BME / EECS 458: Biomedical Instrumentation and Design (Fall 2011)

Website: ctools.umich.edu

This syllabus contains important information regarding the grading criteria and course procedures. Please read this document carefully.

I. General information

Instructor: Xudong (Sherman) Fan, Ph.D. 2158 Lurie Biomedical Engineering Building Office: 734-763-1273 xsfan@umich.edu **Instructor:** Dennis R. Claflin, Ph.D. 2232 Lurie Biomedical Engineering Building Office: 734-615-2598 claflin@umich.edu	Office hours: Monday 5:00 – 6:00 pm or by appointment Office hours: Monday 5:00 – 6:00 pm or by appointment
Lab Manager & Safety Officer: Dana Jackson 1134 Lurie Biomedical Engineering Office: 734-647-9828 dmjackso@umich.edu	Office hours: by appointment
GSI: TBD	Section 2 (Tu, Th 2:30-5:30 PM) Office hours: Tuesday 1:30-2:30 PM
GSI: TBD	Section 3 (Tu, Th 6:30-9:30 PM) Office hours: Tuesday 5:30 to 6:30 pm
GSI: TBD	Section 4 (Tu, Th 9:30 AM-12:30 PM) Office hours: Tuesday 12:30 - 1:30 PM
GSI: TBD	Section 5 (Mo, We 6:30-9:30 PM) Office hours: Wednesday 5:30 – 6:30 PM

Lecture: 1013 DOW, Monday 4:00 – 6:00 PM (4:00 – 5:00 is for lecture and 5:00 – 6:00 is reserved for possible additional lecture or office hour).

Laboratory: 1105 LBME

Course Materials

- Required: Course notes, lab handouts, and associated documents (available by download from CTools, Resources), 192-page-lab notebook (individual, can be purchased in LBME right before lab session. The cost will be $20 and can be paid in cash or check made out to Biomedical Engineering Society)
- Text book: *Medical Instrumentation: Application and Design*, J. G. Webster (Ed.), 4th edition. John Wiley & Sons. (not required, available in the library)

CTools course website

Refer to the CTools course website (BIOMEDE 458 002 F11) for all course information, including lab handouts, lecture slides and syllabus. Course communication will be via CTools “Announcements”. You are required to take a picture of your lab set up including the breadboard circuit and LabVIEW VI for each lab and the final design project, and upload them to the CTools Drop Box for archiving purposes.

II. Lecture Topics, Lab Projects, Schedule

Lecture Topics: The following topics will be covered during the Monday lectures: overview of biomedical instrumentation, instrumentation basics, LabVIEW basics, circuit basics, operational amplifiers, active filters, analog-digital conversion, sampling, signal processing, spirometry, electrocardiography (ECG), pulse oximetry.

Lab Projects: The project topics and number of 3-hour lab periods devoted to each are listed below:

	Project Topic	Number of lab periods
1.	LabVIEW	1
2.	Module 1: Introductory Lab	5
3.	Module 2: Spirometry	4
4.	Module 3: ECG	4
5.	Module 4: Pulse Oximetry	4
6.	Design Project	7

Schedule: The links below point to section-specific calendars that provide explicit lecture times, lab times and topics, due dates, etc. Note that you can toggle different aspects of the calendar (on/off) with checkboxes accessed using the small “down arrow” to the right of the “Agenda” tab (top-right of calendar). The calendars are also accessible via CTools (Resources, Calendars).

Sec 2 Calendar Sec 3 Calendar Sec 4 Calendar Sec 5 Calendar

Important Dates: These are on the Course Calendars (links above), but repeated below for emphasis.

