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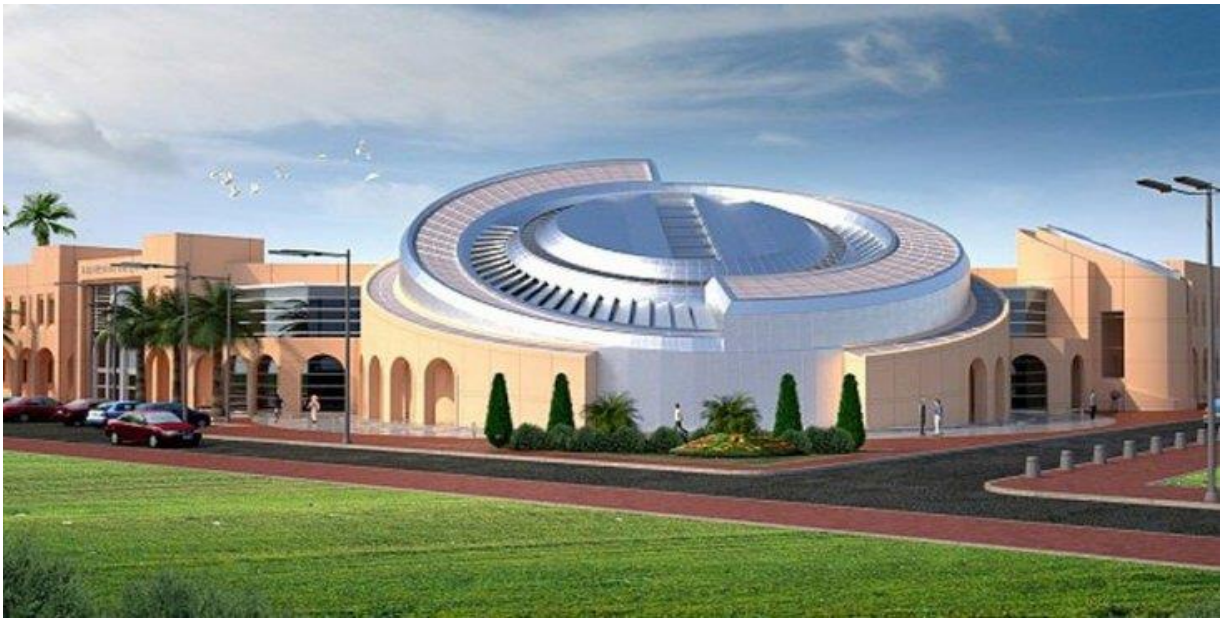
KING FAISAL UNIVERSITY

College Of Engineering

DEPARTMENT OF BIOMEDICAL ENGINEERING

BME 413: BIOMEDICAL INSTRUMENTATION-II

"Lab Manual"



Prepared By: Dr. Preethika Immaculate Britto

Major Topics covered and schedule in weeks:

Topic	Week #	Courses Covered
Instrumentation amplifiers for ECG signal conditioning	1,2	BME 412
Power line noise reduction. Notch filters	3,4	BME 412
Passive filters for biomedical signal conditioning	5.6	BME 412
Active filters for biomedical signal conditioning	7,8	BME 412
Instrumentation amplifiers for biomedical signal conditioning	9	BME 412
The ECG and Heart Sounds	10	BME 412
The ECG and Pulse	11	BME 412
Measurement of EEG artifacts using 3-Electrode technique	12	BME 412
Skeletal Muscle Reflexes	13	BME 412
Electromyogram (EMG) Activity and Muscle Strength	14	BME 412
Final exam	15	

Specific Outcomes of Instruction (Lab Learning Outcomes):

- CLO1. Describe and define the basic medical terms and physical values that can be handled by medical instrumentation. (1)
- CLO2. Apply measurement methods and implementation of electrical and nonelectrical modules in medical instrumentation (2, 6)
- CLO3. Demonstrate the capability to construct and verify small electronic circuit modules and function for biomedical instrumentation. (1, 7)
- CLO4. Demonstrate a detailed understanding of the measuring of basic medical parameters; calculate basic parameters of the equipment for using in electro diagnostic and electro therapy. (1, 2, 6, 7)
- CLO5.Apply an effective scientific written communication skill of experimental findings. (3, 4, 5)

Student Outcomes (SO) Addressed by the Lab:

z	Outcome Description General Engineering Student Outcomes	Contribution
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	H
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
3.	an ability to communicate effectively with a range of audiences	L
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	L
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	H
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	H
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	H

Table of Content

The laboratory and workshop are another means besides lecture room to add knowledge and trained the students in skill. In the laboratories, students can acquire hands-on knowledge such as:

- How to use equipment like meter, signal generator, oscilloscopes, and others.
- How to build and fix the electric and electronic circuits.
- How to apply the theory that was learned during lecture.
- How to analyze the output from the experiments.
- Providing basic for academic research.

PROPER DRESS CODE IN THE LABORATORY

- The dress code is must, Always Display your student ID.
- Wear suitable shoes, slippers or anything similar are not allowed.

THE RULES DURING LABORATORY HOURS

- Keep the bag at the provided place.
- Experiments must be completed in 3 hours during the laboratory session.
- Forbid make noisy or interfere another student.
- No eating and drinking inside the laboratory.
- Request the supervisor or technician to check the circuits' connections before switching on the power supply. Wrong connections can damage equipment/devices.
- Lab reports must be submitted right on time.
- Data acquired by other students are not allowed and will be penalized heavily.
- Data acquired must approved by laboratory supervisor (signed).
- Do not do any walking around to other students' table. Please consult the supervisor/technicians available for any problem/questions.
- Get permission from laboratory supervisor/technician before leaving the lab.
- Switch off the hand-phone during laboratory sessions.

- For current and high voltage laboratory, student must wear the rubber shoe and forbid to wear jewel or any of metal for evade short circuit.
- Bring or take out the laboratory tools without permission is forbidden.
- The replacement laboratory only can be done with permission laboratory coordinator.
- After completing the experiment, students must tidy the table, chair and equipment before leaving the laboratory.
- All students must obey all the instruction given by laboratory supervisor and technician during experiment in the laboratory.

SAFETY

Safety is always an important topic whenever laboratory work is being considered, and it is certainly true in the case of BME 411 lab. Safety is important. The experiments in the laboratory use low voltages and low currents. However, the lab equipment is powered by the 110V, 60Hz, line voltage.

- Be careful with the line voltages.
- Do not touch exposed prongs on the equipment plugs when connecting the equipment to the lines.
- Take care when using power supplies, which may be low voltage but can supply currents in the ampere range. Shorting such, a supply can lead to a serious burn as high currents arc and can ignite flammable material. This is precisely why a car battery needs to be treated with respect.
- The hundreds of amps a battery can supply are enough to cause serious burns.
- The equipment is heavy enough to be generally stable on the bench. Be sure to keep the equipment away from the edges of the benches to avoid having a piece of equipment fall off the bench.
- Besides endangering people who might be struck, falling equipment endangers everyone in vicinity by stressing the power cords, possibly causing a line short or live fault on the equipment, not to mention damage to the expensive lab equipment.
- In general, electronic equipment does not survive harsh treatment.
- The capacitors furnished in your lab kits are electrolytic capacitors with positive and negative terminals. Always connect the positively marked terminal to the most positive terminal in your circuit. An excess negative voltage applied to these capacitors can cause the device to overheat and explode.

Experiment 1: Instrumentation amplifiers for ECG signal conditioning.

I. Objective:

The experiment's objectives are:

1. Getting acquainted with the origin and mechanisms of formation of ECG signals, as well as with their characteristics and the registration methods of ECG.
2. Determination of the ADC range and of the instrumentation amplifier gain for registration of ECG signals.
3. Registration and study of raw ECG signals.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

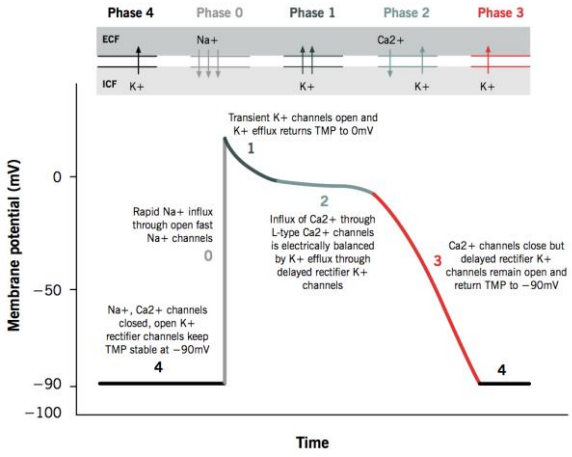
III. Theory:

Origin of ECG signals

The heart cannot pump unless an electrical stimulus occurs first. After the pulses are transmitted, cardiac cells undergo the cycles of depolarization and repolarization. Cardiac cells at rest are considered polarized. This means that no electrical activity takes place. Cell membranes separate different concentrations of ions, such as sodium and potassium, and create a more negative charge inside the cell. This is called the resting potential. After a stimulus occurs, ions cross the cell membrane and produce an action potential, or cell depolarization. When a cell is fully depolarized, it attempts to return to its resting state in a process called repolarization. Electrical charges in the cell are reversed, and then they return to their normal state. A cycle of depolarization-repolarization consists of five phases (0 to 4). The action potential is represented by a curve that shows the voltage changes during the five phases.

During phase 0, the cell receives a pulse from a neighboring cell and is depolarized. Phase 1 is marked by early, rapid repolarization. Phase 2, the plateau phase, is a period of slow repolarization. During phases 1 and 2 and at the beginning of phase 3, the cardiac cell is in its

absolute refractory period. During that period, no stimulus can excite the cell, irrespective of its strength. Phase 3, the rapid repolarization phase, occurs when the cell returns to its original state. During the last half of this phase, when the cell is in its relatively refractory period, a very strong stimulus can depolarize it. Phase 4 is the resting phase of the action potential. By the end of the phase 4, the cell is ready for another stimulus. All that electrical activity is represented on an electrocardiogram. The ECG represents electrical activity only, and not an actual pumping of the heart.



IV. Apparatus:

- Prototyping Board
- Electrodes

V. Procedure:

1. Make sure that the NI ELVIS workstation is ON (workstation power switch is in the **I** position).

2. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF)

3. Launch the ***Biomedical Device Engineering*** lab software.

4. Log into your account.

Part A. Spectrum analysis of generated ECG signals

1. To start the hands-on experiment double click on the ***Instrumentation amplifiers for ECG signal conditioning*** line in the list of labs.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic.

- Connect the **AO 0** output to the **LA** input of the instrumentation amplifier.
- Connect the **RA** input of the instrumentation amplifier to the **GND.**
- Connect the **Out** output of the instrumentation amplifier to the **AI 0** Input.

3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the *ECG parameters* field put a tick mark in the *Enable ECG* checkbox.

5. Open the *Scope* window and in the *Signal parameters* field set the channel range to 5 V.

6. Click the *Start/Stop* button on the lab control panel.

The graph of the amplified signal will appear in the *Scope* window.

7. Adjust the **Rg** potentiometer knob of the instrumentation amplifier on the **Biomedical Device Engineering Board** to achieve the maximum peak ( ) of the amplified ECG signal. 1V

8. Measure the signal and noise amplitudes.

9. Calculate the **SNR** for the registered signal, based on the obtained experimental results (see **Signal-to-noise ratio (SNR)** in **Equations**).

10. Measure the R-R interval of the amplified signal (the interval from the peak of one QRS complex to the peak of the next, see Fig. 9.2-8).

11. Calculate the heart rate, based on the measured R-R intervals. Compare the heart rate calculated value with the heart rate of the generated ECG signal.

12. Click the *Start/Stop* button on the lab control panel.

13. Click *Record* and choose the directory and the file name in which the measurement results will be stored.

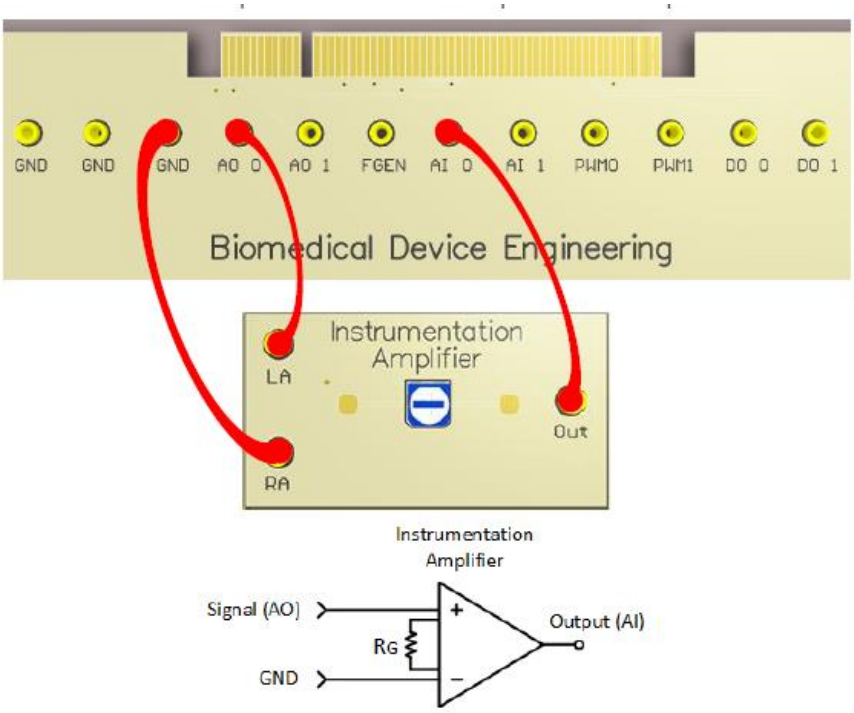


Fig. 9.2-7 Amplification circuit of generated ECG signals

14. Click the *Start/Stop* button on the lab control panel.

15. Wait for 2 or 3 minutes until the data is recorded into the file, and then click *Stop*.

16. Click the *FFT* button.

17. In the open **FFT** window open the file with the measurement results.

18. Choose the corresponding file in TDMS format and click OK. The **TDMS File Viewer** window will open.

19. In the **TDMS File Viewer** window from the expandable **File contents** directory choose the channel for the signal. You can study the selected signal on the *Analog values (graph)* tab of the **TDMS File Viewer** window.

20. Click *Quit*. The spectrum of the selected signal will appear in the **FFT** window.

21. Increase the graph scale for the display of the main characteristics of the saved signal spectrum.

22. Compare the spectrum maximum frequencies with the heart rate and the noise frequency of the generated ECG signal.

23. In the **FFT** window click *Save* to save the screenshot of the FFT window.

24. Close the **FFT** window.

25. In the *ECG parameters field* set the *Heart rate* to 75 beats/min.

26. Repeat the steps #13 – 24 of the Part A of this laboratory to obtain the generated signal spectrum.

27. In the *ECG parameters* field use the following settings:

 Heart rate: 75 beats/min;

 Noise amplitude: 2 mV.

28. Repeat the steps #13 – 24 of the Part A of this laboratory to obtain the generated signal spectrum.

29. In the *ECG parameter*s field use the following settings:

 Heart rate: 75 beats/min;

 Noise amplitude: 2 mV;

 White noise amplitude: 4 mV.

30. Repeat the steps #13 – 24 of the Part A of this laboratory to obtain the generated signal spectrum.

31. Compare the obtained spectrums of the generated signals.

32. Close the *Scope* window.

33. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part B. Registration and spectral analysis of initial ECG signals

1. Click on the right arrow ( ) to switch to the **Part B** of this lab.

2. Connect the ECG leads to the student limbs, as it is shown in Fig

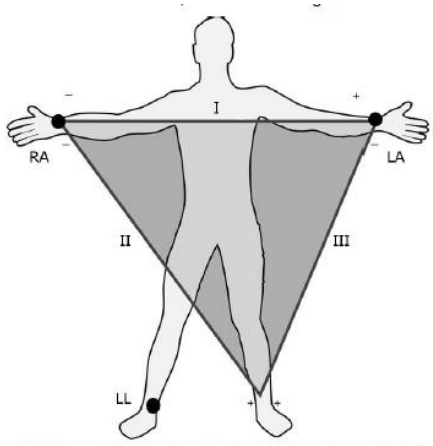
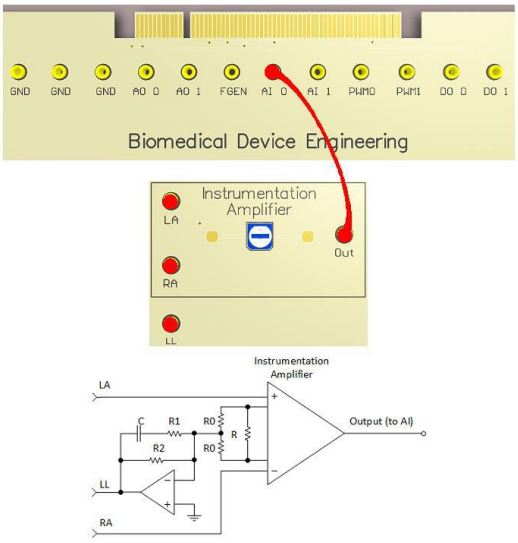


Fig. 9.2-9 Connecting the standard ECG leads for ECG registration

Using the supplied connection wires make the required connections on the board in accordance with the schematic (Fig. 9.2-10).

- Connect the **LA** ECG lead to the **LA** input of the instrumentation amplifier.
- Connect the **RA** ECG lead to the **RA** input of the instrumentation amplifier.
- Connect the **LL** ECG lead to the **LL** output on the board.
- Connect the **Out** output of the instrumentation amplifier to the **AI** 0 input.



4. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.
5. Open the *Scope* window and in the *Signal parameters* field set the channel range to 5 V.
6. Click the *Start/Stop* button on the lab control panel.
7. Adjust the knob of the potentiometer **Rg** of the instrumentation amplifier on the **Biomedical Device Engineering** board to achieve the maximum peak ( ) of the initial ECG signal. 1V □
8. Click the *Start/Stop* button on the lab control panel.
9. Repeat the steps #13 – 24 of the Part A of this laboratory to obtain the spectrum of the initial ECG signal.
10. Compare the calculated values to the measurement results obtained in **Part A** of this laboratory.
11. Close the *Scope* window.
12. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

13. Connect the **DMM** probes to the **DMM** inputs on the **NI ELVIS** workstation (see Fig. 9.1-8, lab #9.1):

- Connect the **DMM** red probe to the **VΩ** input of the **DMM** instrument.
- Connect the **DMM** black probe to the **COM** input of the **DMM** instrument.

14. Click on the **NI ELVIS Instrument Launcher** button

15. In the **DMM** window choose the resistance measuring mode (**Ω**), and click **Run** (see Fig. 9.1-9, lab # 9.1).

16. Using the **DMM** probes measure the resistance of the variable resistor **Rg** of the instrumentation amplifier.

17. Calculate the gain of the instrumentation amplifier, based on the obtained values.

Note: The equation for calculation of the gain of the used instrumentation amplifier is as follows:

$$K = \frac{49.4k\Omega}{R_G} + 1$$

18. Click the *Start/Stop* button on the lab control panel and close the **DMM** window.

19. Close the **NI ELVIS Instrument Launcher** window.

20. Close the lab Front Panel.

VI. Experimental Work:

Equations

1. **Signal-to-noise ratio (SNR)** is defined as the ratio of the useful signal power to the noise (unwanted signal) power:

$$SNR = P_{sig} / P_{noise} = A_{sig}^2 / A_{noise}^2 = (A_{sig} / A_{noise})^2$$

where A_{sig} and A_{noise} are the effective (RMS) values of the signal amplitude and noise, respectively.

2. **Heart rate f:** inverse value of the R-R interval.

Tabulation

Gain of instrumentation amplifier	
SNR	
Heart rate	

Observation:

References:

- Clark, John. The origin of biopotentials. Medical Instrumentation: Application and Design. ResearchGate, 1998.
- Strong P. Biophysical Measurements. Tektronix, Inc., Beaverton, OR, 1970.
- Thakor Nitish V. Biopotentials and Electrophysiology Measurement. CRC Press LLC, 1999.
- Van Hoof C., Puers R. Biopotential Readout Circuits for Portable Acquisition Systems. Springer, v.XV, 2009, p. 164.
- Webster J.G. Ed. Medical Instrumentation – Application and Design, 4th ed. John Wiley & Sons, USA, 2010

Experiment 2: Power line noise reduction. Notch filters

I. Objective:

The experiment's objectives are:

1. Getting acquainted with the types of noises and the causes of their occurrence, as well as with the general methods of noise reduction.

