MODULE 16

BIOLOGICAL INTERFACES

PREREQUISITES: MODULE 04: OP-AMPS II; MODULE 13: SENSORS & TRANSDUCERS.

OUTLINE OF MODULE 16:

What you will learn about in this Module:

- Human interface considerations & safety
- Implantable devices
- Biopotential Electrodes
  - Conducting vs. non-conducting (Webster)
  - Surface
  - Nerve-cuff
- Biopotentials and Body Surface Potentials:
  - EMG (electromyogram) – muscle contraction
  - ERG (electroretinogram) –
  - EOG (electro-oculogram) – angular position of the eye
  - EEG (electroencephalogram) –
  - ECG (electrocardiogram) –
  - ENG (electroneurogram) –
  - MEG (magnetoencephalogram) – magnetic fields generated by brain

What you will build in the lab:

You will be given the equipment and supplies to build one or all of the following, based upon your level of interest: EMG, EOG, ECG, EEG.

INTRODUCTION:

Biomedical Engineering is emerging as the fastest growing area in engineering in the 21st century, and is drawing people from many diverse fields because, well basically, it is so darn interesting. Biological systems have a complexity and elegance that has inspired great thinkers from the beginning of human history. Biological systems are of interest to many professions, including engineers, scientists, artists, architects, and many others. In this module, you will learn a bit about how to take some amazingly simple measurements from a unique biological system (yourself). In general, the most difficult thing to do with a biological system is to acquire a clean and accurate signal. Once you have it captured, it is then relatively simple to manipulate it to get the information you are interested in.

If you are even the least bit uncomfortable hooking non-invasive electrodes to yourself, please feel free to avoid doing so…you may simply read and enjoy the material presented in this Module. Do not do anything to yourself or others that causes any level of discomfort, either physical or psychological.

Safety is the most important consideration in any design, even more so when you start hooking stuff up to a human. Medical safety is a field unto itself, but common sense will get you 90% of the way to a safe design. One good way to develop prototypes for interfacing with humans or animals is to stick with micropower

designs, using exclusively battery power, preferably from low voltage sources such as lithium batteries. Electrical shock is not the only hazard: chemical burns (lithium batteries can explode, but rarely do) and punctures of the skin can lead to infection. Generally, if your procedure does not pass any object through the protective barrier of the skin, it is often considered "non-invasive", and is therefore usually assumed to carry reduced risk when compared with any procedure that penetrates the skin, no matter how small that penetration may be (this includes hypodermic and acupuncture needles). You should be sure that you are fully trained (this course does NOT qualify) before making any measurements on another human. Usually you will also be required to have institutional authorization before conducting any experiments of any kind on humans or higher animals (vertebrates). Failure to comply with this can put people at risk, can cause unnecessary suffering for animals, and is generally very bad karma.

READINGS FROM HOROWITZ AND HILL (H&H): *ART OF ELECTRONICS*

15.08 (interesting, but not essential)

ADDITIONAL READINGS & INTERNET RESEARCH:

Find a copy of the following book: *Medical Instrumentation: Application & Design*, 3rd Edition (John G. Webster, Editor, published by Wiley). You should easily be able to find a more recent or an older version of this book as well, if the 3rd Edition is not readily available. Read chapter 4: The Origin of Biopotentials. If you make an effort to understand everything in this 50 page chapter, you will know a lot about Biopotentials. You may also wish to read Chapter 5: Biopotential Electrodes. At the very minimum, you must read the short section in Chapter 4 that covers each of the following signals: EEG, EOG, and EMG. You will to build a circuit to detect one or more of these for this laboratory. Each of these sections is only a few pages long. If you are registered for this course at U of Michigan, you can borrow this text from the instructor, or can check it out from the engineering or medical library.

MODULE 16

SELF QUIZ

You may refer back to the readings or do additional research on the web to answer the following questions. Assume that you will use surface electrodes (non-invasive).

1: What is an EMG? How is it measured? Be specific, and describe the electrode placement. With surface electrodes, what is the approximate amplitude (voltage) of the signal you would expect to see before amplification?

2: What is an EEG? How is it measured? Be specific, and describe the electrode placement. With surface electrodes, what is the approximate amplitude (voltage) of the signal you would expect to see before amplification?

3: What is an EOG? How is it measured? Be specific, and describe the electrode placement. How accurate is it? Is it linear? If so, over what range of angular displacements?
With surface electrodes, what is the approximate amplitude (voltage) of the signal you would expect to see before amplification?

PLEASE ANSWER THE ABOVE QUESTIONS AND E-MAIL TO THE INSTRUCTOR
"I have neither given nor received aid on this examination, nor have I concealed any violation of the Honor Code"

X_____

MODULE 16

LABORATORY PROJECTS

You will build at least one of the following systems for measuring a biopotential:
EOG – to measure eye position
EMG – to measure muscle contraction
ECG – to measure cardiac activity
EEG – to measure brain activity

You will use only surface electrodes, and will not damage or penetrate the skin. You are NOT required to attach these devices to yourself if you have any reservations about doing so. You are NOT, under any circumstances, to attach one of these devices to another human being. Before trying out your device, you should ask one of the instructors to check the design for safety. And just to be on the safe side, you will design the device using two 9 Volt transistor batteries to power the amplifier.

You may find that your amplifier will work pretty well for more than one of the devices that you can build in this laboratory, so once you have one built and working, you might choose to modify the amplifier slightly to see how well it works for other biopotential signals.

