigned weekly. The laboratory formally meets once each week for 3 hours; however, students normally work outside of these formal hours as they progress through their design projects. The laboratory design projects are a major focus of the class, and significant lecture time is also devoted to discussing approaches, techniques, and commonly encountered problems. Typically, up to three major design projects are assigned, and students work on these design projects in teams of three members. The teams often involve a mixture of electrical engineering and bioengineering students.

**Computer Resources:** The students may have need to use SPICE for circuit simulation, MATLAB / Simulink for general purpose computation and signal processing, and LabVIEW for data acquisition and instrument control. Multisim,

MATLAB, and LabVIEW are available in all of the general purpose computing laboratories in the EE Department.

**Laboratory Resources:** Electronic design, prototyping, testing, and data acquisition is supported in the undergraduate electronics laboratory in room EEB 137. Each bench contains basic electrical instruments, including oscilloscopes, power supplies, function generators, digital multimeters, and computer-based data acquisition and instrument control.

**Laboratory Structure:** The course involves four laboratory design projects. The first project is to design a low-noise biopotential amplifier, and the second project is to extend that system into a full-featured ECG recording system. Student teams can then choose one of three options for the third and fourth design projects which involve the topics of either circulation, respiration, or metabolism. The third design project is a basic measurement function in the domain of choice, e.g. photoplethysmography, spirometry, or limb acceleration. The fourth design project is an extension of the third, leading to a final project which provides a clinically valid physiological assessment, e.g. pulse oximetry, blood gas capnography, or muscle tonometry.

**Grading:** Laboratory Design Projects (75%); Homework (25%)

**ABET Student Outcome Coverage:** This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

- (1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics* **(H)** A working knowledge of mathematics, science, and engineering is needed to grasp the fundamental principles underlying human physiological measurements, and to understand the methods which are used to quantitate these measurements across a broad population of individuals. Mathematical models are developed for each of the physiological processes, and these models are used in the construction of applicable measurement techniques. Each of the four laboratory design projects requires the students to formulate and solve the essential measurement problem and create a solution which is bounded by numerous external constraints.
- (2) *An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors* **(H)** Each of the four laboratory design projects are put in the form of a set of specifications that the final design must meet. These specifications include cost, size, weight, accuracy, repeatability, and in some cases, manufacturability, ease of use, adherence to accepted medical, electrical, and safety standards, and intellectual property rights of existing designs. Students are allowed to use any components, technologies, methods, or approaches that they deem satisfactory in achieving these specifications.

- (3) *An ability to communicate effectively with a range of audiences (M)* Each of the design projects requires a formally written set of design documents which counts for one half of the overall score for each design project. The design documents include sections on purpose, features, ratings, block diagrams, key design equations, complete schematics, complete bill of materials and cost estimate, hardware construction details, alignment procedures, operational warnings and instructions, applicable engineering standards, acknowledgements and references.
- (4) *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (H)* Each of the design projects involves the measurement of human physiological quantities, and as such, a primary element is the professional and ethical responsibility that must be extended to both the human patient and to the field of medicine.
- (5) *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (L)* The design projects are addressed by teams of 2-3 students who must organize themselves and divide up the work among them.
- (6) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (M)* As part of the design process, the students must devise experiments to test their instrumental methods, and then analyze the data that these instrumentation systems produce, in order to insure that the correct physiological variables are being isolated and accurately recorded.
- (7) *An ability to acquire and apply new knowledge as needed, using appropriate learning strategies (M)* As part of each design project, the student teams must research, select, and apply new components. Students are responsible for learning this on their own.

**Prepared By:** R. Bruce Darling

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