2. Designing notch filters with required characteristics.

3. Calculation and measurement of the parameters of passive notch filters; filtration of various signals using notch filters and monitoring their influence on the signals.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

Noise and its classification

Due to the widespread use of electronic circuits (such as, in communication, computation, automation, etc.), different circuits operating in proximity increase the negative influence of the circuits on each other. Electromagnetic interference (EMI) has become the major problem for circuit designers, and it is likely that this problem will become more severe in the future. For large number of commonly used electronic devices this is already seen. In addition, the size of electronic equipment decreases with the increase of using integrated circuits. To the extent of the decrease of the sizes of the devices, and due to the increase of their complexity, circuits of smaller sizes are used, thus increasing the probability of mutual interferences.

Today's equipment designers need to do more than just making their systems to operate under ideal laboratory conditions. Besides solving this obvious task, they must also guarantee the operation of an equipment in real world, nearby other equipment. This means that the equipment should not be affected by external noise sources and should not itself be a source of noise for the environment. The overall elimination (or, more exactly, the compensation) of electromagnetic interferences must be the designer's main objective.

Noise can be defined as any unwanted electrical signal in the circuit different from the useful signal that hinders the transfer, measurement, or processing of an information-bearing signal. The noise, to various extent, exists practically in all environments. For example, there are several types of noises in a digital cellular mobile phone system, such as acoustic background noise, thermal noise, electromagnetic radio-frequency noise, co-channel interference, radio-channel distortions, echo, and the processing noise. Noise and distortions are the main limiting factors in communication and measurement systems. For this reason, the theory and practice of noise rejection is at the core of the communication and measuring systems. Noise reduction and distortion removal are important problems for applications, such as cellular mobile communication, speech recognition, image processing, medical signal processing, radar, sonar, and for any other application in which the signals cannot be isolated from noise and distortions. Depending on the source of noise, and considering the physical nature of its occurrence, there are different types of noises:

- **Acoustic noise** is one of the most common types of noise available in different degrees in everyday environment, and which occurs in the result of movements, vibrations, and source interference.
- **Electromagnetic noise** is available at all frequencies, and particularly at radio frequencies. All electric devices, such as radio and television transmitters and receivers, generate electromagnetic noise.
- **Electrostatic noise** is generated in the presence of a voltage with/without current flow. Fluorescent lighting is one of the more common sources of electrostatic noise.
- **Channel distortions, echo, and fading** take place due to non-ideal characteristics of communication channels. UHF radio channels used by cellular mobile phone operators are particularly sensitive to the channel propagation characteristics.
- **Noise processing**: Processing of a noise occurred due to the digital/analog processing of signals, for example, the quantization noise in digital coding of speech or image signals, the lost data packets in digital data transfer systems.
- Depending on the frequency and timing characteristics the noise can be divided into the following main categories:
- **Narrow-band noise** is a noise with a narrow bandwidth (for example, 50/60 Hz power line interference).

- **White noise** is a "purely" white noise with a flat power spectrum. Theoretically, the white noise contains all the frequencies of equal intensity.
- **Band-limited white noise** is a band-limited noise which usually covers the limited spectrum of the device or the signal of interest.
- **Colored noise** is a colored or any wide-band noise with a non-flat spectrum (such as, pink noise, red noise, and autoregressive noise).
- **Pulse noise** consists of short pulses with random amplitude and duration.
- **Transient noise** consists of relatively long noise pulses.

IV. Apparatus:

- Prototyping Board
- Electrodes

V. Procedure:

1. Make sure that the NI ELVIS workstation is ON (workstation power switch is in the **I** position).

2. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

3. Launch the ***Biomedical Device Engineering*** lab software.

4. Log into your account.

Step-By-Step Instructions

Part A. Bode graphs of notch filters

1. To start the hands-on experiment double click on the ***Power line noise reduction. Notch filters*** line in the list of labs

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.3-7).

- Connect the **FGEN** output to the **AI 1** input and **In** input of the notch filter.
- Connect the **Ref** set input of the notch filter to **GND.**

- Connect the **Out** output of the notch filter to the **AI 0** input.

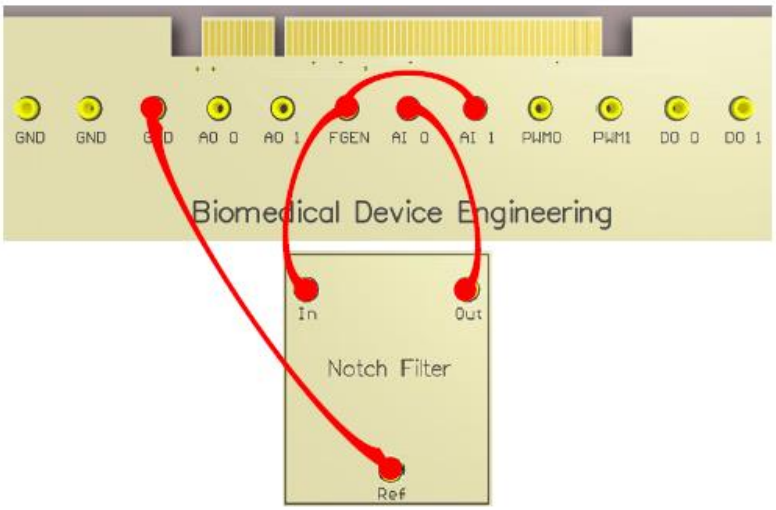
3. Calculate the maximum notch frequency of the notch filter shown in Fig. 9.3-7 for the following component values:

$$R_1 = R_2 = 2R_3 = 10kOhm$$

$$C_2 = C_3 = 0.5C_1 = 0.33\mu F$$

$$f_{notch} = \frac{1}{2\pi RC}$$

Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.



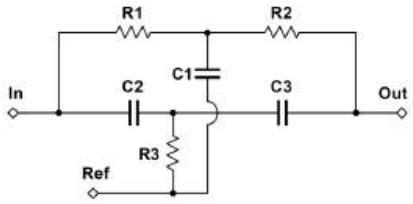


Fig. 9.3-7 Registration circuit of Bode graphs of notch filters

5. Click on the **NI ELVIS Instrument Launcher** button.

6. Launch the **Bode Analyzer** (Fig. 9.3-8) from *NI ELVISmx Instrument Launcher*.

7. In the **Bode Analyzer** window use the following settings (Fig. 9.3-8):

- *Stimulus Channel:* AI 1;

- *Response Channel:* AI 0;
- *Start Frequency:* 5 Hz;
- *Steps*: 20.

8. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the notch filter.

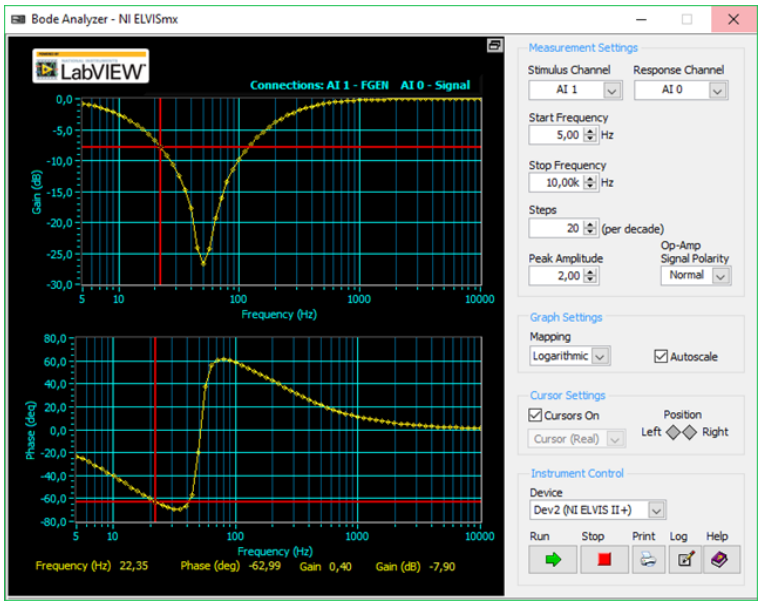
9. In the **Bode Analyzer** window enable the cursors by ticking the *Cursors On* field, and using the cursors study the frequency and phase characteristics of the filter. Compare the watched results with the theoretical values.

10. Determine the notch frequency of the filter and compare the measured value with its calculated value obtained in step #3 of Part A of this lab.

11. In the **Bode Analyzer** window click **Print** and choose Export to File.

12. Click **File** and choose the directory and the file name in which the obtained Bode graphs will be stored.

13. Click **OK** to save the screenshots of the obtained Bode graphs.



14. Close the **Bode Analyzer** window.

15. Close the **NI ELVIS Instrument Launcher**.

16. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part B. Study of the influence of notch filters on the generated ECG signals

1. Click on the right arrow () to switch to the **Part B** of this lab.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.3-9).

- Connect the **AO 0** output to the **AI 0** input and **In** input of the notch filter.
- Connect the **Ref** setting input of the notch filter to **GND**.
- Connect the **Out** output of the notch filter to **AI 0** input.

3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the **ECG parameters** field tick the **Enable ECG** checkbox, and use the following settings:

- *Heart rate*: 75 beats/min;
- *Power line noise amplitude*: 6 mV.

5. Open the *Scope* window and in the *Signal parameters* field set the range for both channels AI 0 and AI 1 to 10 V.

6. Click **Run**.

The graphs of the generated (**AI 0**) and filtered (**AI 1**) signals will appear in the scope traces area of the *Scope* window.

7. Measure the amplitudes of the generated and filtered signals, as well as the noise level for each signal.

8. Calculate SNR for both the generated and the filtered signals (see **Signal-to-noise ratio (SNR)** in **Equations**). Compare the obtained values.

9. Click on the *Start/Stop* button on the lab control panel.

10. Click *Record* and choose the directory and the file name in which the measurement results will be stored.

11. Click on the *Start/Stop* button on the lab control panel.

12. Wait for 2 or 3 minutes until the data is recorded into the file, and the click *Stop*.

13. Click on the **FFT** button.

14. In the open **FFT** window click *Open* and open the file with the measurement results.

15. Choose the corresponding file in .TDMS file format, and then click **OK**. The **TDMS File Viewer** window would open.

16. From the **File contents** expandable directory branch choose the **AI 0** signal channel for the non-filtered ECG signal.

17. Click **Quit**. The spectrum of the selected signal will be displayed in the **FFT** window.

18. Increase the graph scale for the display of the main characteristics of the saved signal spectrum.

19. In the **FFT** window click *Save* to save the screenshot of the window.

20. In the **FFT** window click *Open* to open the file with the measurement results, and then click **OK**.

21. From the **File contents** expandable directory branch choose the **AI 1** signal channel for the filtered ECG signal.

22. Click **Quit**. The spectrum of the selected signal will be displayed in the **FFT** window.

23. Increase the graph scale for the display of the main characteristics of the saved signal spectrum.

24. In the **FFT** window click *Save* to save the screenshot of the window.

25. Compare the obtained spectrums of the generated and filtered ECG signals.

26. Close the **FFT** window.

27. Close the *Scope* window.

28. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

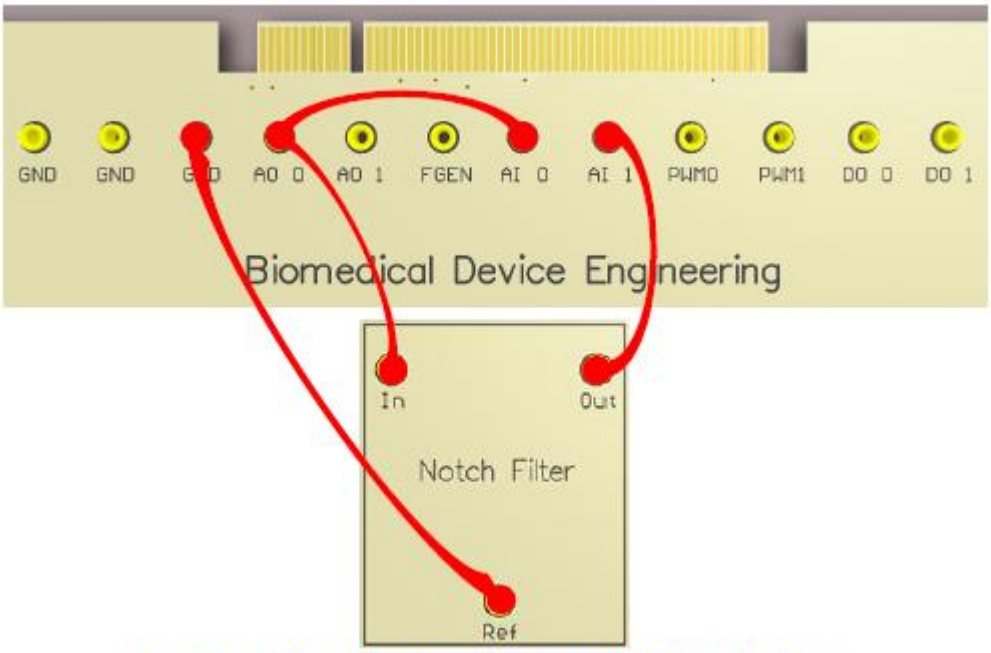


Fig. 9.3-9 Filtration circuit of generated ECG signals using Notch filter

Part C. Power line noise reduction in ECG signals using notch filters

1. Click on the right arrow ( ) to switch to the following **Part C** of this lab.

2. Connect the ECG leads to the student limbs, as it is shown in Fig. 9.3-10.

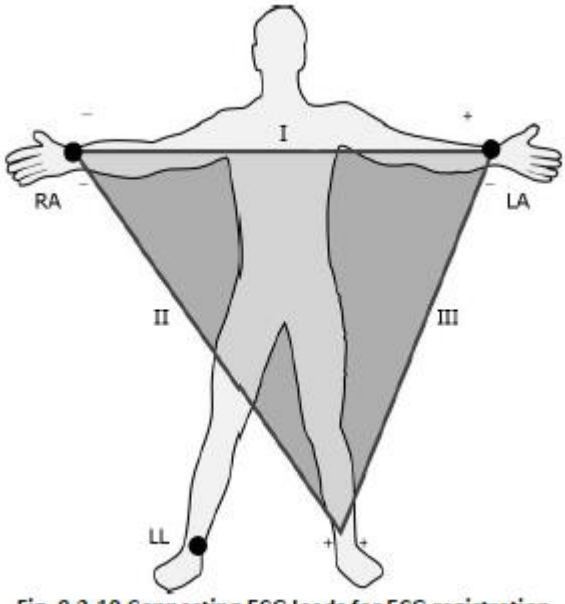


Fig. 9.3-10 Connecting ECG leads for ECG registration

3. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.3-11).

- Connect the **LA** ECG lead to the **LA** input of the instrumentation amplifier.
- Connect the **RA** ECG lead to the **RA** input of the instrumentation amplifier.
- Connect the **LL** ECG lead to the **LL** output on the board.
- Connect the **Out** output of the instrumentation amplifier to the **AI 0** input and **In** input of the notch filter.
- Connect the **Ref** input of the notch filter to **GND**.
- Connect the **Out** output of the notch filter to the **AI 1** input.

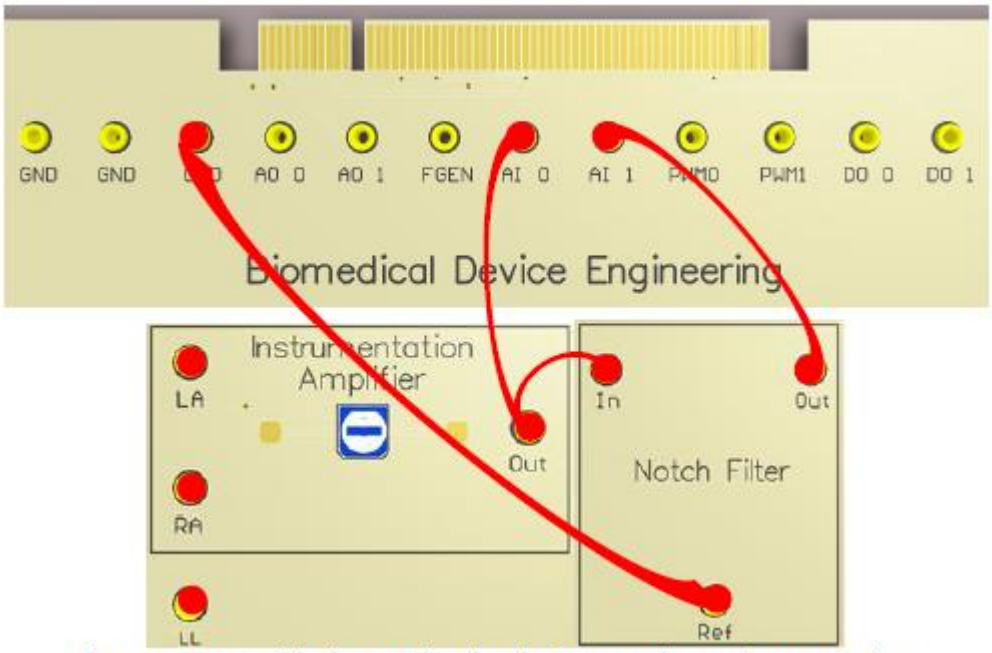


Fig. 9.3-11 Pre-amplification and filtration circuit of ECG signals using a notch filter

4. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

5. Open the *Scope* window and in the *Signal parameters* field set the channel range to 5 V.

6. Click **Run**.

The graphs of the initial (AI 0) and filtered (AI 1) ECG signals will appear in the *Scope* window.

7. Adjust the **RG** variable resistor knob of the instrumentation amplifier on the **Biomedical Device Engineering** board to achieve the maximum peak ( ) of the initial ECG signal. 1B □

8. Click *Stop*.

9. Repeat the steps # 10 – 24 of Part B of this lab to obtain the spectrums of the initial and filtered ECG signals.

10. Compare the obtained spectrums of the initial and filtered ECG signals.

11. Close the **FFT** window.

12. Close the *Scope* window.

13. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

VI. Experimental Work:

Equations

1. Signal-to-noise ratio (SNR) is defined as the ratio of the useful signal power P_c to the noise power P_u (unwanted signal):

$$SNR = P_{sig} / P_{noise} = A_{sig}^2 / A_{noise}^2 = (A_{sig} / A_{noise})^2$$

where A_{sig} and A_{noise} are the effective (RMS) values of the signal and noise amplitudes, respectively.

2. Heart rate (f): inverse value of the R-R interval:

$$f = 1/(R - R_{int})$$

3. Notch frequency of a passive notch filter for the schematic in Fig. 9.3-7:

$$f_{notch} = \frac{1}{4\pi R_3 C_3}$$

Tabulation

SNR	
Heart rate (f)	
Notch Frequency	

References:

- Clark, John. The origin of biopotentials. Medical Instrumentation: Application and Design. ResearchGate, 1998.
- Strong P. Biophysical Measurements. Tektronix, Inc., Beaverton, OR, 1970.
- Thakor Nitish V. Biopotentials and Electrophysiology Measurement. CRC Press LLC, 1999.
- Van Hoof C., Puers R. Biopotential Readout Circuits for Portable Acquisition Systems. Springer, v.XV, 2009, p. 164.
- Webster J.G. Ed. Medical Instrumentation – Application and Design, 4th ed. John Wiley & Sons, USA, 2010

Experiment 3: Passive filters for biomedical signal conditioning.

I. Objective:

The experiment's objectives are:

1. Getting acquainted with the types and operation of passive filters.

2. Designing and implementation of passive filters with the required characteristics.

3. Calculation and measurement of the parameters of passive filters; filtration of various signals using different types of passive filters and monitoring their influence on the signals.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

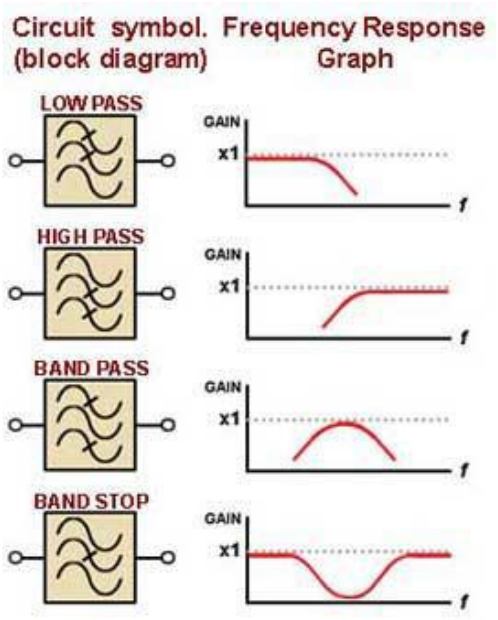
III. Theory:

Passive filters

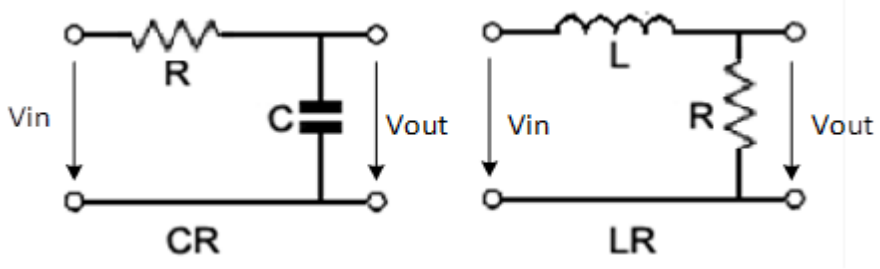
Passive filter circuits are used to reduce the signal amplitude. Passive filters are frequency selective devices which allow to reduce the signal amplitude at some frequencies without affecting the signals of other frequencies, i.e. they filter unwanted signals. An ideal filter separates sand passes input signals depending on their frequency.