Step I: Decide which signal you wish to measure. You will only view the signal on an oscilloscope unless you go to the extra effort to attach the output to a data acquisition system (see Module-19). The easiest ones to do are the EOG and the EMG.

Step II: Design your device. Since you will only be looking at the signal on an oscilloscope, all you really need are surface electrodes and an appropriate amplifier.

Surface Electrodes: This will probably be the most challenging aspect of this laboratory exercise if you are not registered for the class. Students who are registered can simply ask one of the instructors for disposable surface electrodes. If you are doing this module on your own, you will need to find or make your own electrodes. If you wish to make your own electrodes, you can start by re-reading Webster (the chapter on biopotential electrodes contains a detailed description of how to make silver-silver chloride (Ag-AgCl) electrodes with a simple laboratory setup. You can also search the web for more Ideas (try searching "surface electrodes"). You can make primitive but functional electrodes with 1/8" diameter flat-head copper or stainless steel solid rivets, which are available in most hardware stores. The 1/8" diameter rivet shaft will be convenient for wire attachment, and the rivet head will be approximately ¼" in diameter, about right for a surface electrode. The bottom line is that making biopotential electrodes is tricky business, so if possible, find commercially available ones.

Amplifier: You need to take a guess at how large the initial signal will be. You should be able to find this in the readings in Webster. Then, you should design an amplifier that will amplify that signal so that the peak amplitude is about 1 Volt. This

means you will be using Op-amps. I suggest you use the LF444 op-amp, since it is extremely stable and will operate on very low power. Use two 9 Volt transistor batteries to power your amplifier, supplying +/- 9 volts, so that the output signal can swing both positive and negative.

Hints: If the gain you require is greater than 100, use several stages of amplification. For example, you could use two amplifier circuits in series, each with a gain of -100, to get a final gain of +10,000. You might wish to use a difference amplifier in the first stage, rather than a single-ended amplifier. You may also need to add an AC-coupled amplifier at or near the first stage to eliminate drift. This is just a high-pass amplifier (look this up on the web, or in H&H). You might set the cutoff at about 0.1 sec, for example, to eliminate low-frequency drift in your system. But to begin with, just start with simple amplifiers and see how well they work in your system.

Step III: DRAW YOUR SCHEMATIC using ExpressSCH. Include the electrodes on the schematic, and a note about their placement on the surface of the body.

Step IV: Once you have taken the safety measures detailed at the beginning of this laboratory exercise, you may wish to actually try out your device.

Test your amplifier: You can do this by using a loop of wire as an input, instead of the surface electrodes. You should be able to pick up 60 Hz noise in the room from the lights. Turn out the lights, and the noise should diminish. You should also be able to pick up noise from electric motors, etc., in the vicinity.

Place the electrodes in the locations you have selected, based on your readings and internet research. Attach them to the inputs of your amplifier. Attach the output of your amplifier to the oscilloscope. Set the time base on the oscilloscope foe a slow sweep, something like 0.2 or 0.5 seconds per division. Turn your amplifier ON. Depending on the signal you are trying to detect, do one of the following things:

EMG: contract a surface muscle that lies between or near the electrodes.
EOG: look to the right and left.
EEG: use your brain.
ECG: just be alive.

Play around for a while until you get a good signal. You may need to make modifications to your amplifier, or you may need to try different electrode placements. Once you have what you think is a good signal, you should record it somehow. You can use a “single-shot” setting on the oscilloscope to hold the trace, for example, then trace it onto a piece of paper. Singe the EOG is just a DC signal, you can skip the oscilloscope altogether and just use the DVM. Set the scale to 2 VDC and read the output voltage when looking in different directions.

Step V: Validate your device. This will depend on what device you built.

EMG: Observe how the signal changes for different levels of contraction (none, light, medium, and maximal). What aspects of the trace change (amplitude, frequency, …?). Find some information on IEMG (integrated EMG). Some people claim to be able to reliably measure muscle contractile force using surface IEMG, but these reports are generally not believed by mainstream scientists.

EOG: Put markers on the wall such that you will have to move your eyes a known angle to view each one. Be sure not to move your head, though. You may need someone else to read the voltage values. If you built two identical amplifier systems you could measure eye angle in two directions: right-left and up-down. Draw a calibration curve for your device by plotting eye angle vs. output voltage. Be sure to note which angles correspond to looking toward your nose vs. looking away from your nose. Place the electrodes around the opposite eye and re-calibrate.

ECG: If you have the electrodes placed properly, you should be able to see something like the classic q-r-s wave (see Webster, or search the web). Webster describes several placements for electrodes in subsequent chapters to those that were assigned for your readings. If you are only using two electrodes you may need to move them around a bit to get a good signal. Once you have it working, try relaxing in a chair for a few minutes, and note the time interval between the q-r-s peaks. Then, stand up and raise your arms over head. Move your arms around vigorously for a few seconds and note the effect on the interval between q-r-s peaks.

EEG: The signal you see will depend on many factors, such as the area of the brain that your electrodes are over. Unless you shave your head and use very good electrodes it may be difficult to get a good signal. You will need to do a bit of research on your own for this one, but consider looking at several areas simultaneously (you will need to build several amplifier systems to do this, of course).

Be sure to hand in an electronic copy of your final schematic using ExpressSCH, plus copies of any tracings that you made.

FEEDBACK

Was this Module useful and informative?

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Is there a topic that should get more or better coverage?

_____

In what way can this Module be improved:

Content: _____

Depth of Coverage: _____

Style: _____

Any additional comments that will help us to improve this course:

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If you prefer, you may e-mail comments directly to Bob Dennis: yoda@umich.edu