Date		Event
September	6	No labs
	7	No labs
	12	First lecture
	26	Homework 1 due
October	3	Homework 2 due
	13	Lab Practical deadline
	17 & 18	Fall Study Break (no lecture, labs)
	31	Design Project proposals due
November	7	Design Project proposals, parts lists & presentation schedules finalized
	14	Design Project proposal oral presentations
	24 & 25	Thanksgiving Break (no labs)
December	12	Design Project final oral presentations (final meeting of class)

Lab Project Descriptions:

General introduction and guidelines for each lab project will be given in lecture. The GSI will also give a brief overview of the lab during the first lab session of each lab project. Lab project handouts will be posted on CTools prior to each lab.

- **LabVIEW** – Tutorial to introduce the LabVIEW graphical programming environment and “virtual instruments”. Tutorial concludes with data acquisition using National Instruments A-D hardware.
- **Module 1: Introductory Lab** – Introduction to lab instruments, electronic circuits, programming, testing, data acquisition, signal processing theory, and lab safety.
- **Module 2: Spirometry** – Develop a spirometer system to measure respiratory flow rates.

- **Module 3: ECG** – Develop an electrocardiography (ECG) system to acquire, analyze, and display electrocardiograms.
- **Module 4: Pulse Oximetry** – Develop a system for determining the saturation level of hemoglobin in arterial blood using optical measurements.
- **Design Project** – Develop a prototype instrumentation system that demonstrates proof-of-concept of a biomedical instrument that is selected by the lab group. The project deliverables include design documents, a lab demonstration, an in-class presentation, and a final project report. The instructor(s) will post a list of projects in October for you to choose from. Each group needs to submit their design proposal to the instructor by October 31. The proposal should be 1 page long presenting the project they choose, overall project design, and a parts list. The parts list should contain the name, price, and quantity of the parts you need and where to order them, so that the appropriate parts can be ordered ahead of time. The budget for each design project is $50 per group. The proposal needs to be approved by the instructor and GSIs by November 7, 2011. If your group has justifiable reasons to change or improve the design after November 7, discuss it with the instructor or your GSI. The parts list cannot be changed after November 7.

III. Lab Groups

The lab projects are performed in groups, with each group consisting of 3-4 students. The lab group will be assigned by GSIs during the first lab session for each Section and finalized by the end of the second lab session for each Section (week of September 12). Students will be assigned to groups with the goal of balancing expertise; each group will have at least one member with LabVIEW experience and one with circuit experience (based on a questionnaire you will fill out). For each lab project, each group will designate 1-2 hardware engineer(s) (breadboard circuit) and 1-2 software engineer(s) (LabVIEW). Each group member should alternate between hardware and software roles throughout the semester.

IV. Grading Criteria

Lab Practical (individual)	Pass/Fail
Homework (individual)	10 pts
Lab Notebook and Performance (individual)	40 pts
Lab Reports (group)	20 pts
Lab Design Project (group/individual)	30 pts
Total:	**100 pts**

The letter grade associated with the median score is expected to be in the range of “A-” to “B+”

More details on grading criteria for each item are described as follows:

Homework (10 pts) (2 sets, 5 pts for each set)

There will be two homework sets on circuit basics, LabVIEW, and signal processing theory, all covered during the first three weeks.

> *Due dates are on Course Calendars (see above). Only electronic submission to CTools Dropbox is accepted.*

Individual Lab Notebook and Lab Performance (40 pts, 10 pts each for each Module – Introductory Lab, Spirometry, ECG, and Pulse Oximetry) → See Appendix I for details on grading of the Lab Notebook and Lab Performance

Each student should have a scientific lab notebook with a table of contents labeled. The lab notebook will be graded by the GSI after completion of each lab module based on correctness and completeness. You only need to record the notes related to your main responsibility (*i.e.*, software/hardware).

In addition to the Lab Notebook, your performance in lab will be evaluated by the GSI and your group peers for each lab module.

A photocopy of the lab notebook related to each lab module should be turned in to your GSI one week after the completion of the lab module. You keep the original lab notebook for your own lab use. Remember to sign and date the original lab notebook.