Depending on the working frequency range, the filter circuits are given different names. The symbols of some filters used in block diagrams, and their frequency response characteristics are given in figure below.

The frequency response graph is the dependence of the gain on the frequency which is used for determination of the influence of the filter on the wave amplitude and displays relative levels of the output voltage in different frequency ranges. Passive filters do not contain any active components, such as transistors, which allow to increase the output voltage level of the filter. They contain only passive components (resistors, capacitors, and inductors). This means that in simple capacitance-resistance (CR) filters the signal amplitude at the filter output cannot be higher than the input signal amplitude. For this reason, the maximum gain on all the frequency response graphs is less than unity.



Passive filters use the combinations of passive components R, L and C. In low -frequency applications (up to 100 kHz), passive filters are generally implemented using simple RC (Resistance-Capacitance) circuits, while higher-frequency filters (above 100 kHz) are commonly implemented based on RLC (Resistor-Inductor-Capacitor) components. Inductors and capacitors reply to frequency changes in different ways. If in simple low pass filter circuits, we replace the components L and C relative to R, then both combinations of passive components L, R and C, R will have the same effect



IV. Apparatus:

- Prototyping Board
- Electrodes

V. Procedure:

Preparations

1. Make sure that the NI ELVIS workstation is ON (workstation power switch is in the **I** position)..

2. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Attention: *Unless explicitly specified, all electric connections on the board should always be made when the electric power supply to the board is disconnected. The power switch should be in* ***O*** *(OFF) position.*

3. Launch the ***Biomedical Device Engineering*** lab software.

4. Log into your account.

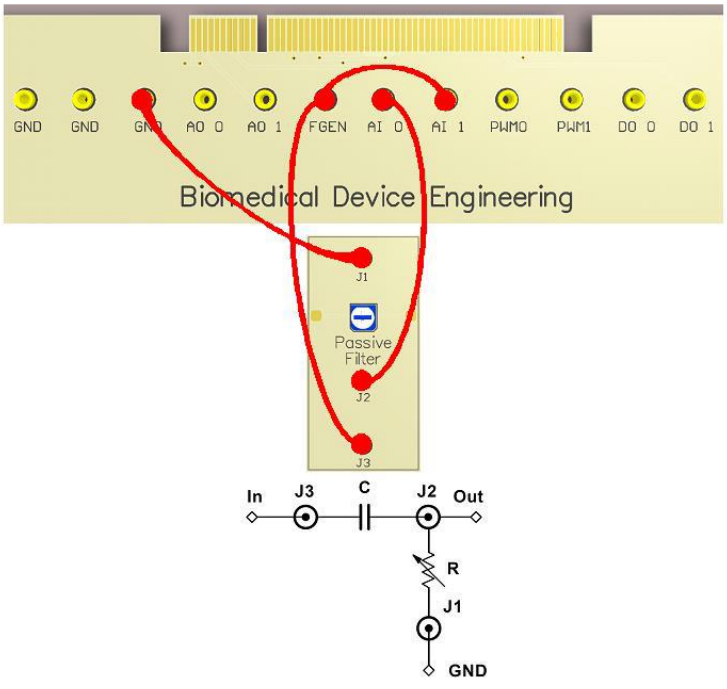
Step-By-Step Instructions

Part A. Bode graphs of high pass (HP) and low pass (LP) filters

1. To start the hands-on experiment double click on the ***Passive filters for biomedical signal conditioning*** line in the list of labs

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.4-12).

- Connect the **FGEN** output to the **AI 1** input and **J3** contact of the passive filter.
- Connect the **J1** contact of the passive filter to **GND.**
- Connect the **J2** contact of the passive filter to **AI 0** input.



1. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

2. Click on the **NI ELVIS Instrument Launcher**.

3. From the *NI ELVISmx Instrument Launcher* open the **Bode Analyzer** tool.

4. Turn the variable resistor (**R**) knob of the passive filter on the **Biomedical Device Engineering** board up to its rightmost position (corresponds to the maximum value of the **R**).

5. In the **Bode Analyzer** window use the following settings:
- *Stimulus Channel:* AI 1;
- *Response Channel:* AI 0:
- *Start Frequency:* 5 Hz;
- *Steps*: 50.

6. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the filter.

7. In the **Bode Analyzer** window enable the cursors, and using the cursors determine the cut-off frequency **fc** of the filter.

8. Connect the **DMM** probes to the **DMM** inputs on the **NI ELVIS** workstation (see Fig. 9.1-8, lab # 9.1).
- Connect the **DMM** red probe to the **VΩ** input of the **DMM** instrument.
- Connect the **DMM** black probe to the **COM** input of the **DMM** Instrument.

9. Launch the **DMM**.

10. In the **DMM** window choose the resistance measuring mode (**Ω**), and click **Run**.(see Fig. 9.1-9, lab # 9.1).

11. Using the **DMM** probes measure the resistance of the variable resistor **R** of the passive filter.

12. Having the values of **R** and **fc**, calculate the capacitance of the capacitor **C** used in the passive filter circuit.

13. Using the calculated value of **C**, calculate the required value of the resistance of the variable resistor, providing the cut-off frequency of 100 Hz.

14. When measuring the resistance of the variable resistor **R** using the **DMM** probes, try to achieve its calculated value obtained in step #5. Leave the variable resistor in this position.

15. Click **Stop** and close the **DMM** window.

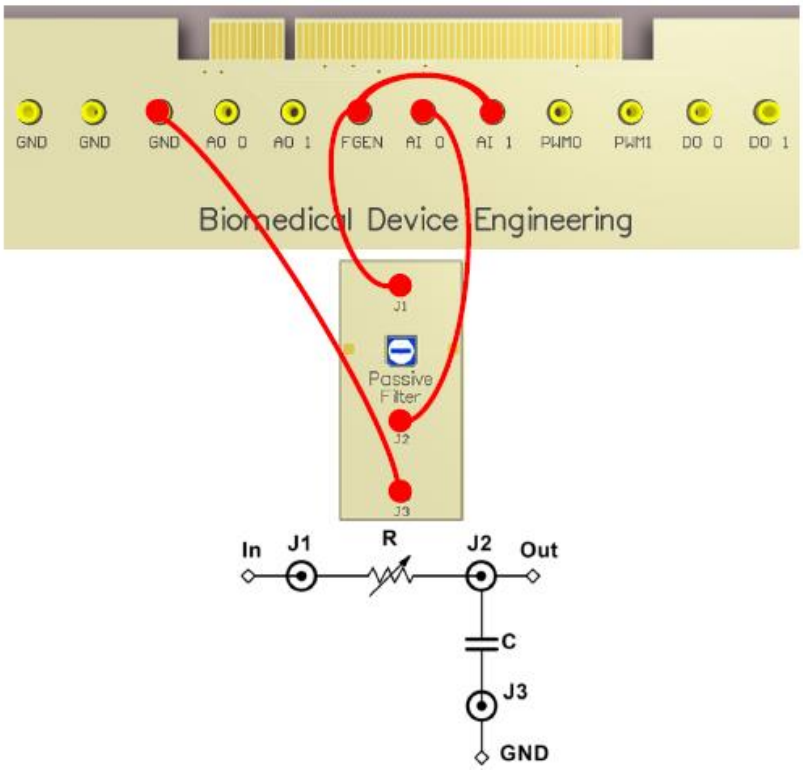
16. In the **Bode Analyzer** window click **Run** to measure the filter frequency characteristics for the new value of the variable resistor **R**.

17. Using the cursors in the **Bode Analyzer** window determine the new value of the filter cut-off frequency **fc**. Make sure that the new value of the cut-off frequency is equal to 100 Hz.

18. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

19. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.4-13)

- Connect the **FGEN** output to the **AI 1** input and **J1** contact of the passive filter.
- Connect the **J3** contact of the passive filter to the **GND**.
- Connect the **J2** contact of the passive filter to the **AI 0** input.



20. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

21. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the low pass filter.

22. Using the cursors in the **Bode Analyzer** window determine the cut-off frequency **fc** of the low pass filter. Make sure that the cut-off frequencies of the LP and HP filters are the same.

23. Close the **Bode Analyzer** window.

24. Close the **NI ELVIS Instrument Launcher** window.

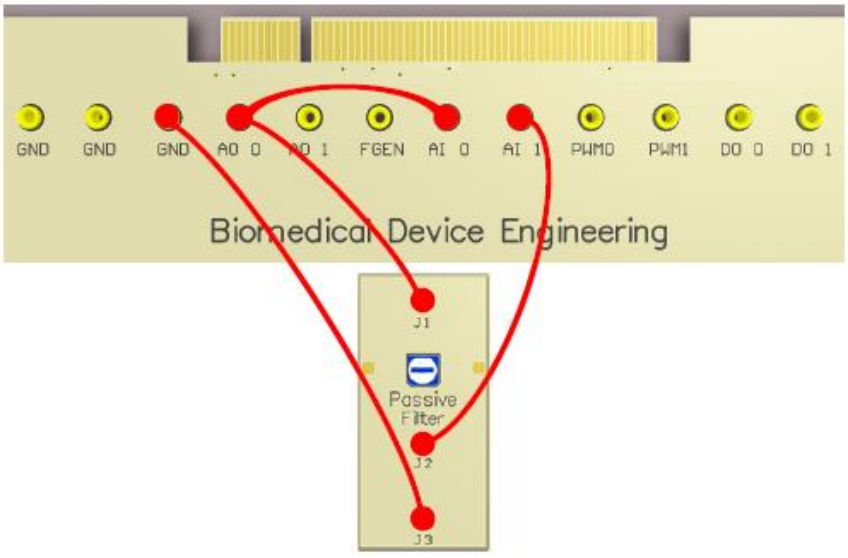
25. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part B. Studying the influence of the passive low pass filters on the generated ECG signals.

1. Click on the right arrow to switch to the **Part B** of this lab.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic.

- Connect the **AO 0** output to the **AI 0** input and **J1** contact of the passive filter.
- Connect the **J3** contact of the passive filter to the **GND**.
- Connect the **J2** contact of the passive filter to the **AI 1** input.



3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the **ECG parameters** field choose **Enable ECG**, and set the *White noise amplitude* to 4 mV.

5. Open the *Scope* window and in the *Signal parameters* field set the range for both channels AI 0 and AI 1 to 0.1 V.

6. Click **Run**.
The graphs of the generated (**AI 0**) and filtered (**AI 1**) signals will appear in the *Scope* window.
7. Measure the generated and filtered signal amplitudes, as well as the noise level for each signal.

8. Calculate the **SNR** values for the generated and filtered signals. Compare the obtained values.

9. Click **Stop**.
10. Click *Record* and choose the directory and the file name in which the measurement results will be stored.

11. Click *Start*.

12. Wait for 2 or 3 minutes until the data is recorded into the file, and then click *Stop*.

13. Click on the **FFT** button.

14. In the open **FFT** window click *Open* to open the file with the measurement results.

15. Select the corresponding file in. TDMS format and click **OK**. The **TDMS File Viewer** window will open.

16. From the expandable **File contents** directory choose the signal of the AI 0 channel (non-filtered ECG signal).

17. Click **Quit**. The selected signal spectrum will appear in the **FFT** window.

18. Increase the graph scale for the display of the main characteristics of the signal spectrum.

19. In the **FFT** window click *Save* to save the screenshot of the window.

20. In the **FFT** window click *Open* to open the file with the measurement results, and then click **OK**.

21. In the **TDMS File Viewer** window from the expandable branches of the **File contents** directory choose the signal of the AI 1 channel (filtered ECG signal).

22. Click **Quit**. The selected signal spectrum will appear in the **FFT** window.

23. Increase the graph scale for the display of the main characteristics of the signal spectrum.

24. In the **FFT** window click *Save* to save the screenshot of the window.

25. Compare the obtained spectrums of the generated and filtered ECG signals.

26. Close the **FFT** window.

27. Close the *Scope* window.

28. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part C. Filtration of ECG signals using passive low pass filters

1. Click on the right arrow () to switch to the following **Part C** of this lab.

2. Connect the ECG leads to the student limbs, as it is shown in Fig

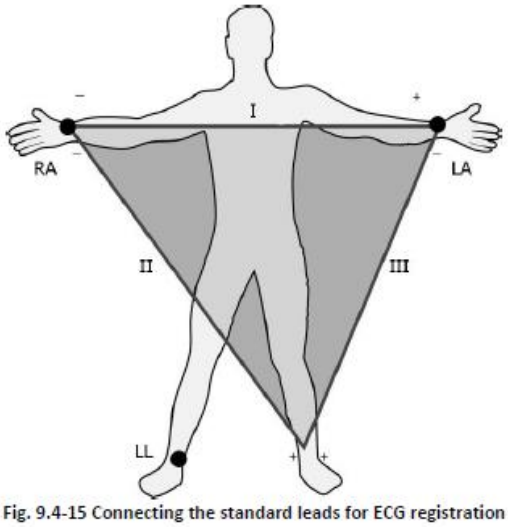


Fig. 9.4-15 Connecting the standard leads for ECG registration

3. Using the supplied connector leads make the required connections on the board in accordance with the schematic (Fig. 9.4-16).

- Connect the **LA** ECG lead to the **LA** input of the instrumentation amplifier.
- Connect the **RA** ECG lead to the **RA** input of the instrumentation amplifier.
- Connect the **LL** ECG lead to the **LL** output on the board.
- Connect the **Out** output of the instrumentation amplifier to the **AI 0** input and to the **J1** contact of the passive filter.
- Connect the **J3** contact of the passive filter to the **GND**.
- Connect the **J2** contact of the passive filter to the **AI 1** input.

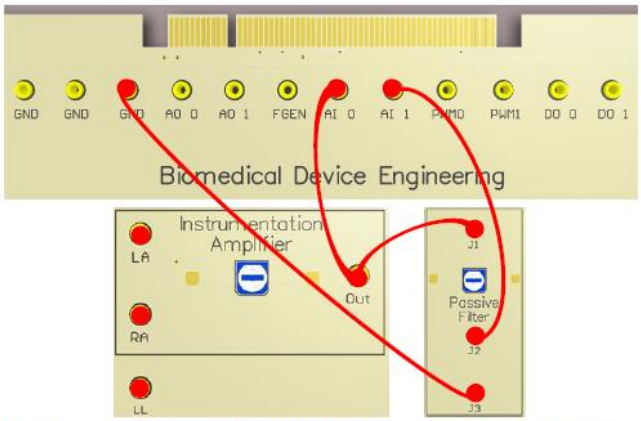


Fig. 9.4-16 Pre-amplification and filtration circuit of the ECG signals of the passive low pass filter

4. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

5. In the *Scope* window in the *Signal parameters* set the channel range to 5 V.

6. Click **Run**.

The graphs of the initial (**AI 0**) and filtered (**AI 1**) ECG signals will appear in the *Scope* window.

7. Turn the potentiometer knob of the instrumentation amplifier on the **Biomedical Engineering Board** trying to achieve the maximum peak ( ) of the initial ECG signal. 1V □

8. Click *Stop*.

9. Repeat the steps # 10 – 24 of **Part B** of this lab to obtain the spectrums of the initial and filtered ECG signals.

10. Compare the obtained spectrums of the initial and filtered ECG signals.

11. Close the **FFT** window.

12. Click **Run**.

13. By turning the knob of the variable resistor **R** of the passive filter change the cut-off frequency and study its influence on the ECG signal.

14. Close the *Scope* window.

15. Click *Stop* and close the lab Front Panel.

16. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

VI. Experimental Work:

Tabulation

References:

- Clark, John. The origin of biopotentials. Medical Instrumentation: Application and Design. ResearchGate, 1998.
- Strong P. Biophysical Measurements. Tektronix, Inc., Beaverton, OR, 1970.
- Thakor Nitish V. Biopotentials and Electrophysiology Measurement. CRC Press LLC, 1999.
- Van Hoof C., Puers R. Biopotential Readout Circuits for Portable Acquisition Systems. Springer, v.XV, 2009, p. 164.
- Webster J.G. Ed. Medical Instrumentation – Application and Design, 4th ed. John Wiley & Sons, USA, 2010

Experiment 4: Active filters for biomedical signal conditioning

I. Objective:

The experiment's objectives are:

1. Getting acquainted with the types and operation of active filters.
2. Designing and implementation of active filters with the required characteristics.
3. Calculation and measurement of the parameters of active filters; filtration of various signals using different types of passive filters and monitoring their influence on the signals.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

Active filters

The signal-to-noise ratio is watched at the output of most of the biological measuring systems. A signal is a part of a data in which the researcher is interested in, and the remaining data can be a noise. The noise includes unwanted biological data and interference from nonbiological sources, received or generated in the measuring equipment. Hence, it is desirable to remove it while maintaining the signal. A signal can be cleared using a properly selected filter. If the signal and noise spectrums occupy separate frequency ranges, then a filter can be used to suppress the noise.

An electrical filter is a frequency-selective devise which is used to transfer the given frequency range with simultaneous suppression of out-off range signals. Depending on the type of the components used in their circuits, the filters can be either active or passive. The passive filter circuits contain only passive components (resistors, capacitors, and inductors).

The main disadvantage of passive filters is that the output signal amplitude is lower than that of the input signal, i.e. the gain is always less than unity, and the load impedance affects the filter characteristics. In passive filter circuits containing multiple stages, this loss in signal amplitude

called the attenuation can be critical. One of the methods of restoring or controlling the signal loss is amplification using active filters.

Active filters contain active components (such as, operational amplifiers, transistors, or FET transistors) supplied from external power source which is used for the input signal amplification. In active filter circuits an operational amplifier (op-amp) is usually used. An op-amp has a high input impedance, a low output impedance, and a voltage gain which is determined by the resistors in feedback loop circuit.

Active filters offer several advantages over passive filters. Since the op-amp can provide the given gain, unlike passive filters, the input signal is not attenuated. Due to the high input and low output impedances of an op-amp, an active filter does not overload the system.

Active filters provide accuracy, stable tuning, and high immunity to electromagnetic interference.

There are two principal reasons for the use of active filters. First, the feeding amplifier can be used to shape the frequency response of the filter, for example, to assign the slope speed of the frequency response between the pass band and the stop band (while when using passive filters it is required to use inductors which, as a rule, cover the surrounding electromagnetic waves, and usually are of large sizes). Secondly, the feeding amplifier can be used to match the filter and electronic components controlled by the amplifier. This is required to exclude their influence on the filter operation.

IV. Apparatus:

- Prototyping Board
- Electrodes

V. Procedure:

Preparations

1. Make sure that the NI ELVIS workstation is ON (workstation power switch is in the **I** position).
2. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).
3. Launch the ***Biomedical Device Engineering*** lab software.

4. Log into your account.

Step-By-Step Instructions

1. To start the hands-on experiment double click on the ***Active filters for biomedical signal conditioning*** line in the list of labs.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic

- Connect the **FGEN** output to the **AI 1** input and **In** input of the high pass filter.
- Connect the **Out** output of the high pass filter to the **AI 0** input.

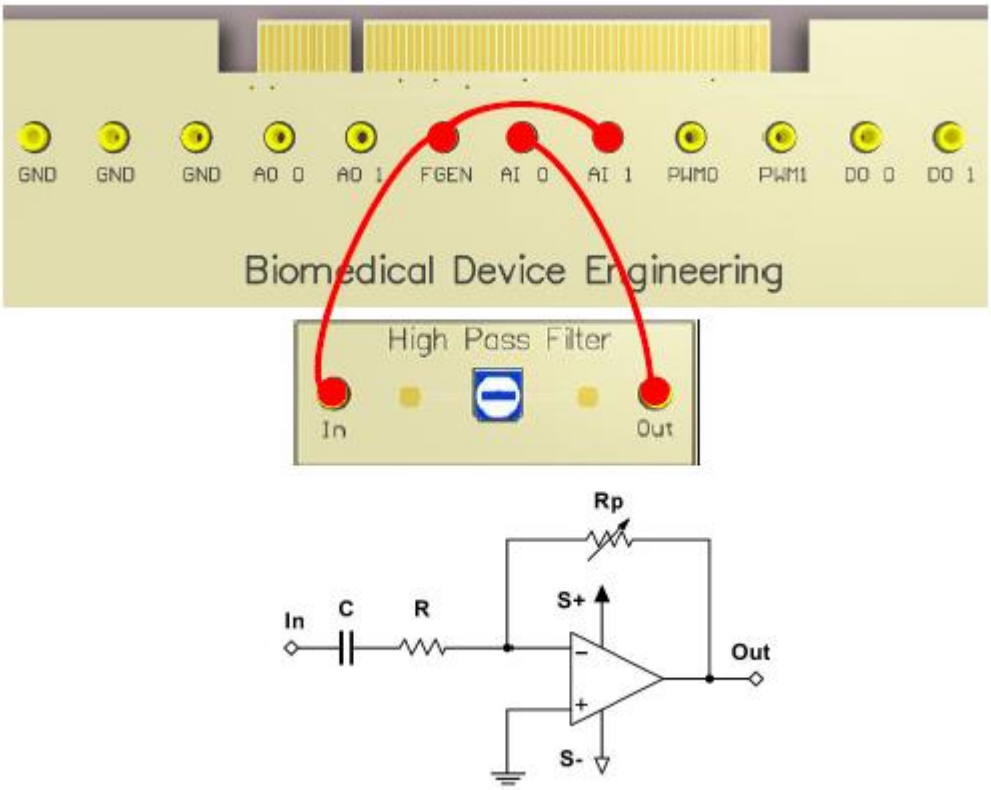


Fig. 9.5-15 Registration circuit of the Bode graphs of a high pass filter

3. Turn the knob of the variable resistor **Rp** of the high pass filter on the **Biomedical Device Engineering** board up to the rightmost position (corresponds to the maximum value of **Rp**).

4. Connect the **DMM** probes to the **DMM** inputs on the **NI ELVIS** workstation (see Fig. 9.1-8, lab # 9.1).

- Connect the **DMM** red probe to the **VΩ** input of the **DMM** instrument.
- Connect the **DMM** black probe to the **COM** input of the **DMM** instrument.

5. Click on the **NI ELVIS Instrument Launcher** button.

6. Launch the **DMM**.

7. In the **DMM** window choose the resistance measuring (**Ω**), and then click **Run.**

8. Using the **DMM** probes measure the resistance of the variable resistor **Rp** of the high pass filter.

9. Click **Stop** and close the **DMM** window.

10. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

11. Click *Start/Stop* on the lab control panel to turn ON the amplifier.

12. From the *NI ELVISmx Instrument Launcher* open the **Bode Analyzer** window.

13. In the **Bode Analyzer** window use the following settings:
- *Stimulus Channel:* **AI 1**;
- *Response Channel*: **AI 0**;
- *Start Frequency:* 5 Hz;
- *Steps :* 50;
- *Peak Amplitude:* 0.01 V;
- *Op-Amp Signal Polarity:* inverse signal.

14. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the filter.

15. In the **Bode Analyzer** window enable the cursors and using the cursors determine the maximum gain (dB) and the cut-off frequency **fc** of the filter.

16. Calculate the maximum output voltage of the filter, to make sure that the output signal is not saturated during the changes of the frequency characteristics.

17. Using the measured values of **Rp** and the maximum gain (dB), calculate the resistance of the resistor **R** in the high pass filter circuit (Fig. 9.5-15).

18. Calculate the capacitance of the capacitor **C** in the high pass filter circuit, using the values of **R** and the cut-off frequency **fc**.

19. Turn the knob of the variable resistor **Rp** of the high pass filter on the **Biomedical Device Engineering** board up to the mean position.

20. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the filter for the new value of the variable resistor **Rp**.

21. Using the cursors in the **Bode Analyzer** window determine the new values of the maximum gain (dB) and of the cut-off frequency **fc** of the filter.

22. Click on the Start/Stop button on the control panel to turn OFF the amplifier.

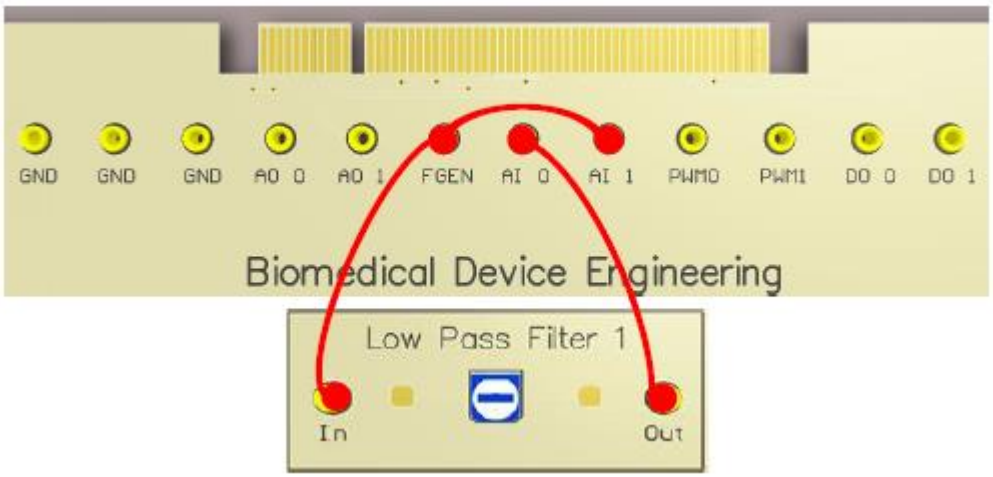
23. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

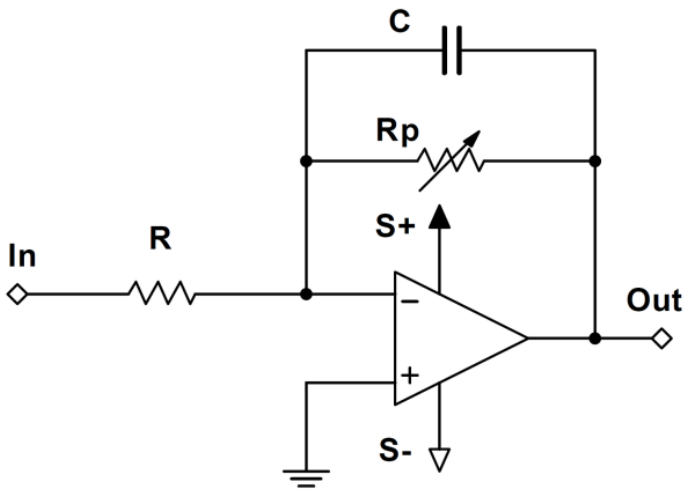
Part B. Bode graphs of active low pass filters.

1. Click on the right arrow to switch to the Part B of this lab.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.5-16):

- Connect the **FGEN** output to the **AI 1** input and **In** input of the Low Pass Filter 1.
- Connect the **Out** output of the Low Pass Filter 1 to the **AI 0** input.





3. Turn the knob of the variable resistor **Rp** of the Low Pass Filter 1 on the **Biomedical Device Engineering** board up to its mean position.

4. Open the **DMM** window and click **Run**.

5. Using the **DMM** probes measure the resistance of the variable resistor **Rp** of the low pass filter.

6. In the **DMM** window click **Stop**.

7. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

8. Click *Start/Stop* on the lab control panel to turn on the amplifier.

9. From the *NI ELVISmx Instrument Launcher* open the **Bode Analyzer** window.

10. In the **Bode Analyzer** window use the following settings:

- *Stimulus Channel:* AI 1;
- *Response Channel:* AI 0;
- *Start Frequency:* 1 Hz;
- *Steps:* 30;
- *Peak Amplitude:* 0.1 V;
- *Op-Amp Signal Polarity:* Inverted signal.

11. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the filter.

12. In the **Bode Analyzer** window enable the cursors and using the cursors determine the maximum gain (dB) and the cut-off frequency **fc** of the filter.

13. Make sure that the output signal has not been saturated during the changes of the frequency characteristics and calculate the maximum output voltage of the filter and compare its value with the value of the saturation voltage.

14. Using the measured values of **Rp** and of the maximum gain (dB), calculate the resistance of the resistor **R** in the low pass filter circuit (Fig. 9.5-16).

15. Calculate the capacitance of the capacitor **C** in the low pass filter circuit (Fig. 9.5-16), using the values of the variable resistor **Rp** and the cut-off frequency **fc**.

16. Having the value of **C**, calculate the required value of the variable resistor, providing the cut-off frequency of 100 Hz.

17. Click Start/Stop on the lab control panel to turn OFF the amplifier.

18. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

19. Open the **DMM** window and click **Run**.

20. When measuring the resistance of the variable resistor **R** using the **DMM** probes, try to achieve its calculated value, in order to provide the cut-off frequency of 100 Hz. Leave the variable resistor in this position.

21. Click **Stop** and close the **DMM** window.

22. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

23. Click *Start/Stop* on the lab control panel to turn ON the amplifier.

24. In the **Bode Analyzer** window click **Run** to measure the frequency characteristics of the filter for the new value of the variable resistor **Rp**.

24. Using the cursors in the **Bode Analyzer** window determine the new values of the maximum gain (dB) and of the cut-off frequency **fc** of the filter. Make sure that the cut-off frequency is equal to 100 Hz.

25. Close the **Bode Analyzer** window.

26. Close the **NI ELVIS Instrument Launcher** window.

27. Click **Stop**.

28. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part C. Studying the influence of active low pass filters on the generated ECG signals

1. Click on the right arrow () to switch to the following **Part C** of this lab.

2. Using the supplied connector leads make the required connections on the board in accordance with the schematic (Fig. 9.5-17).

- Connect the **AO 0** output to the **AI 0** input and to the **In** input of the Low Pass Filter 1.
- Connect the **Out** output of the Low Pass Filter 1 to the **AI 1** input.

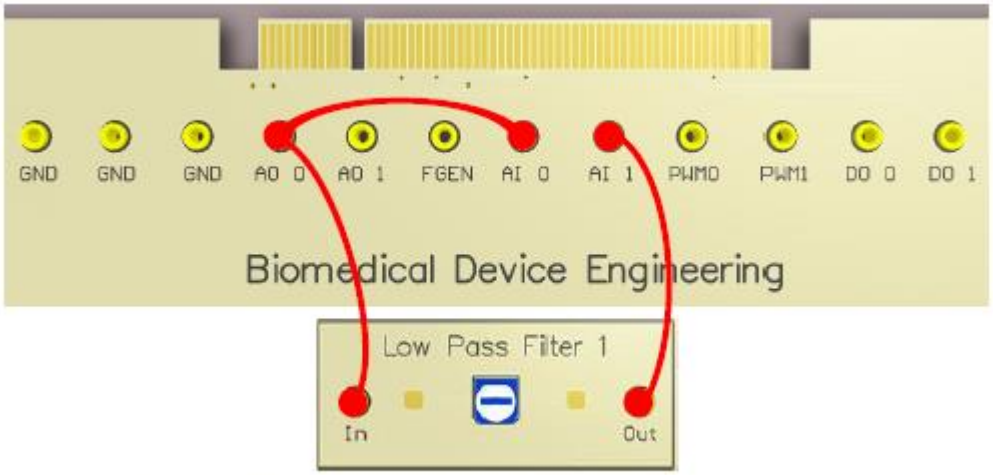


Fig. 9.5-17 Filtration of generated ECG signals using active low pass filter

3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the *ECG parameters* field choose *Enable ECG*, and set the *White noise amplitude* to 4 mV.

5. Open the *Scope* window and in the *Signal parameters* field set the range for both channels AI 0 and AI 1 to 100 mV.

6. Click **Run**.

The graphs of the generated (AI 0) and filtered (AI 1) signals will appear in the *Scope* window.

7. Change the amplitudes of the generated and filtered signals, as well as the noise level for each signal.

8. Calculate the *SNR* for the generated and filtered signals. Compare the obtained values with the values obtained for the passive low pass filter for 100 Hz frequency in Part B of the lab #9.4.

9. Click **Stop**.

10. Click *Record* and choose the directory and the file name in which the measurement results will be stored.

11. Click **Run**.

12. Wait 2 or 3 minutes until the data is recorded into the file, and then click *Stop*.

13. Click on the **FFT** button.

14. In the open **FFT** window click *Open* to open the file with the measurement results.

15. Choose the corresponding file in .TDMS format, and then click **OK**. The **TDMS File Viewer** window will open.

16. From the expandable **File content**s directory choose the signal channel AI 0 (non-filtered ECG signal).

17. Click **Quit**. The spectrum of the selected signal will appear in the **FFT** window.

18. Increase the graph scale for the display of the main characteristics of the signal spectrum.

19. In the **FFT** window click *Save* to save the screenshot of the window.

20. In the **FFT** window click Open to open the file with the measurement results, and the click **OK**.

21. In the **TDMS File Viewer** window from the expandable **File contents** directory choose the signal channel AI 1 (filtered ECG signal).

22. Click **Quit**. The spectrum of the selected signal will appear in the **FFT** window.

23. Increase the graph scale for the display of the main characteristics of the signal spectrum.

24. In the **FFT** щwindow click Save to save the screenshot of the window.

25. Compare the obtained spectrums of the generated and filtered ECG signals with the values obtained for the passive low pass filter for 100 Hz frequency in the Part B of the lab # 9.4.

26. Close the **FFT** window.

27. Close the *Scope* window.

28. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

VI. Experimental Work:

Tabulation

References:

- Clark, John. The origin of biopotentials. Medical Instrumentation: Application and Design. ResearchGate, 1998.
- Strong P. Biophysical Measurements. Tektronix, Inc., Beaverton, OR, 1970.
- Thakor Nitish V. Biopotentials and Electrophysiology Measurement. CRC Press LLC, 1999.
- Van Hoof C., Puers R. Biopotential Readout Circuits for Portable Acquisition Systems. Springer, v.XV, 2009, p. 164.
- Webster J.G. Ed. Medical Instrumentation – Application and Design, 4th ed. John Wiley & Sons, USA, 2010

Experiment. 5 Instrumentation amplifiers for biomedical signal conditioning

I. Objective:

The experiment's objectives are:

1. Getting acquainted with the origin and mechanisms of formation of biomedical signals, as well as with the characteristics and registration methods of biopotentials; studying the main operating principles and the detailed circuit diagrams of instrumentation amplifiers.

2. Studying the methods of generating and registering analog signals, as well as the amplification methods of the generated signals using an instrumentation amplifier.

3. Determination of the gain of an instrumentation amplifier.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

Biomedical signals are used in biomedical applications for extracting the required information on a biological system under study. For example, the process of information extraction can be as simple as estimating the mean heart rate of a patient by a physician with the fingertips, or as complicated as the analysis of the structure of internal soft tissues by a complex Computed Tomography (CT) machine. In biomedical applications, like in many other applications, only detecting a signal is not sufficient. To extract the required information, the obtained signals must be processed due to the presence of a noise which must be removed, or since the required information is not visible in the signal. In such cases, an appropriate transformation is usually applied, to extract the required information. The processing of biomedical signals creates certain problems, mainly due to the complexity of the baseline system and the requirement of indirect, non-invasive measurements. There are many signal processing methods and algorithms. The choice of the best processing method depends on the objective of processing, the test conditions, and the main signal parameters.

One of the varieties of biomedical signals is a bioelectric signal generated by nerve and muscle cells. The source of bioelectric signals is the membrane potential, which under certain conditions can be excited for generation of an action potential. For single cell measurements the action potential itself represents a biomedical signal. When making more rough measurements, for example, using surface electrodes as sensors, the bioelectric signal is generated by an electric field created by many cells distributed in the neighbourhood of an electrode. Bioelectric signals are probably the most important bio signals. Since most important biosystems use excitable cells, the bio signals can be used for the study and monitoring of the main functions of systems. A relatively simple transducer is used for detection of a bioelectric signal. The transducer is needed, since in biomedical medium the electrical conductivity is carried by ions, whilst in measuring system it is carried by electrons. All this leads to the fact that the bioelectric signals are widely used in most biomedical applications.

IV. Apparatus:

- Prototyping Board
- Electrodes

V. Procedure:

Step-By-Step Instructions

Part A. Generation and registration of an analog signal. Studying the influence of the measurement range on the Signal-to-Noise Ratio (SNR) of registered signals.

1. To start the hands-on experiment double click on the ***Instrumentation amplifiers for biomedical signal conditioning*** line in the list of labs**.**

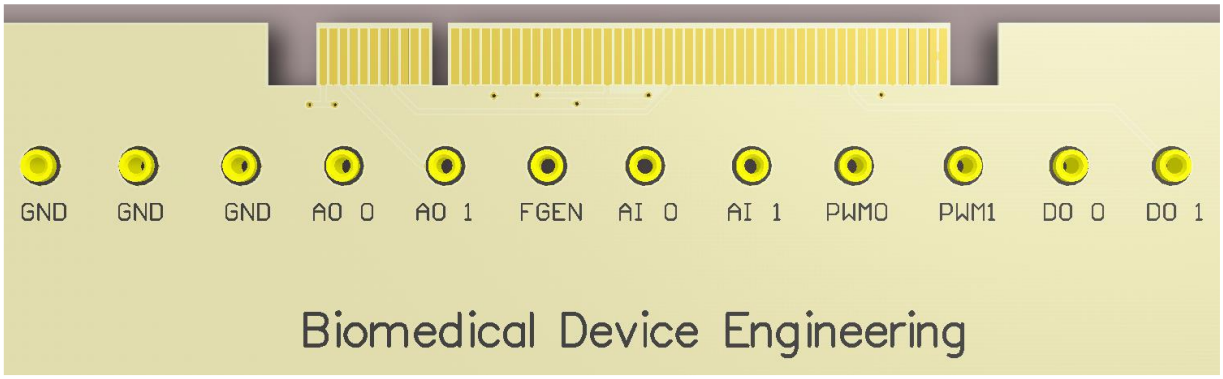
2. Using the supplied connector wires make the required connections on the board in accordance with the schematic

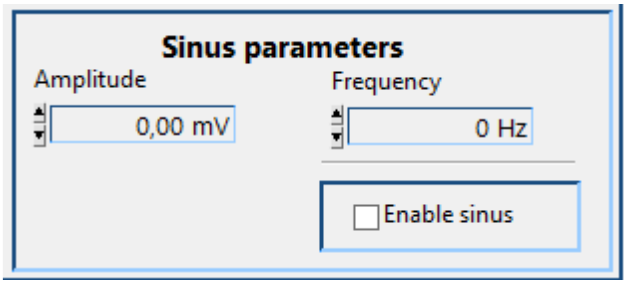
- Connect the **AO 1** output to the **AI 1** input.

Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

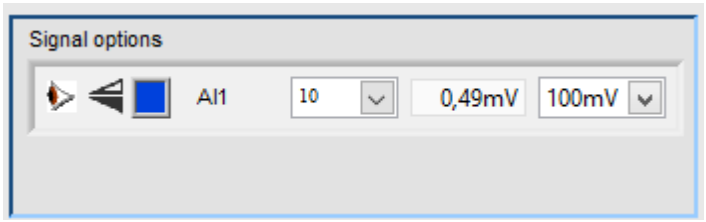
4. In the *Sine wave parameters* field (Fig. 9.1-5) put a tick mark in the *Enable sine wave* checkbox, and use the following settings:

- *Amplitude*: 5 mV;
- *Frequency*: 10 Hz.





Open the *Scope* window, and in the *Signal parameters field* set the channel range equal to 100 mV.



6. Click the *Start/Stop* button on the lab control panel. The generated signal will appear in the *Scope* window.

7. Using the scaling icons (see *Scaling menu* in section *8.1. Controls common for all windows*), determine the amplitude of the registered sine wave.

8. Determine the signal and noise amplitudes.

9. Calculate the signal-to-noise ratio (SNR see in **Equations**) for the registered signal, based on the obtained experimental data.

10. Calculate the ADC resolution (the quantization error) for the selected measuring range (see **ADC voltage resolution** in **Equations**).

11. Compare the registered noise level to the calculated value of the ADC resolution, and draw corresponding conclusions.

12. In the *Scope* window, set the channel range equal to 1V in the *Signal parameters* field (Fig. 9.1-6).

13. Repeat the steps # 7 – 11 of Part A of this lab.

14. In the *Scope* window, set the channel range to 100 mV (minimal ADC range of NI ELVIS workstation) in the *Signal parameters* field, Fig. 9.1-6.