Group Lab Reports (20 pts, 5 pts each for each Module – Introductory Lab, Spirometry, ECG, Pulse Oximetry)

At the end of each lab module, each group turns in one lab report to the GSI. The lab report should be a summary of the lab module and discussion of the issues following the instruction in the handout. The lab report will be graded by group, *i.e.*, your labmates and you will receive the same score for the lab report. You should participate in preparation of each lab report and each group member is required to write at least one report. Each lab report should be 2-4 pages. Use Times New Roman (11 pts or larger) or Arial (10 pts or larger), and 0.75-inch margin. Learn to be concise and emphasize all key points.

The lab report is due one week after the completion of each lab module.

Group Final Lab Design Project (30 pts)

Each group is required to develop a prototype instrumentation system that demonstrates proof-of-concept of a biomedical instrument that is selected by the lab group. Each group will give a 10-minute proposal presentation in the lecture session on November 14 (Monday). The schedule will be determined and notified by November 7. The lab demo of the project will be evaluated in the lab sessions on December 7 and 8 (your last lab session) and the final project presentations will be given on December 12 (Monday).

The 30 pts will be distributed as follows:

	GSI	Instructor	Peers
Final oral presentation	5 pts	5 pts	-
Final lab demo	5 pts	5 pts	-
Final report	4 pts	-	-
Individual effort	3 pts	-	3 pts

Note: Please note that an assessment of your lab notebook entries for the Final Design Project will be incorporated in the individual effort evaluation given by your GSI.

Individual Lab Practical (Pass/Fail) → See Appendix II for details

The Lab practical is designed to evaluate the basic skills required for this course (*e.g.*, construct breadboard circuits and build LabVIEW VI). The lab practical handout is given in Appendix II. Complete the Lab Practical yourself without help from others. You are encouraged to complete your Lab Practical test as early as the end of the Introductory Lab module. You can take the Lab Practical as many times as you want, but you have to pass it no later than 5 weeks after the class begins in order to continue the class.

Appendix I

Laboratory Notebook Guidelines

Maintaining a lab notebook is a valuable skill required for work in any lab (academic or industrial). A good lab notebook should allow a second party to read what you did, understand your analysis and, if necessary, repeat your experiment exactly. A useful guideline to keep in mind while maintaining your notebook is that you should be able to pick up your notebook two years later and, given the same apparatus, repeat the experiment to obtain a similar data set. This is not only useful to other parties who need to use your notebook, but can save hours of frustration when preparing manuscripts for scientific publication. More immediately, a well-maintained notebook facilitates trouble-shooting, either on your own or with the assistance of the course instructor or teaching assistants.

You should only write in your lab notebook using a pen, and all entries should be dated. Pages should be numbered, and you are required to sign each page. This is a common practice in both academic and industrial research labs whereby the signee certifies that the work contained on that page is authentic. Your lab notebook should have a table of contents so that it is easy to find the different experiments.

It is important that the student acknowledge references wherever necessary. Students should however be wary of using internet resources as primary references. In general, you should not use an internet reference unless no other references could be found. In many cases, you may find a primary reference by consulting a particular web page, but in this case it is the primary reference that should be cited.

What is expected for our lab write-ups?

We do *not* expect you to write a full “formal lab report” for each experiment that is performed in your lab book. This is not the role of a lab notebook. Instead, your lab notebook should be thought of a log book for each experiment. Keep the following checklist in mind as you compose your notebook. Including these details should become habitual.

Notebook checklist

- Keep up with the table of contents (if table of contents is included)
- Date and sign each page
- Mark clearly where each new entry begins
- Number each page consecutively
- Do NOT tear pages. Do NOT erase or white out any data (you can use a single strikethrough line to “correct” an error, but the error must remain legible after the strikethrough line).
- Use continuation notes when necessary
- Properly void all blank pages or portions of pages (front and back)
- Enter all information directly into the notebook
- Properly introduce and summarize each experiment
- Include complete details of all first-time procedures
- Include calculations
- Properly cite all references for background materials, designs, *etc*.
- Use a pen (not pencil) for all entries in the notebook

How are your lab notebook and lab performance graded (10 pts each for Introductory Lab, Spirometry, ECG, and Pulse Oximetry; 40 pts in total)?