15. Repeat the steps # 7 – 11 of **Part A** of this lab.

16. Compare the obtained values of SNR for all three measuring ranges.

17. Click *the Start/Stop button on the lab control panel*.

18. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part B. Amplification of generated signals using an instrumentation amplifier

1. Click on the right arrow () to switch to the Part B of this lab.

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic

- Connect the **AO 1** output to the **AI 1** input.
- Connect the **AO 1** output to the **LA** input of the instrumentation amplifier.
- Connect the **RA** input of the instrumentation amplifier to the **GND**
- Connect the **Out** output of the instrumentation amplifier to the **AI 0** input.

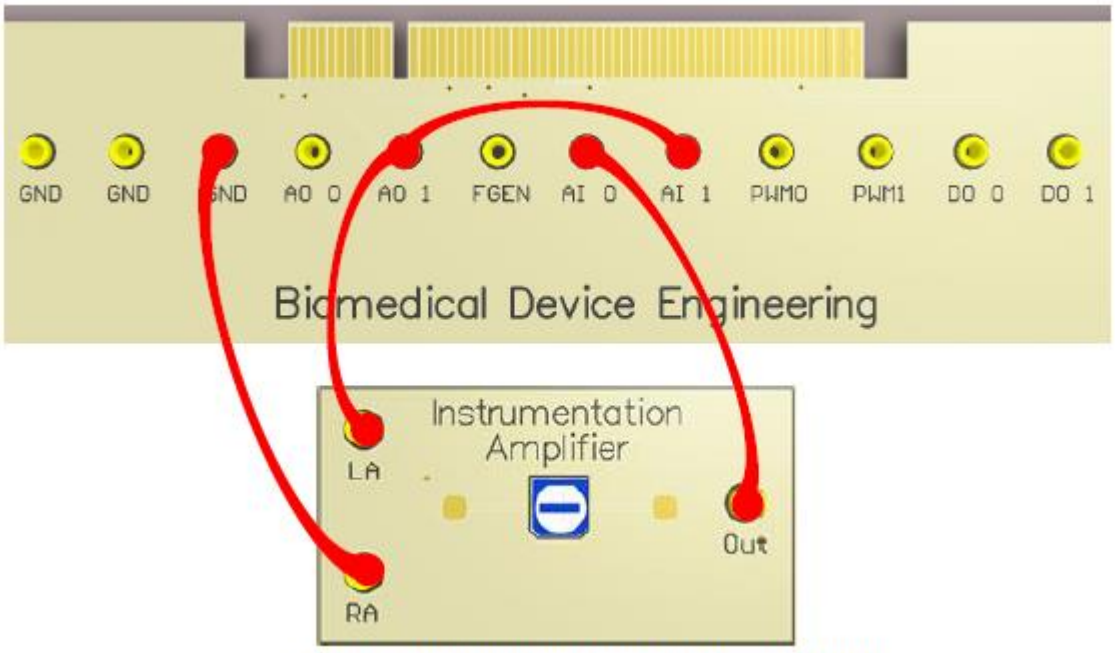


Fig. 9.1-7 Amplification circuit of generated signals

3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the *Sine wave parameters* field (Fig. 9.1-5) put a tick mark in the *Enable sine wave* checkbox, and use the following settings:
- *Amplitude*: 5 mV;
- *Frequency*: 10 Hz.

5. Open the *Scope* window and in the *Signal parameters* field (Fig. 9.1-6) set the range for both channels AI 0 and AI 1 to 100 mV.

6. Click the *Start/Stop* button on the lab control panel.
The graphs of the generated signal (**AI 1**) and of the amplified signal (**AI 0**) will appear in the *Scope* window.

7. Change the full-scale range gain by turning the potentiometer knob of the instrumentation amplifier on the **BM Device Engineering** board. Watch the amplified signal changes.

8. In the *Signal parameters* field of the *Scope* window set the range for the AI 0 channel to 5 V.

9. Change the full-scale range gain by turning the potentiometer knob of the instrumentation amplifier on the **BM Device Engineering** board. Watch the amplified signal changes.

10. Gradually turn the potentiometer knob of the instrumentation amplifier on the **BM Device Engineering** board up to its rightmost position. This corresponds to the maximum value of RG (minimum amplification).

11. Study and determine the amplitudes of the registered signals using the scaling icons in the corner of the graph display area (see the *Scaling menu* in section *8.1. Controls common for all windows*).

12. Calculate the instrumentation amplifier gain for the maximum value of RG (minimum amplification), based on the obtained experimental data (see **Gain (G)** in **Equations**).

13. Achieve the maximum possible amplification of the signal without saturation by gradually turning the potentiometer knob on the **Biomedical Device Engineering** board. Leave the potentiometer in this position (corresponds to the maximum amplification without saturation).

14. Determine the amplified signal and noise amplitudes.

15. Calculate the **SNR** of the amplified signal. Compare the calculated value to the SNR levels measured in Part A of this lab (see **Signal-to-Noise Ratio (SNR)** in **Equations**).

16. Based on the obtained experimental data, calculate the instrumentation amplifier gain for the current value of RG (maximum amplification without saturation).

17. Click the Start/Stop button on the lab control panel.

18. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

19. Connect the **DMM** probes to the **DMM** inputs on the **NI ELVIS II** workstation (Fig. 9.1-8).

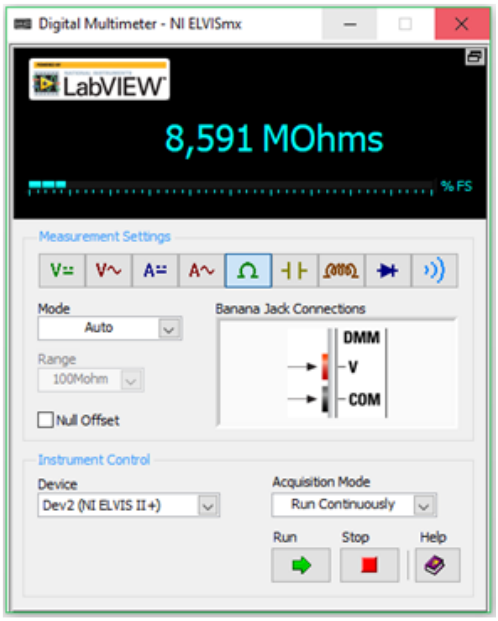
- Connect the **DMM** red probe to the **VΩ** input of the **DMM** tool.

- Connect the **DMM** black probe to the **COM** input of the **DMM**.

20. Click on the **NI ELVIS Instrument Launcher**.

21. Launch the **DMM**.

22. In the **DMM** window choose the resistance measuring mode (**Ω**), and click *Run* (Fig. 9.1-9).



23. Using the **DMM** probes measure the resistance of the variable resistor **RG** of the instrumentation amplifier.
24. Using the measured value of the resistance, calculate the instrumentation amplifier gain for the current value of **RG** (maximum amplification without saturation).
25. Compare the calculated value of the gain to the gain value obtained in step #16 in the Part B of this lab.

26. Gradually turn the potentiometer knob of the instrumentation amplifier on the **BM Device Engineering** board up to its rightmost position. This corresponds to the maximum value of RG (minimum amplification).

27. Using the **DMM** probes measure the new value of the variable resistor connected to the instrumentation amplifier.

28. Based on the obtained experimental data, calculate the instrumentation amplifier gain for the maximum resistance of the resistor RG (minimum amplification).

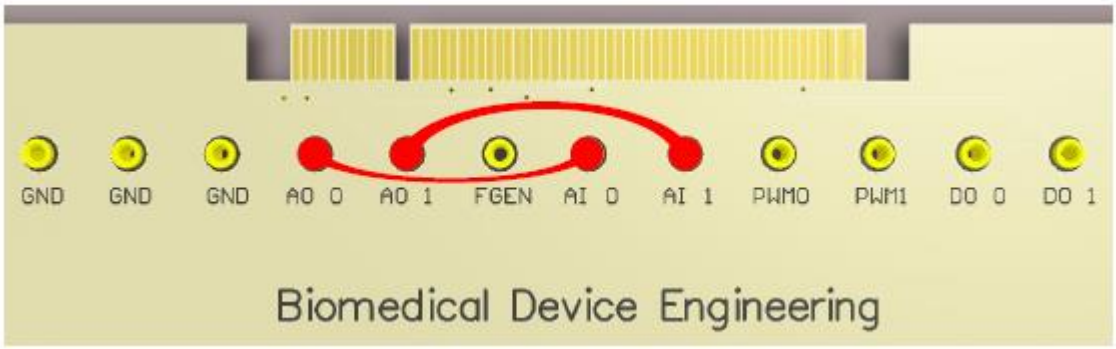
29. Compare the calculated value of the minimum gain with the value obtained in step #12 in Part B of this lab.

30. Close the **DMM** window.

31. Close the **NI ELVIS Instrument Launcher** window.

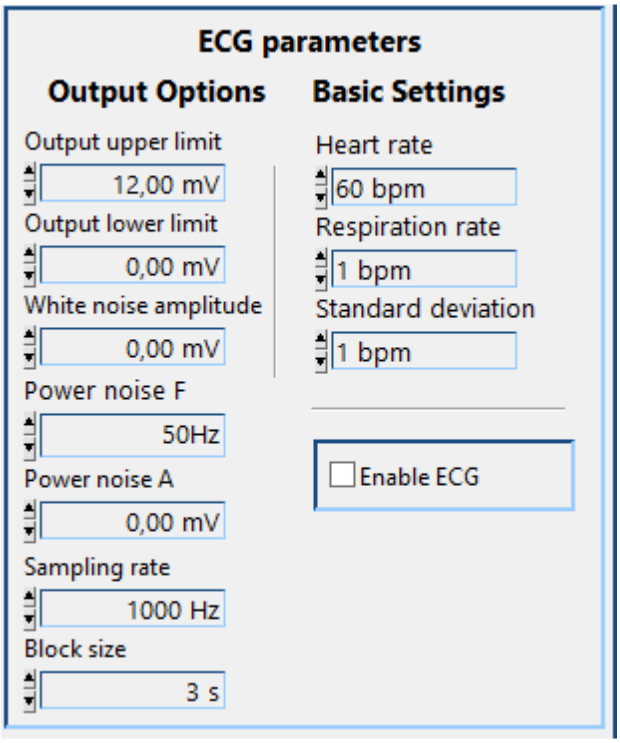
Part C. Generation of ECG signals under the influence of the power line magnetic induction

1. Click on the right arrow ( ) to switch to the following Part C of this lab.
2. Using the supplied connector wires make the required connections on the board in accordance with the schematic (Fig. 9.1-10).
- Connect the **AO 0** output to the **AI 0** input.
- Connect the **AO 1** output to the **AI 1** input.



3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

4. In the *ECG parameters* field (Fig. 9.1-11) put a tick mark in the *Enable ECG* checkbox, and set the *Power line noise amplitude* to 80 mV.



5. In the Sine wave parameters field (Fig. 9.1-5) put a tick mark in the Enable sine wave checkbox, and use the following settings:

- Amplitude: 80 mV;
- Frequency: 50 Hz.

6. Open the Scope window and in the Signal parameters field (Fig. 9.1-6) set the range for both channels AI 0 and AI 1 to 100 mV.

7. Click the Start/Stop button on the lab control panel.

The graphs of the generated signal (AI 1) and of the ECG signal with a noise (AI 0) will appear in the scope traces area of the Scope window.

8. Study the generated signals.

9. Click the *Start/Stop* button on the lab control panel.

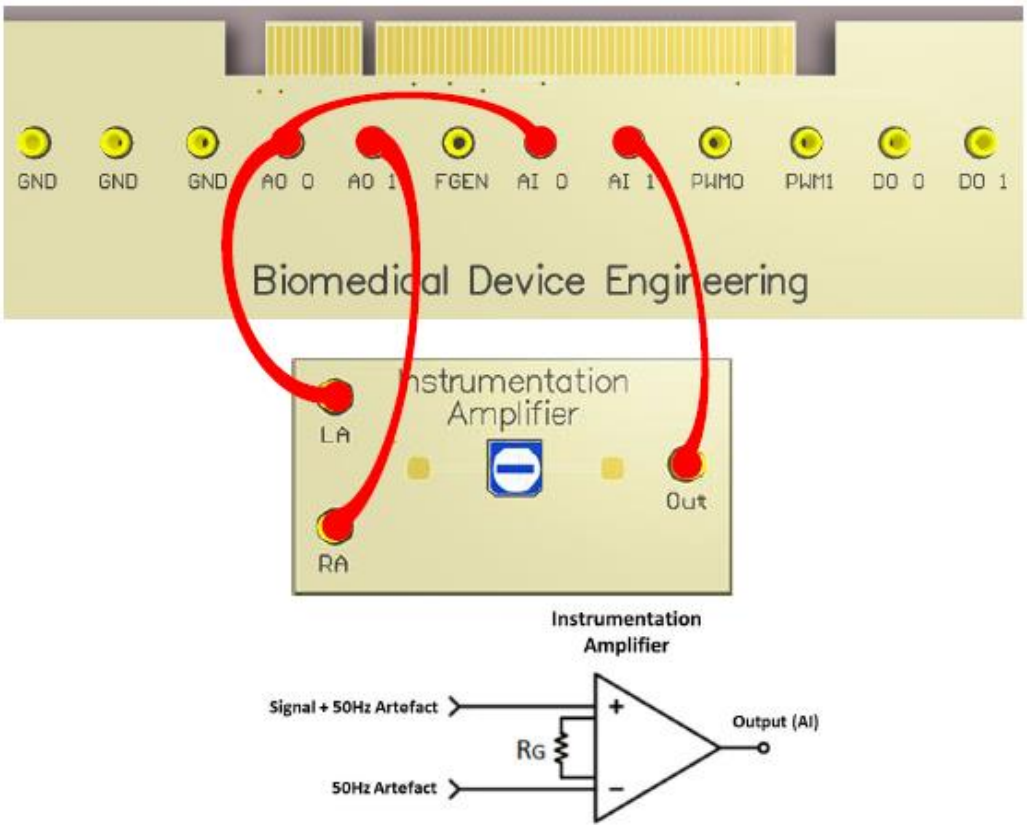
10. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

Part D. Suppression of common mode signals using an instrumentation amplifier.

1. Click on the right arrow () to switch to the following part of this lab (**Part D**).

2. Using the supplied connector wires make the required connections on the board in accordance with the schematic.

- Connect the **AO 0** output to the **AI 0** and **LA** inputs of the instrumentation amplifier.
- Connect the **AO 1** output to the **RA** input of the instrumentation amplifier.
- Connect the **Out** output of the instrumentation amplifier to the **AI 1** input.



3. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **I** (ON). The **Power** LED on the board will turn ON.

- In the *ECG parameters* field (Fig. 9.1-11) put a tick mark in the *Enable ECG* checkbox, and set the *Power line noise amplitude* to 80 mV.

4. In the *Sine wave parameters* field (Fig. 9.1-5) put a tick mark in the *Enable sine wave* checkbox, and use the following settings:

- *Amplitude:* 80 mV;
- Frequency: 50 Hz.

5. Open the *Scope* window and in the *Signal parameters* field (Fig. 9.1-6) set the range for both channels **AI 0** and **AI 1** equal to 5V.

6. Click the *Start/Stop* button on the lab control panel.

The generated ECG signal with noise (**AI 0**) and the separated and amplified ECG signal (**AI 1**) will appear in the graph display area of the *Scope* window.

7. Change the full-scale range gain by turning the potentiometer knob of an instrumentation amplifier on the **Biomedical Device Engineering** board. Watch the amplified signal changes.

8. In the *Sine wave parameters* field (Fig. 9.1-5) slightly change the sine wave amplitude and watch the amplified signal changes.

9. Click *Stop* to exit the lab.

10. Set the **PROTOTYPING BOARD POWER** switch on the **NI ELVIS** workstation into position **O** (OFF).

VI. Experimental Work:

Equations

1. Signal-to-Noise Ratio (SNR) is defined as the ratio of the useful signal power P_{sig} to the noise (unwanted signal) power P_{noise}:

$$SNR = P_{sig} / P_{noise} = A_{sig}^2 / A_{noise}^2 = (A_{sig} / A_{noise})^2$$

where A_{sig} and A_{noise} are the effective values of the signal and noise amplitudes, respectively.

2. ADC voltage resolution: the ratio of the full voltage measurement range (E_{FMR}) to the number of voltage intervals (from -10V to 10V for the ADC of the NI ELVIS workstation):

$$Q = E_{FMR} / 2^M$$

where M is the ADC resolution in bits.

3. Gain (G): the ratio of the output signal amplitude (V_{out}) to the input signal amplitude (V_{in}):

$$G = V_{out} / V_{in}$$

References:

- Clark, John. The origin of biopotentials. Medical Instrumentation: Application and Design. ResearchGate, 1998.
- Strong P. Biophysical Measurements. Tektronix, Inc., Beaverton, OR, 1970.
- Thakor Nitish V. Biopotentials and Electrophysiology Measurement. CRC Press LLC, 1999.
- Van Hoof C., Puers R. Biopotential Readout Circuits for Portable Acquisition Systems. Springer, v.XV, 2009, p. 164.
- Webster J.G. Ed. Medical Instrumentation – Application and Design, 4th ed. John Wiley & Sons, USA, 2010

Experiment. 6 The ECG and Heart Sounds

I. Objective:

To study the phasing of heart sounds to the ECG.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

Background:

Blood enters the arterial system from the ventricles of the heart in a pulsatile manner. However, when blood is leaving the arterial system through the capillaries, it flows in a continuous manner. Between contractions, when the heart is relaxed and blood is not being pumped into the arterial system, there is still enough pressure in the arterial system to move blood along the arteries. The pressure in the arterial system exists because the elasticity of the arteries allow them to distend and recoil and function as a pressure reservoir.

When the ventricles contract, the pressure of the blood inside the ventricles increases to close the atrioventricular valves. Further contraction increases the ventricular pressure until it exceeds the arterial pressure. At this point, when the arterial pressure is at its lowest point during the cardiac cycle (called diastolic pressure) the semilunar valves are forced open, and blood flows into the artery. Blood entering the arterial system inflates the arteries a little and increases blood pressure to a maximum, which is the systolic pressure.

In this lab you will record the ECG from a subject and listen to the characteristic “lub-dub” heart sounds. The “lub” sound occurs during the early phase of ventricular contraction and is produced by closing of the atrioventricular valves, which prevents blood flow into the atria. When the ventricles relax, the blood pressure drops below what is in the artery and the semilunar valves close, producing the “dub” sound.

IV. Apparatus:

- PC
- IX-ELVIS
- USB cable
- Power supply
- Red, black, and green ECG leads
- EMN-100 Event marker
- Stethoscope
- Alcohol swabs
- Disposable ECG electrodes

V. Procedure:

ECG Electrodes and Event Marker Setup

1. Locate the electrode lead wires and EMN-100 event marker
2. Plug the mini-DIN connector to the EMN-100 event marker into the Channel 3 input of the IX ElVIS
3. Insert the connectors on the red, black, and green electrode lead wires into the matching sockets of Channel 1 of the IX-ELVIS
4. Instruct the subject to remove all jewellery from their wrists and ankles.
5. Use an alcohol swab to clean a region of skin on the inside of the subject's right wrist. Let the area dry. Then, rough up the skin in that area with an emery board. This improves the conductivity of the electrodes.
6. Remove a disposable ECG electrode from its plastic shield, and apply the electrode to the scrubbed area on the wrist.
7. Repeat Steps 5 and 6 for the inside of the left wrist and the inside of the right ankle.
8. Snap the lead wires onto the electrodes, so that:
    a. the red (+1) lead is attached to the left wrist,
    b. the black (-1) lead is connected to the right wrist,
    c. the green (C or ground) lead is connected to the right leg.

9. Instruct the subject to sit quietly with their hands in their lap. If the subject moves, the ECG trace will move off the top or bottom of the screen. If the subject moves any muscles in the arms or upper body, electromyograms (EMGs) from the muscles will appear on the ECG recording as noise.

Procedure

1. Place the head of the stethoscope on the left side of the subject's chest and listen for the heart sounds.
2. Move the stethoscope head to different positions until heart sounds are heard clearly.
3. Heart sounds can also be heard by placing the stethoscope over the arteries in the neck.
4. Click on the Record button. Hold the stethoscope head on the subject's chest with one hand and the event marker in the other.
5. Press the event marker when you hear the "lub", or first heart sound, and release it when you hear the "dub", or second heart sound.
6. After recording for twenty seconds, click Stop to halt recording.
7. Select Save in the File menu on the LabScribe window.

Data Analysis

8. Scroll through the recording and find a section of data with four to six exemplary ECG waveforms and consistent responses on the event marker channel, in succession.
9. Use the Display Time icons to adjust the Display Time of the Main window to show at least four complete ECG/heart sound cycles on the Main window. Four adjacent ECG/heart sound cycles can also be selected by:
    - Placing the cursors on either side of a group of four complete ECG/heart sound cycles; and
    - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the segment with the four selected ECG/heart sound cycles to the width of the Main window.
    - Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window

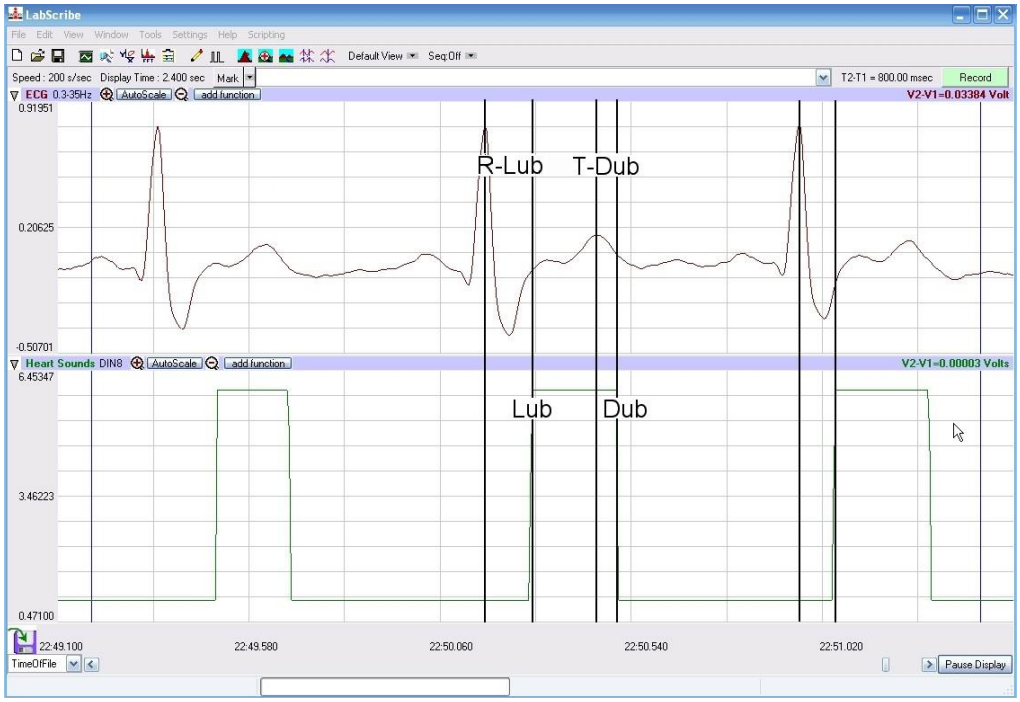


Figure 1: ECG and event marker recordings displayed in the Analysis window. Lines and labels were added to figure to indicate the locations where cursors should be placed to measure the time intervals between the R wave and the "lub" and the T wave and the "dub".

10. Once the cursors are placed in the correct positions for determining the time intervals on each ECG cycle, the values of these intervals can be recorded by typing their names and values directly into the Journal, or on a separate data table.
11. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the intervals from the recording to the Journal. To use these functions:
    - Place the cursors at the locations used to measure the time intervals between the ECG waves and the heart sounds.
    - Transfer the name of the mathematical function used to determine the time intervals to the Journal using the Add Title to Journal function in the ECG Channel pull-down menu.
    - Transfer the values for the time intervals to the Journal using the Add Ch. Data to Journal function in the ECG Channel pull-down menu.
12. Use the mouse to click on and drag the cursors to specific points on the ECG recording to measure the following:

- The R-Lub Interval, which is the time interval between the peak of an R wave and the onset of the event mark. The onset of the event mark indicates the occurrence of the first heart sound or "lub". Record the value for T2-T1 of either channel. Measure this time interval for two additional ECG cycles.
- The T-Dub Interval, which is the time interval between the peak of a T wave and the offset of the event mark.
- The offset of the event mark indicates the occurrence of the second heart sound or "dub".
- Record the value for T2-T1 of either channel. Measure this time interval for two additional ECG cycles.

13. Calculate the following values and type your results into the Journal
    - The average R-Lub interval.
    - The average T-Dub interval.

VI. Experimental Work:

Questions

1. Why does the lub sound occur around the peak of the R wave?
2. Is the time delay between the R wave and the lub sound always the same? Explain why the time delay is or is not the same.
3. Why does the dub sound occur around the peak of the T wave?
4. Is the time delay between the T wave and the dub sound always the same? Explain why the time delay is or is not the same.

Observations

References:

LabVIEW manual

Experiment. 7 The Electrocardiogram (ECG) and the Pulse

I. Objective:

In this experiment, you will simultaneously record a subject's single lead ECG and the pulse wave in the finger. This exercise will demonstrate the time delay that occurs between the electrical events in the heart and mechanical events in the circulatory system. You will also examine the effects of temperature on peripheral circulation.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

The cardiac cycle involves the sequential contractions of the atria and the ventricles which are triggered by action potentials in the myocardial cells. The combined electrical activity of the myocardial cells produces electrical currents that spread through the body fluids. These currents are large and detectable by recording through electrodes placed on the skin. The regular pattern of signals produced by the heart is called the electrocardiogram or ECG

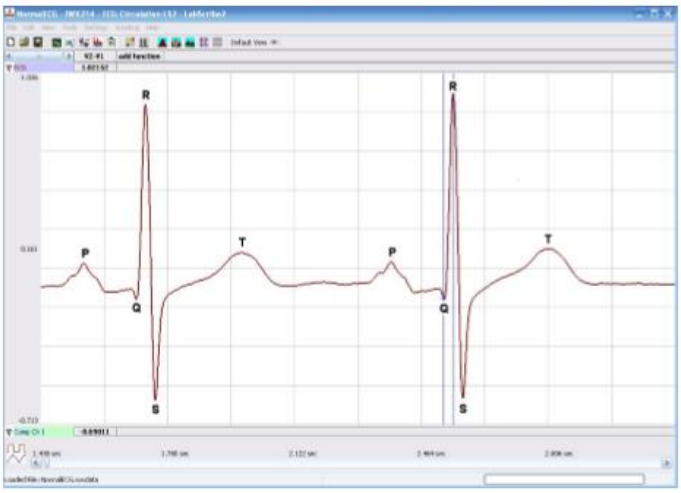


Figure CP-1-B1: ECG recording displayed in the Main window with labels showing the P, QRS, and T waves.

The components of the ECG (Figure CP-1-B1) are correlated to electrical activity in the atria and ventricles such that:

• Atrial depolarization produces the P wave.

• Atrial repolarization and ventricular depolarization produce the QRS complex.

• Ventricular repolarization produces the T wave.

The depolarization of the myocardial cells in the ventricle causes the ventricles to contract and force blood into the major arteries of the circulatory system in a pulsatile manner.

IV. Apparatus:

- PC or Macintosh computer
- IX-ELVIS USB cable
- Power supply
- Red, black, and green ECG lead wires
- PTN-104 Pulse plethysmograph
- Stethoscope
- Alcohol swabs
- Disposable ECG electrodes
- Ice, cold and hot water,
- plastic bags

V. Procedure:

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.

2. Connect the IX-ELVIS to the computer with the supplied USB cable.

3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.

2. On the Main window, pull down the Settings menu and select Load Group.

3. Locate the folder that contains the settings group, ELVISNI.iwxgrp. Select this group and click Open.

4. Pull down the Settings menu again. Select the ECGPulse-LS2 settings file.

5. After a short time, LabScribe will appear on the computer screen as configured by the ECGPulse-LS2 settings.

6. The settings used to configure the LabScribe software and the IX-ELVIS for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

ECG Cable and Pulse Transducer Setup

1. Locate the PTN-104 pulse plethysmograph (Figure CP-1-S1) and the ECG electrode lead wires (Figure CP-1-S2).

2. Plug the mini-DIN connector to the PTN-104 into the Channel 3 input of the IX-ELVIS (Figure CP-1-S3).

3. Insert the connectors on the red, black, and green electrode lead wires into the matching sockets of Channel 1 of the IX-ELVIS (Figure CP-1-S3).

4. Instruct the subject to remove all jewellery from their wrists and ankles.

Figure CP-1-S1: The PTN-104 pulse plethysmograph.

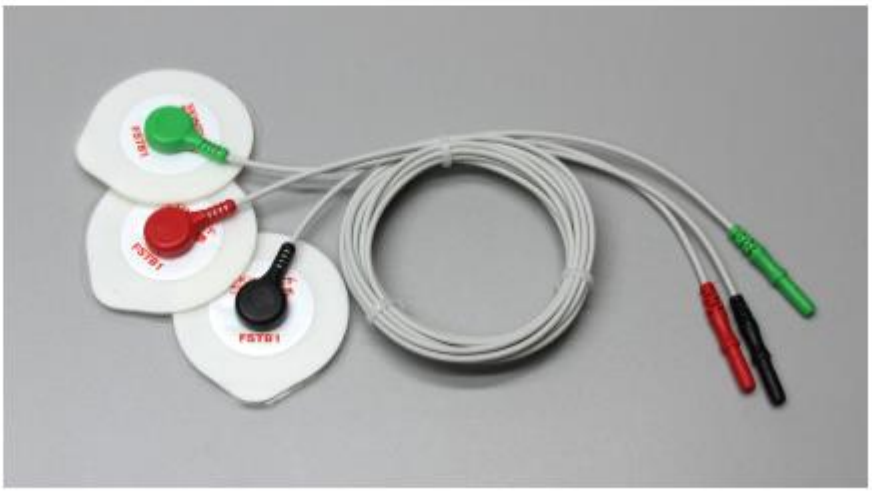


Figure CP-1-S2: The ECG lead wires snapped to disposable electrodes..

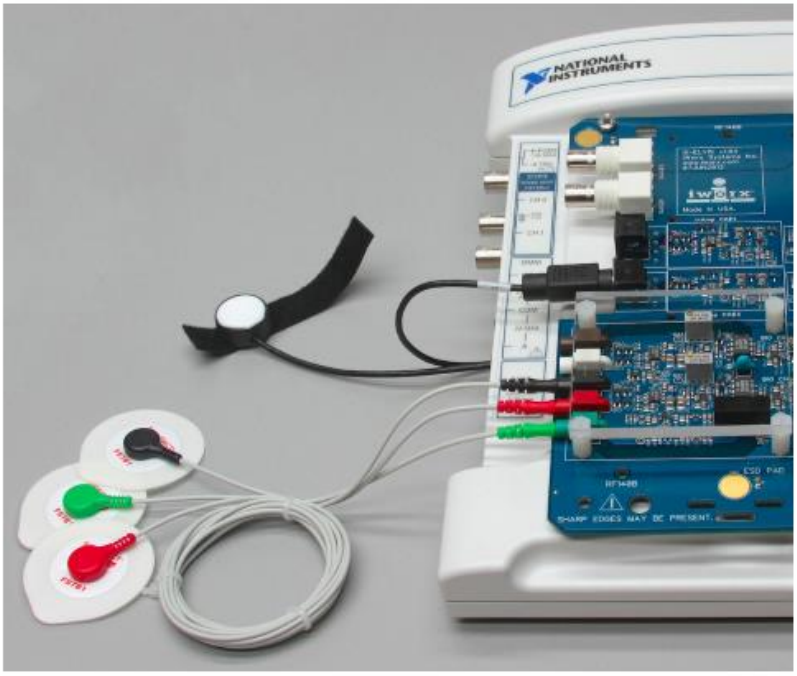


Figure CP-1-S3: The ECG leads and pulse transducer connected to an IX-ELVIS.

5. Use an alcohol swab to clean and scrub a region with little or no hair, on the inside of the subject's right wrist. Let the area dry.

6. Remove a disposable ECG electrode from its plastic shield, and apply the electrode to the scrubbed area on the wrist.

7. Repeat Steps 5 and 6 for the inside of the left wrist and the inside of the right ankle. 8. Snap the lead wires onto the electrodes, so that:

- the red (+1) lead is attached to the left wrist,
- the black (-1) lead is connected to the right wrist,
- the green (C or ground) lead is connected to the right leg.

9. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of the subject's middle finger or thumb, and wrap the Velcro strap around the end of the finger to attach the transducer firmly in place.

10. Instruct the subject to sit quietly with their hands in their lap. If the subject moves, the ECG trace will move off the top or bottom of the screen. If the subject moves any muscles in the arms or upper body, electromyograms (EMGs) from the muscles will appear on the ECG recording as noise.

VI. Experimental Work:

Exercise 1: The ECG and the Pulse in a Resting Subject

1. Click on the Record button, located on the upper right side of the LabScribe Main window (Figure CP-1-L1). The signal should begin scrolling across the screen.
2. Note: If the user clicks the Record button and there is no communication between the IXELVIS and computer, an error window will appear in the center of the Main window. Make sure the IX-ELVIS is turned on and connected to the USB port of the computer. Click OK and select the Find Hardware function from the LabScribe Tools menu.
3. Click on the AutoScale button at the upper margin of the ECG, Pulse, and Pulse Integral channels. Your recording should look like Figure CP-1-L1.

• If the signal on either the ECG or the Pulse channel is upside down when compared to trace in Figure CP-1-L1, click on the downward arrow to the left of the channel title and select the Invert function. The trace should now look similar to the one in the figure

• If a larger ECG signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.

• If the pulse signal is small or noisy, adjust the tension on the strap holding the pulse plethysmograph to the finger.

4. When you have a suitable trace, type "<Subject's Name> Resting ECG/Pulse" in the Mark box to the right of the Mark button. Press the Enter key on the keyboard to attach the comment to the data. Record for a minute or two.
5. Click Stop to halt recording. Your data may look like Figure CP-1-L1.

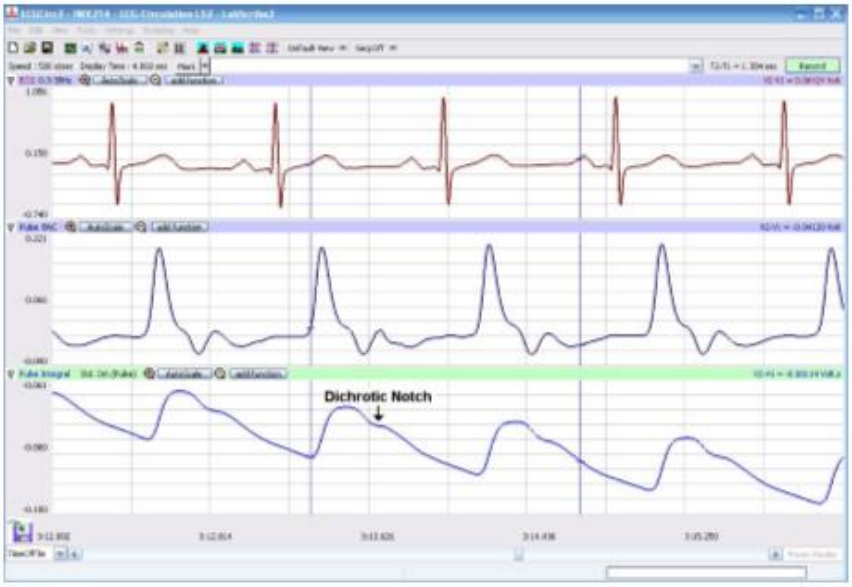


Figure CP-1-L1: ECG, pulse, and pulse integral displayed on the Main window. The arrow is placed above a dichrotic notch.

6. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file. Designate the file type as *.iwxdata. Click on the Save button to save the data file.

Data Analysis

1. Scroll through the recording and find a section of data with five or six exemplary ECG/pulse cycles in succession.
2. Use the Display Time icons to adjust the Display Time of the Main window to show at least four complete ECG/Pulse cycles on the Main window. Four adjacent ECG/Pulse cycles can also be selected by:

    • Placing the cursors on either side of a group of four complete ECG/Pulse cycles; and

    • Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the segment with the four selected ECG/Pulse cycles to the width of the Main window.
3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window (Figure CP-1-L3)
4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The names of the mathematical functions used in the analysis, V2-V1 and T2-

T1, appear in this table. The values for V2-V1 and T2-T1 from each channel are seen in the table across the top margin of each channel. In this exercise you will only need to record the values for T2-T1.

5. Once the cursors are placed in the correct positions for determining the time intervals on each ECG/Pulse cycle, the values of the time intervals can be recorded in the online notebook of LabScribe by typing their names and values directly into the Journal, or on a separate data table.
6. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the parameters from the recording to the Journal.
7. To use these functions:

    • Place the cursors at the locations used to measure the amplitudes and period of the ECG/Pulse cycle.

    • Transfer the names of the mathematical functions used to determine the amplitudes and time interval to the Journal using the Add Title to Journal function in the ECG Channel pull-down menu.

    • Transfer the values for the amplitudes and beat period to the Journal using the Add Ch. Data to Journal function in the ECG Channel pull-down menu.

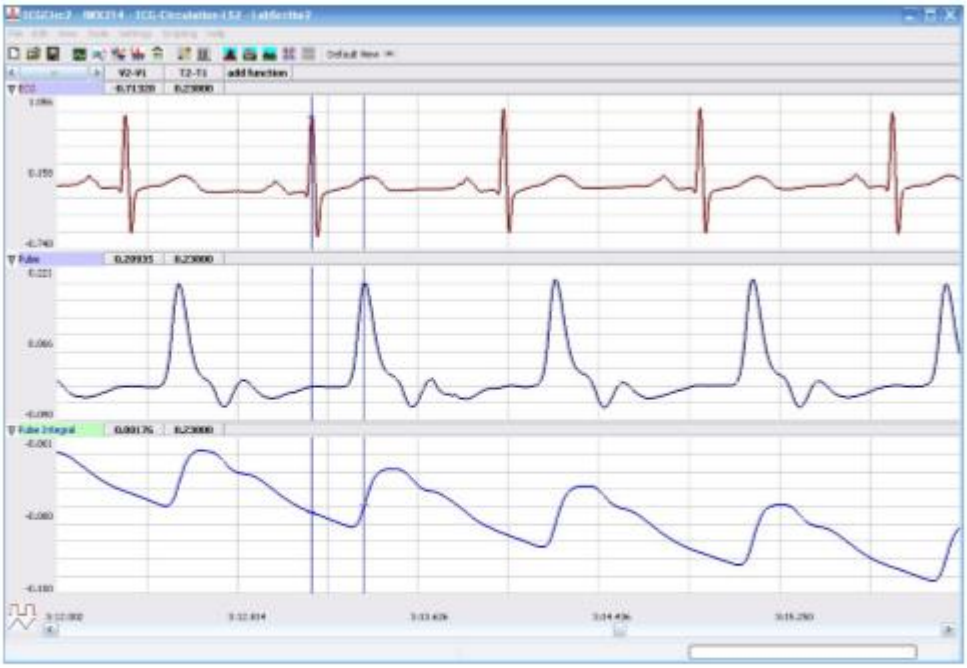


Figure CP-1-L3: ECG, pulse and pulse integral displayed on the Analysis window with cursors in place to measure the R-Pulse interval with the T2-T1 function.

8. Use the mouse to click on and drag the cursors to specific points on the ECG/Pulse recording to measure the following:

    • The beat period, which is the time interval between two adjacent R waves (Figure CP-1-L3). To measure the beat period, place one cursor on the peak of an R wave and the second cursor on the peak of the adjacent R wave. The value for T2-T1 on the ECG channel is the beat period. Measure the beat period for two additional pairs of R waves.

    • The R-Pulse interval, which is the time interval between the peak of the R wave and the peak of the pulse wave that follows the R wave (Figure CP-1-L3). To measure this interval, place one cursor on the peak of an R wave and the second cursor on the peak of the pulse wave to its right. The value for T2-T1 on any channel is this interval. Measure this interval for two additional ECG/Pulse cycles.

9. Calculate the following values and record your results into the Journal or on a separate data table:

    • The average beat period, in seconds/beat.

    • The heart rate, which is expressed in beats per minute and calculated from the average beat period by using the following equation:

    Heart Rate (beats/minute) = 60 seconds/minute/# seconds/beat

    • The average R-Pulse interval.