Each student should have a scientific lab notebook with a table of content labeled. The lab notebook will be graded by the GSI after completion of each lab module based on correctness and completeness. You only need to record the notes related to your main responsibility (*e.g.*, software/hardware). A photocopy of the lab notebook is due one week after each lab module.

Pre-lab problem set (10% of the grade, 1 pt for each module)

Pre-lab problem sets will be given in the lab handouts prior to each lab. Read the handouts and answer the pre-lab questions on your lab notebook before the lab (with the date marked before the lab). The pre-lab problem sets should be answered by you without consulting other students.

Lab preparation (20% of the grade, 2 pts for each module)

Putting some effort into preparation before beginning each lab project will pay large dividends in both your understanding of the project and your ability to finish in a reasonable amount of time. You will take away more meaningful information from the lab, and will finish sooner. When marking your lab book, the GSIs will be looking for evidence that the student prepared for the experiment in advance. In particular, the student should have read the lab outline provided for the experiment and summarized the objectives of the experiment in their own words. The student should also have created an brief, informal checklist of what needs to be done to complete the experiment, *i.e*., what calibrations need to be completed, what samples need to be studied, what data needs to be collected. This will not necessarily be complete, but some forethought by the student will save time during the experiment itself. Remember that you only have a few sessions to complete each project, and due to the nature of some projects, this will require that the student has thought through them in advance. Don't worry if, during the experiment, you realize that you forgot something in your "Lab Preparation" checklist -- this is the nature of science! This section should also contain a brief review or discussion of relevant theoretical considerations (both electrical and physiological), any background that you found useful in terms of understanding the material, and the responses to any pre-laboratory questions. Further background may be included in subsequent sections as it is needed. Finally, you should include a preliminary design for your portion of the project. This entails different tasks for each engineering role, which should be specified by the student. Things to look for would include circuit diagrams and hardware specs for the hardware engineer, LabVIEW screenshots or pseudo-code and system diagrams for the software engineer. References for all information should be properly cited in your notebook.

To summarize, your lab preparation should include:

- Summary of lab objectives
- Review of theoretical background
- General task checklist
- Student engineering role (hardware and software)
- Preliminary design
- Responses to lab-specific questions (pre-lab questions)

Experiment and design (20% of the grade, 2 pts for each module)

As you perform the experiment, you should keep a running log of what was done *in your own words*. Verbatim recitation is not required nor recommended. Data should be recorded as it is collected, with units and experimental uncertainties included. If possible, the data should be presented in a clearly labeled table. If a mistake is made, do *not* erase the data. Instead, draw a single line neatly through the data, as this data may in the future prove to not be incorrect after all. Experimental uncertainties should be justified, especially in abnormal cases. For example, when quoting a current measured from a digital ammeter, you may be able to use an uncertainty based on the last decimal place. However, if the current is fluctuating slightly, you must take the bounds of the fluctuation as your uncertainty rather than half the smallest decimal place. A large part of being a good engineer or researcher lies in applying reasonable and justifiable uncertainties to measured values.

Basic analysis of your data should be performed as you work to verify that your results are reasonable and/or expected. This can save much frustration later when you attempt to perform more rigorous calculations based on your data. Furthermore, this is a good time to ask the GSI or the instructor if things are on the right track. You might discover, too late, that you had a problem in the way that the apparatus was used or put together. Since part of the grade for lab notebooks will be derived from the quality of the experimental data, it is better to find a mistake when you can do something about it.

The design process for your instrumentation system will likely be iterative. After collecting a data set from your preliminary design, you may find it necessary to change your design and repeat the experiment(s), *etc*. This process should be outlined as succinctly and clearly as possible, with relevant data being shown for each design phase (data relevant to the engineering role of the student).