Observation

References:

LabVIEW manual

Experiment. 8 Measurement of EEG artifacts using 3-Electrode technique

I. Objective:

- Learn to collect EEG signals from the left and right cerebral hemispheres.
- learn to recognize common EEG artifacts caused by movements such as eye blinks, facial muscle contractions, and head movement.
- learn to recognize and analyze Alpha and Beta EEG patterns associated with closed and open eye conditions.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

The EEG is a continuous recording of waves of varying frequency and amplitude. The number of wave cycles or peaks that occurs in an EEG pattern in a set period of time is its frequency. One EEG wave cycle occurring in a second of time is known as a Hertz (Hz). The amplitude of the EEG pattern is the strength of the pattern in terms of microvolts of electrical energy. There are four basic EEG frequency patterns as follows: Beta (14-30 Hz), Alpha (8-13 Hz), Theta (4-7 Hz), and Delta (1-3 Hz). In general, the amplitude of the EEG increases as the frequency decreases.

IV. Apparatus:

- Computer
- IX-ELVIS
- USB cable
- Power supply
- Red, black, and green EEG leads.
- EEG electrodes

V. Procedure:

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.
2. Connect the IX-ELVIS to the computer with the supplied USB cable.
3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet.
4. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.
2. On the Main window, pull down the Settings menu and select Load Group.
3. Locate the folder that contains the settings group, ELVISNI.iwxgrp. Select this group and click Open.
4. Pull down the Settings menu again. Select the EEGActivity-LS2 settings file.
5. After a short time, LabScribe will appear on the computer screen as configured by the EEGActivity-LS2 settings
6. The settings used to configure the LabScribe software and the IX-ELVIS for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window

EEG Cable Setup

1. Locate the red, black, and green EEG electrode lead wires
2. After the electrodes are secured in position, the red, black, and green EEG lead wires will be plugged into the respective sockets of Channel 1 of the IX-ELVIS
3. Select one person from your group to be the subject in this experiment
4. Use alcohol swabs to clean the skin where the electrodes will be placed. Three electrodes will be placed on the head:
    - One is high on the forehead, to the left or right of the centerline.
    - One about two inches above the right ear, on the right temporal lobe.
    - One on the parietal-occipital area, two inches to the right of the midline.

5. Once the electrodes are in place, plug the three electrode lead wires into Channel 1 of the IX ELVIS.
    a. The lead from the electrode over the left temporal lobe is connected to the red or +1 input. (This will be switched to the right after all exercises have been completed).
    b. The lead from the electrode over the left parietal-occipital area is connected to the black or -1 input. (This will be switched to the right after all exercises have been completed).
    c. The lead from the ground electrode on the forehead is connected to the green or C input.
6. The electrodes need to have as little hair as possible under their centers.
7. Remove the plastic protective covering from the disposable electrodes before applying the electrodes to the proper location
8. Once the electrodes are in place, plug the three electrode lead wires into the IX-ELVIS
9. The lead wire for the ground electrode should not hang down in the person's eyes. Drape it loosely over the top of the subject's head. This lead can be secured under a headband.
10. Drape the leads for the other electrodes over the subject's shoulder to the lead pedestal which hangs freely down the subject's back and over the chair. There should be no tension on the electrodes.
11. The subject should sit quietly with their hands in their lap

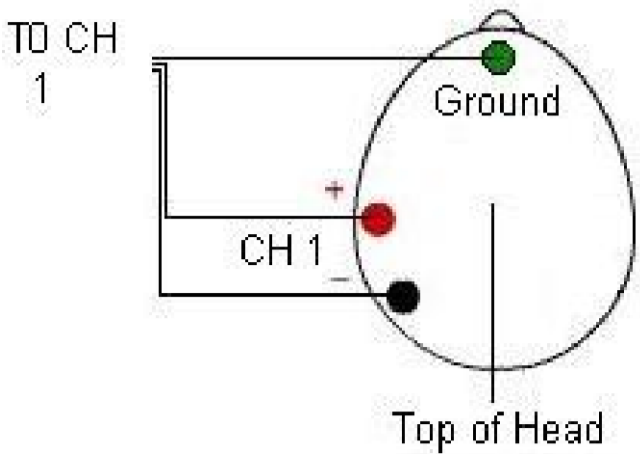


Figure:1 The equipment used to measure the EEG from a subject.

VI. Experimental Work:

Exercise 1: Common EEG Artifact

1. Ask the subject to sit quietly and not move unless told to do so, and to keep his or her eyes open during this phase of the experiment.
2. Click on the Record button, located on the upper right side of the LabScribe Main window (Figure PP-1-L1). The signal should begin scrolling across the screen.

   Note: If the user clicks the Record button and there is no communication between the IX-ELVIS and computer, an error window will appear in the center of the Main window. Make sure the IX-ELVIS is turned on and connected to the USB port of the computer. Click OK and select the Find Hardware function from the LabScribe Tools menu.
3. Click on the AutoScale buttons at the upper margin of all the channels. Your recording should look like Figure 2
4. Type "<Subject's Name>-Resting EEG" in the Mark box to the right of the Mark button. Press the Enter key on the keyboard to attach the comment to the data. Continue recording.
5. Instruct the subject to blink his or her eyes when asked, during the next thirty seconds of the recording. Type "B" for Blink in the Mark box before each time the subject is asked to blink. Press the Enter key on the keyboard to mark the recording when each blink occurs.
6. Instruct the subject to contract his or her facial muscles by frowning or smiling when asked, during the next thirty seconds of the recording. Type "F" for Frown or "S" for Smile in the Mark box before each time the subject is asked to do so. Press the Enter key on the keyboard to mark the recording when each frown or smile occurs.
7. Instruct the subject to rotate or tilt his or her head when asked, during the final thirty seconds of the recording. Type "R" for Rotate or "T" for Tilt in the Mark box before each time the subject is asked to do so. Press the Enter key on the keyboard to mark the recording when each rotation or tilt occurs.
8. Click Stop to halt recording.
9. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file. Designate the file type as *.iwxdata. Click on the Save button to save the data file

Data Analysis

1. Scroll through the recording using the scroll bar at the bottom of the Main window. Stop at marks (vertical lines in the EEG record) where you have entered comments.
2. Notice that movement of any kind will cause artifacts in the EEG record.
3. Actual variations in waking brain activity are potentials with amplitudes that are significantly lower than the amplitudes of artifacts.

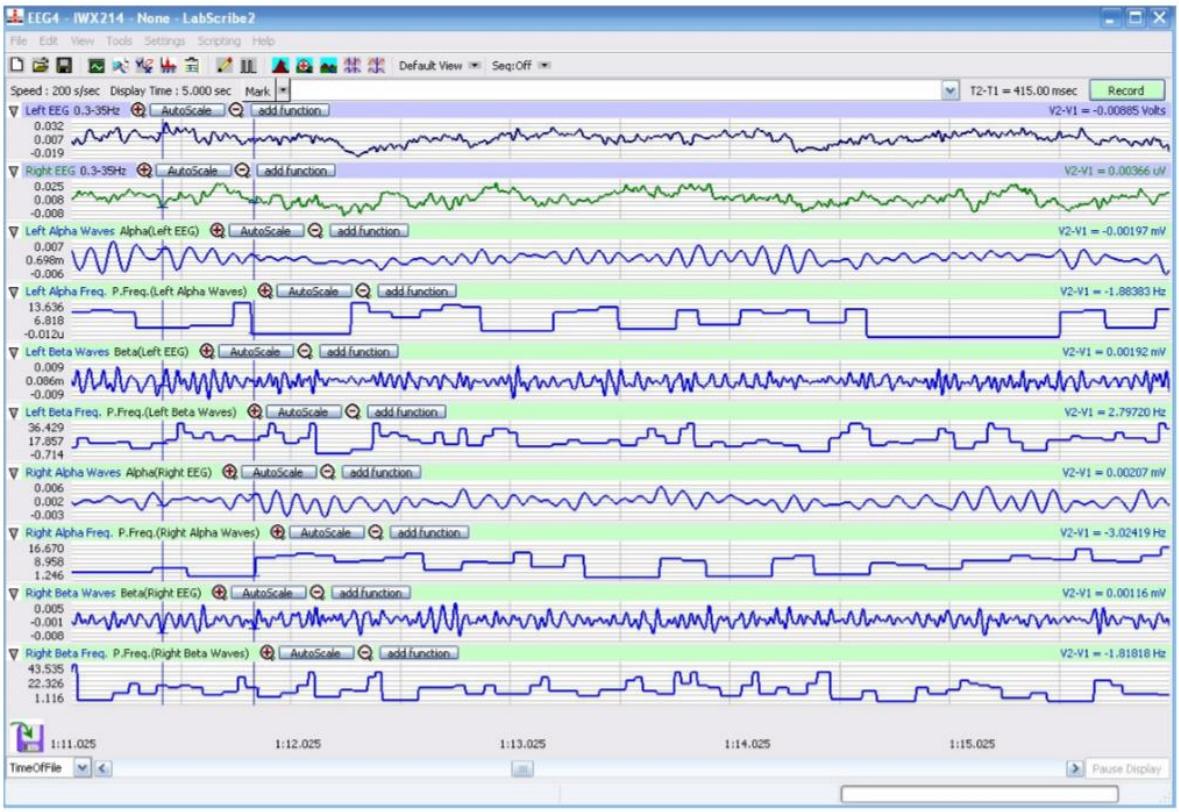


Figure: 2 EEG recording showing both the right and left hemispheres at the same time

Exercise 2: Alpha and Beta EEG Patterns

1. Instruct the subject that he or she needs to avoid any movement other than opening or closing his or her eyes when asked. The subject should have his or her eyes open at the beginning of the recording.
2. Click Record, and then click the AutoScale buttons for all six channels. You should observe an EEG recording similar to the two topmost traces in Figure

3. Type “O” for Eyes Open in the Mark box to the right of the Mark button. Press the Enter key on the keyboard to mark the recording. Record for twenty seconds.
4. While the subject has his or her eyes open, type “C” for Eyes Closed in the Mark box. Press the Enter key on the keyboard to mark the recording as you instruct the subject to close his or her eyes. Record the subject’s EEG pattern with his or her eyes closed for twenty seconds.
5. Continue to record the subject’s EEG pattern for a total of 2 minutes as the subject alternates having his or her eyes open or closed for twenty second periods. Mark the recording with an O or a C each time the subject opens or closes his or her eyes.
6. Click Stop to halt recording.
7. Select Save in the File menu

Data Analysis

1. Scroll through the data recorded in this exercise and find an artifact-free section of data recorded while the subject’s eyes were open.
2. Use the Display Time icons in the LabScribe toolbar (Figure 3) to adjust the Display Time of the Main window to show a ten second artifact-free section of data on the Main window. This section of data can also be selected by:
    a. Placing the cursors on either side of the data recorded while the subject’s eyes were open, and
    b. Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the period to the width of the Main window.
3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window
4. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The names of the mathematical function used in the analysis, Max-Min and Mean appears in this table. The values for Max-Min and Mean on each channel are seen in the table across the top margin of that channel.
5. Once the cursors are placed in the correct positions for determining the difference between the maximum and minimum amplitudes and the mean frequency of the waves in a ten-second section of data, the values of these parameters can be recorded in the on-line notebook of LabScribe by typing their names and values directly into the Journal, and on Table PP-1-L1.

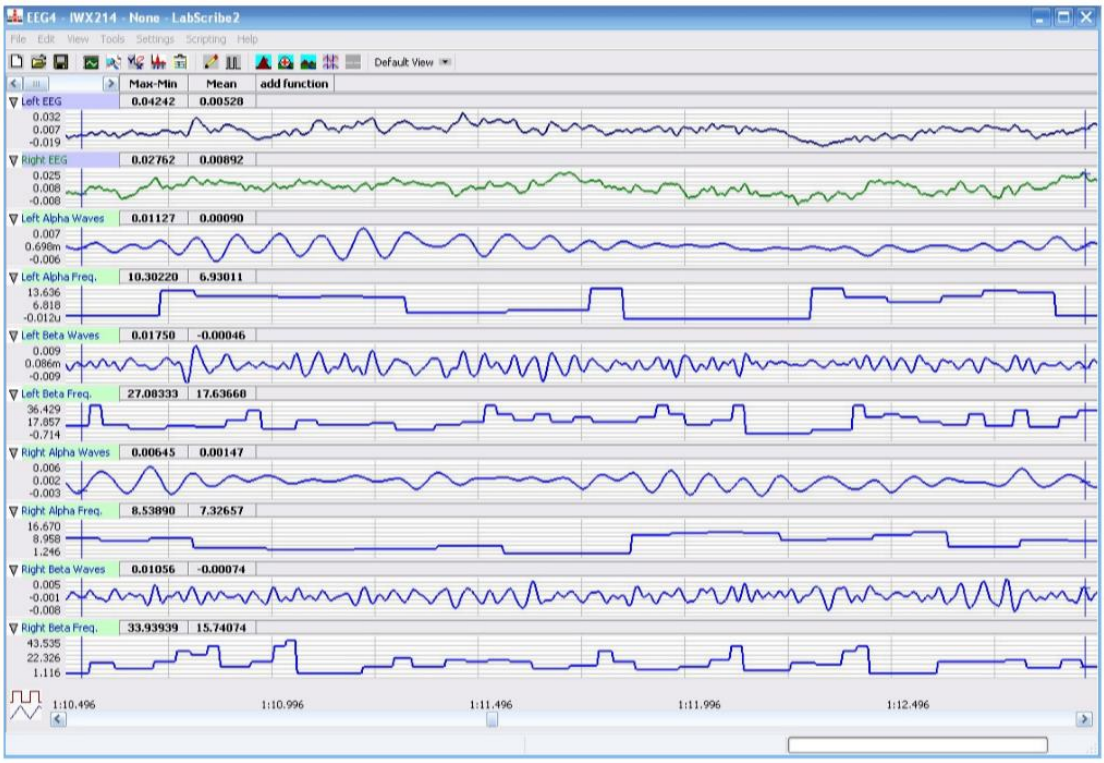


Figure 3: Recording of EEG from the left and right temporal regions of the brain displayed on the Analysis window. The complete EEG signal is displayed in the uppermost channel. The Alpha and Beta waves derived from the complete EEG signals and the frequencies of those waves from each temporal region are displayed on the lower channels

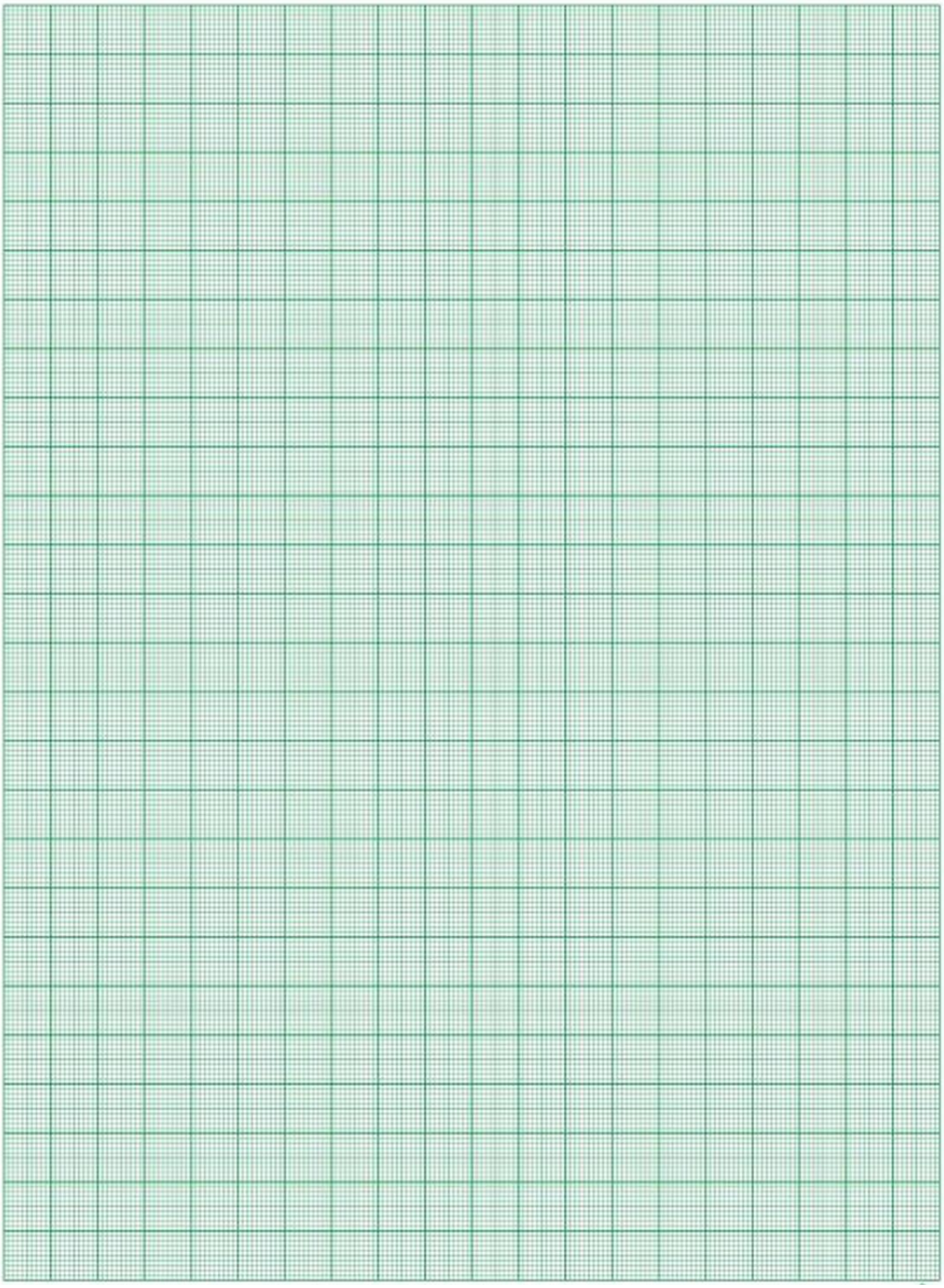
6. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the means into the Journal.
7. To use these functions:
    a. Place the cursors at the locations used to measure the values for the parameters of the EEG waves in the selected region of data.
    b. Transfer the name of the mathematical function used to determine the values of the parameters to the Journal using the Add Title to Journal function in the pull-down menu of any channel.
    c. Transfer the values of the parameters of the EEG waves to the Journal using the Add Ch. Data to Journal function in the Left EEG Channel pull-down menu.

8. Use the mouse to click on and drag a cursor to each margin of the data displayed on the Analysis window. The values for the following parameters should be recorded:
    a. The differences between the maximum and minimum wave amplitudes (Max-Min) of the waves displayed on the Left Alpha, Left Beta, Right Alpha, and Right Beta Wave channels.
    b. The mean frequency (Mean) of the waves displayed on the Left Alpha, Left Beta, Right Alpha, and Right Beta Frequency channels.
9. After recording the values return to the Main window. Scroll through the recording and find an artifact-free section of data recorded while the subject's eyes were closed.
10. Repeat Steps on an artifact-free section of data recorded while the subject's eyes

Tabulation

	Max-Min Amplitude(mV)		Mean Frequency(Hz)	
	Eyes open	Eyes Closed	Eyes open	Eyes Closed
Alpha waves				
Beta waves				

Observations



References:

LabVIEW manual

Experiment. 9 - Skeletal Muscle Reflexes

I. Objective:

Students will record electromyograms (EMGs), the summation of asynchronous electrical activity (muscle action potentials) in the multiple fibers in the muscle, and use them to determine the time between the stretch of the tendon and the arrival of the motor impulse at the muscle.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

Studying the vertebrate stretch reflex is a good way to introduce students to the topics of stretch receptors, nerve conduction velocity, electromyograms (EMG), and motor control. Specialized receptors in the muscle respond to the stretching of the tendon attached to the muscle, and then send signals to motor neurons through a single synapse. The muscle fibers depolarize and twitch (contract) in response to the incoming impulse from the motor neuron. The Stretch Receptor Skeletal muscles have specialized receptors which convey information about muscle length, tension, and pressure to the central nervous system.

The sensory receptors responsible for providing information about the length, or the rate of change of the length, of a muscle are called muscle spindles. Arranged in parallel with muscle fibers (Figure NP-2-B1), the spindles are stretched when the muscle is stretched by an external force. Therefore, these receptors play a significant role in developing antigravity reflexes and maintaining muscle tone. Muscle spindles contain a small bundle of intrafusal fibers which do not contribute to the overall tension of the muscle, but regulate the excitability of the sensory afferent spindle nerves by mechanically deforming the receptors. These fibers are innervated by gamma motor neurons. The majority of a muscle consists of extrafusal fibers, which are innervated by alpha motor neurons and are responsible for developing muscle tension.