This section should include:

- Actual experimental setup
- Information about equipment and components used
- Description of how data was collected
- Raw data
- Preliminary analysis and design iteration, as relevant to student eng. role
- Any other details necessary to evaluate what you did and/or recreate your experiment exactly.

Data analysis (20% of the grade, 2 pts for each module)

Upon completion of the data collection portion of the experiment (collection of final data set), you should immediately analyze your data as recommended in the lab outline. Graphs should be fixed into your lab notebook using tape or glue, not staples. Graphs should be clearly labeled, and any fits that were performed should be shown together with the raw data so that the reader can judge how well the fit agrees with the experimental data. As for error analysis, you should propagate all errors as you perform computations using experimental data with associated uncertainties. However, it is *not* necessary to show these error analysis calculations unless something unconventional was done. This section should be roughly similar for every lab group member.

This section should include:

- Description and justification of analytical techniques/algorithms used
- Processed/derived data
- Calculations

Conclusions (10% of the grade, 1 pt for each module)

You should include a *concise* conclusion to each experiment where you comment on how well the experiment met your initial objectives, on systematic vs. experimental errors that may be responsible for discrepancies between experimental and expected/theoretical values, and on any problems that were encountered over the course of the experiment. Note that this should be more a summary of the lab report conclusions, not a repetition. In this section, any type-setting mistakes that are discovered in the lab outline and suggestions on how to improve the lab in the future should also be included. Some of these lab outlines are in the process of being overhauled and your comments will be considered.

Overall lab performance (20% of the grade, 2 pts for each module)

Your performance in each lab will be evaluated by the GSI (50% of 2 pts) and your group peers (50% of 2 pts) for each lab module.

Appendix II

Design Lab Practical

Objectives: The Lab Practical is designed to validate your knowledge and lab skills in basic circuit design and testing, signal acquisition, and software development. You must pass the lab practical to pass this course.

Grading: The lab practical is graded as Pass/Fail. In order to pass the course, you must pass the lab practical. You can take the lab practical as many times as necessary, without penalty. However, the professor will be notified of your progress after two failed attempts.

Requirements: Outside materials (*e.g.*, notes) or resources (*e.g.*, LabVIEW files) are NOT allowed. You will only be given 1.5 hours to complete the Lab Practical (office hours, overflow lab stations). If you cannot complete the practical with in the allotted time, you will have to start from the beginning on your next attempt. If you are taking the practical more than once, bring in all documentation from your previous attempts.

Tasks:

1. Design and build a LabVIEW VI to acquire one analog channel and display the time series and power spectrum for a 2-second block. The VI must save the raw data to disk. Take screenshots of your block diagram and front panel and paste them to a MS Word file.
2. Use your VI to acquire 3 signals with different frequencies from the function generator. Show screenshots of the raw data and its power spectrum. Verify that the power spectrum is accurate and the acquired signal is not aliased by comparing the maximum power spectrum frequency to the input frequency. Be sure to document the amplitude, frequency, and offset settings on the function generator.
3. Use Excel or Matlab to open the data you saved in step 2. Calculate the mean, standard deviation, and RMS for each of the signals using either Excel or Matlab. Verify that the calculated RMS matches what you would expect from the input. Include a plot of one of the signals showing time vs. voltage. Indicate the frequency of the signal on the plot. Put the Matlab code or the formulas used in Excel into the MS Word file.
4. Design and build a specified active filter using the LM741 chip. The filter type (low, high, or band-pass), cutoff frequencies, and gain will be specified by the GSI. Please document these design specifications. If the exact specs cannot be met due to limitations in component selection, use the closest possible values.
5. Create a bode plot for your designed filter to verify that it meets the specs.
6. Turn in all documentation, figures, plots, and codes to the GSI for evaluation.
7. Sign the honor code.

Suggestion: In order to complete the Lab Practical under the 1.5-hour time constraints, it is recommended that you practice the tasks during office hours.