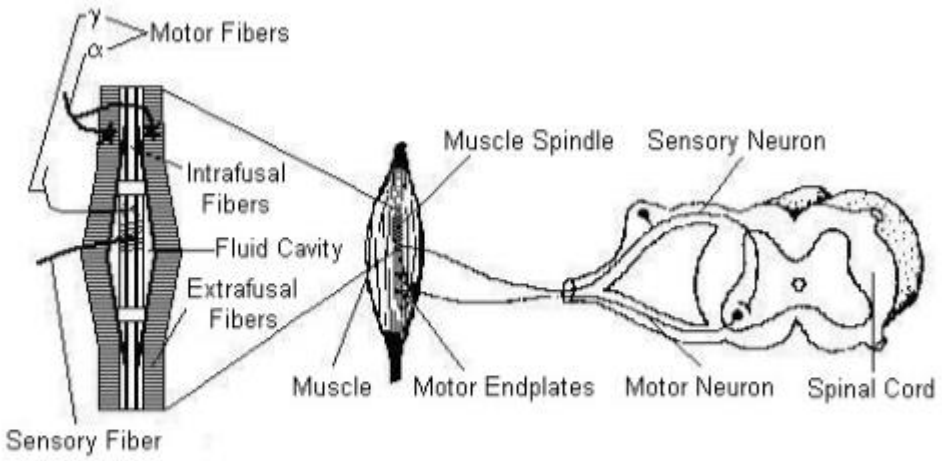


Figure NP-2-B1: A monosynaptic stretch reflex arc.

The Stretch Reflex

When a muscle is stretched, excitation of its muscle spindles causes a reflex contraction of the muscle. This reflex response is known as a stretch (myotatic) reflex. The minimal delay between the muscle stretching and the reflex contraction is due to its monosynaptic pathway. The sensory afferent nerves from the spindles synapse directly with motor neurons; there are no interneurons. This pathway constitutes the shortest possible reflex arc (Figure NP-2-B1).

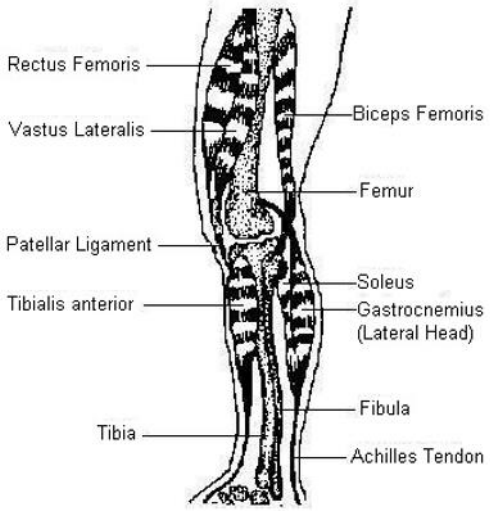


Figure NP-2-B2: The major extensors and flexors of the human knee and ankle joints. The stretch reflexes used in this exercise are elicited by striking the patellar tendon or the Achilles tendon.

As an example of the stretch reflex, consider the reflex response that occurs when a person jumps from a low stool to the floor. The extensor muscles of the legs (Figure NP-2-B2) are stretched on landing, lengthening all their muscle spindles. The discharge of the muscle spindles is conveyed to the central nervous system through the fast-conducting Aα afferent axons. These sensory axons enter the spinal cord through the dorsal root and synapse with the motor neurons of the same extensor muscle. In turn, the motor neurons trigger the contraction of the extensor muscle to oppose the stretch produced by landing, completing the reflex arc. This reflex is one of the main reasons you keep your balance and do not fall down when changing certain body positions.

Students will record electromyograms (EMGs), the summation of asynchronous electrical activity (muscle action potentials) in the multiple fibers in the muscle, and use them to determine the time between the stretch of the tendon and the arrival of the motor impulse at the muscle. Two reflexes in a human subject will be studied: the Achilles tendon reflex, and the patellar tendon (knee-jerk) reflex. Conduction times and nerve velocities for each reflex arc will be determined and compared. The effect of pre-existing tension in the effector muscle, or motor activity in other muscle groups, upon reflex responses will be measured. The coordination of motor activity in antagonistic muscles will also be studied.

IV. Apparatus:

- PC or Macintosh computer
- IX-ELVIS USB cable
- Power supply
- Red, black, and green EMG leads
- Alcohol swabs
- Disposable EMG electrodes
- PTN-104 pulse plethysmograph
- and reflex hammer

V. Procedure:

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.
2. Connect the IX-ELVIS to the computer with the supplied USB cable.

3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

Start the Software

1. Start the Software

2. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.

3. On the Main window, pull down the Settings menu and select Load Group.

4. Locate the folder that contains the settings group, ELVISNI.iwxgrp. Select this group and click Open.

5. Pull down the Settings menu again. Select the SkeletalMuscleReflexes-LS2 settings file.

6. After a short time, LabScribe will appear on the computer screen as configured by the SkeletalMuscleReflexes-LS2 settings.

7. The settings used to configure the LabScribe software and the IX-ELVIS for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

EMG Cable and Reflex Hammer Setup

1. Locate the PT-104 pulse plethysmograph (Figure NP-2-S1) and the red, black, and green EMG electrode lead wires (Figure NP-2-S2).

2. Plug the mini-DIN connector to the PTN-104 into the Channel 3 input of the IX-ELVIS (Figure NP-2-S4). 3. Plug the red, black, and green EMG lead wires into their respective sockets of Channel 1 of the IX-ELVIS (Figure NP-2-S4).

4. Use an alcohol swab to clean and abrade three regions on the calf of the left leg for electrode attachment. One area is near the ankle, the second is in the middle of the calf muscle, and the third area is about 3 inches below the back of the knee. Let the areas dry.

5. Remove the plastic disk from a disposable electrode and apply it to one of the abraded areas. Repeat for the other two areas.

Figure NP-2-S1: The PT-104 pulse plethysmograph.

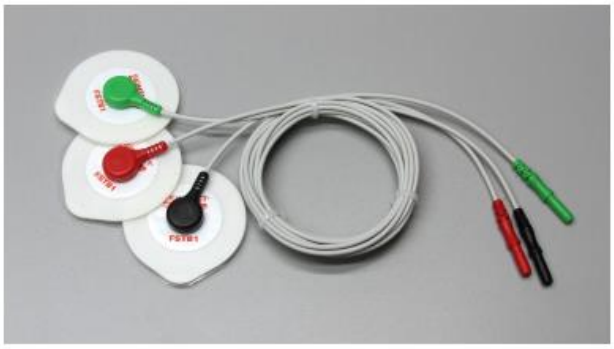


Figure NP-2-S2:EMG lead wires connected to disposable electrodes.

1. Snap the ends of the EMG lead wires onto the disposable electrodes (Figure NP-2-S3), so that:
   • the red (+1) lead wire is attached to the electrode near the back of the knee.
   • the black (-1) lead wire is attached to the electrode in the middle of the calf muscle.
   • the green (C) lead wire is attached to the electrode on the ankle that functions as the ground.
2. Attach the plethysmograph to the side of the head of the patellar hammer with its velcro strap. When the reflex hammer strikes the tendon, the plethysmograph will emit a signal which marks the recording on the Tendon Tap channel at the point in time when the tendon was struck

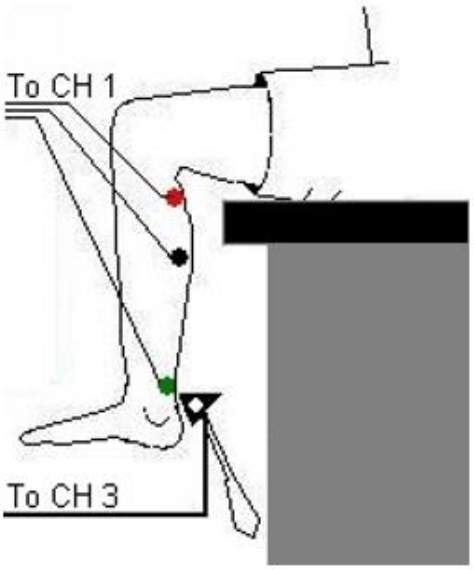


Figure NP-2-S3: Circuit diagram for recording electromyograms from the calf muscles.

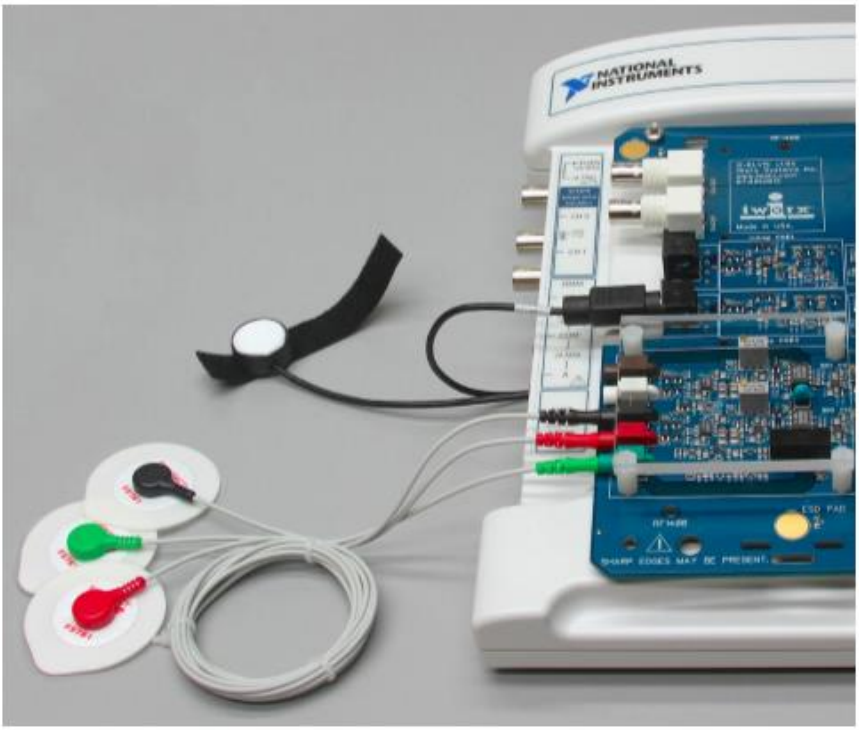


Figure NP-2-S4: The EMG lead wires and pulse transducer connected to the IX-ELVIS.

VI. Experimental Work:

Exercise 1: Achilles Tendon Reflex

Aim:

To determine conduction time from tendon tap to response of the gastrocnemius muscle in the Achilles tendon reflex arc.

Procedure

1. Instruct the subject to sit on a lab bench so that the subject's thighs are supported by the top of the bench and his or her calves hang freely. The subject could also kneel on a padded chair with the subject's ankles and feet hanging over the edge of the seat.
2. The Achilles tendon is located above the heel and connects the gastrocnemius muscle to the tarsal bone of the foot. Tap the tendon with the wide end of the reflex hammer a few times to locate a point on the tendon which produces a consistent contraction of the gastrocnemius muscle and a downward movement of the foot (plantar flexion). The opposite, upward movement is known as dorsiflexion.
3. Click Record and then instruct the subject to move his or her foot up and down to demonstrate the type of EMG that occurs during plantar flexion and dorsiflexion. Click AutoScale on the EMG Calf channel.
4. Type "<Subject's Name> Achilles Tendon Reflex" in the Mark box that is to the right of the Mark button. Press the Enter key on the keyboard to mark the recording. Continue recording.
5. Instruct the subject that the exercise has begun and that his or her tendon could be tapped at any time.
6. Tap the subject's Achilles tendon to elicit the stretch reflex. Record a total of ten trials using the same tapping force.
7. After the tenth trial, click Stop to halt recording.
8. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file. Designate the file type as *.iwxdata. Click on the Save button to save the data file. 9. Repeat this exercise on the same subject using different amounts of force.

Data Analysis

1. Scroll to the beginning of the data recorded for Exercise 1 to display the first trial on the Main window.
2. Use the Display Time icons to adjust the Display Time of the Main window to show both the signal made by tapping the tendon and the EMG response on the Main window. This trial can also be selected by:
    - Placing one cursor before the beginning of the signal from the tendon tap and the second cursor after the subject's EMG response; and
    - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the complete reaction trial to the width of the Main window (Figure NP-2-L1).

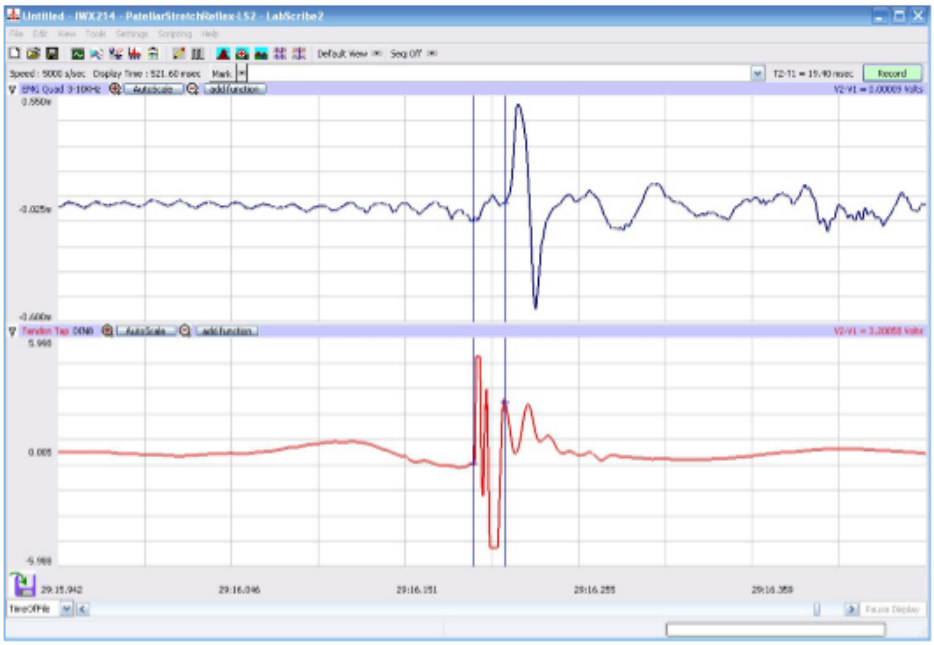


Figure NP-2-L1: An Achilles tendon reflex response and patellar hammer signal displayed on the Main window. The cursors are in position to measure the reflex conduction time

3. Click on the Analysis window icon in the toolbar or select Analysis from the Windows menu to transfer the data displayed in the Main window to the Analysis window
4. Look at the Function Table that is above the display of the EMG Calf channel displayed in the Analysis window. The mathematical function, T2-T1, should appear in this table. The value for T2-T1 is seen in the table across the top margin of the EMG Calf channel.
5. Use the mouse to click on and drag a cursor to the onset of the signal recorded from plethysmograph on the reflex hammer which is displayed on the Tendon Tap channel. Drag

the other cursor to the beginning of the EMG wave which is recorded on the EMG Calf channel.

6. Once the cursors are placed in the correct positions for determining the reflex conduction time, record the value for T2-T1 in the Journal. The value can be recorded in the on-line notebook of LabScribe by typing its name and value directly into the Journal. Values can also be recorded in separate data table.
7. The functions in the channel pull-down menus of the Analysis window can also be used to enter the name and value for T2-T1 into the Journal. To use these functions:
    - Place the cursors at the locations used to measure the reaction time.
    - Transfer the name of the T2-T1 function to the Journal using the Add Title to Journal function in the Reaction Time Channel pull-down menu.
    - Transfer the value for T2-T1 to the Journal using the Add Ch. Data to Journal function in the Reaction Time Channel pull-down menu.
8. Once the reflex conduction time in the first trial is measured and recorded, use the scroll bar at the bottom of the Analysis window to move the data from the second trial onto the window. If needed, use the Display Time icons to adjust the width of the Analysis window to show both the signal from the tendon tap and the subject's EMG response on the same window.
9. Repeat Steps 5 through 7 on the data from the second trial.
10. Use the same techniques used in Steps 5 through 8 to measure the reflex conduction times from the other eight trials.

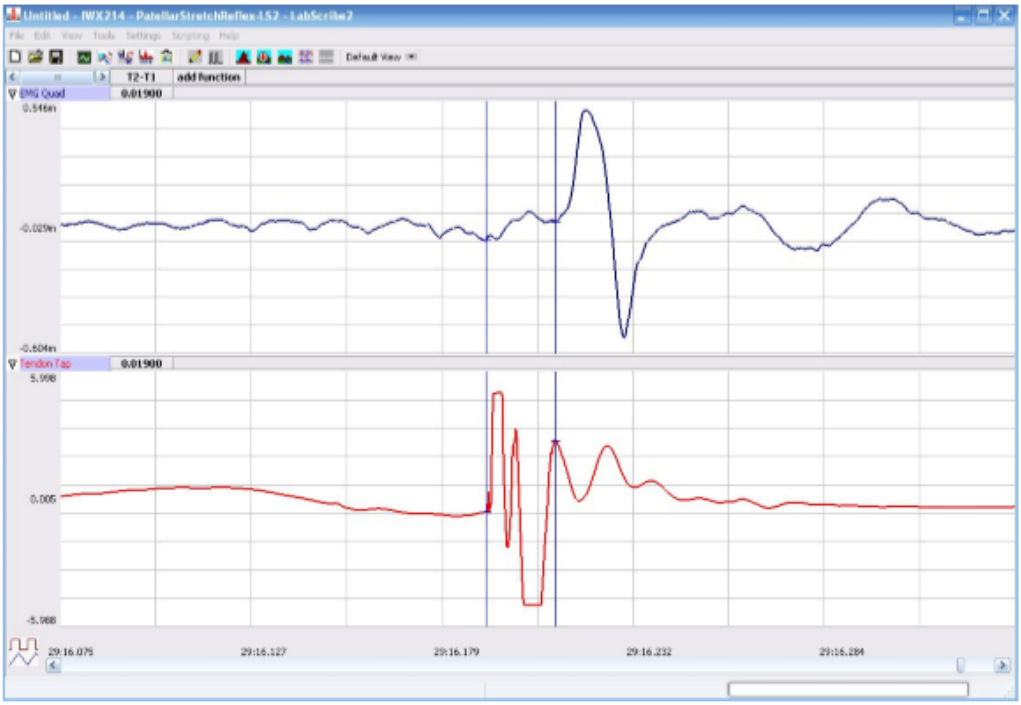


Figure NP-2-L3: An Achilles tendon reflex response and patellar hammer signal displayed on the Analysis window. The cursors are in position to measure the reflex conduction time.

11. Once the reaction times in all ten trials have been measured and recorded, open the Journal and use the values to determine the mean reflex conduction time of the subject. Discard the longest and shortest times from the data set, and determine the average of the eight remaining reaction times. Record the mean reflex conduction time for the Achilles reflex at this relative strength of tap in Table NP-2-L1.
12. Measure the distance between the belly of the subject's calf muscle and the site of the sensorimotor synapse in the spinal cord. For the purpose of this exercise, assume that the sensorimotor synapse is at spinal segments L5 and S1, which are just above the top of the hip bone. Multiply this measurement by 2 to determine the total length of the nerve path.
13. Even though this stretch reflex is known as a monosynaptic reflex, the pathway includes the neuromuscular synapse (NMJ) as well. Assume that synaptic transmission takes about 0.5 msec, calculate the conduction velocity in the nerves composing this reflex pathway by the equation:

$$\text{Conduction Velocity (m/sec)} = \frac{\text{Total path length (mm)}}{\text{(Mean reflex time (msec) - 0.5msec)}}$$

14. Record the conduction velocities for the Achilles reflex recorded from the three different tapping strengths in Table.

Exercise 2: Patellar Tendon (Knee Jerk) Reflex

Aim: To determine conduction time from tendon tap to response of the quadriceps muscle in the patellar tendon reflex arc.

Procedure

1. Instruct the subject to sit on a lab bench so that the subject's thighs are supported by the top of the bench and his or her calves hang freely.
2. Remove the lead wires of the EMG recording cable from the electrodes over the subject's calf muscle. Keep these electrodes on the subject's calf muscle.
3. Place a new set of recording electrodes on the quadriceps muscle of the subject on the medial side of the thigh (Figure NP-2-L4), so that:
    - the black (-1) lead wire is attached to an electrode which is about 12cm from the knee.
    - the red (+1) lead wire is attached to an electrode which is about 10cm above the negative electrode.
    - the green (C) lead wire is attached to the electrode on the knee that functions as the ground.
4. Feel the position of the patellar tendon just below the kneecap. Place one hand on the patella (kneecap), and use the other hand to tap the patellar tendon with the reflex hammer. Find the point on the patellar tendon that causes the greatest response from the quadriceps muscle.
5. Click Record and then instruct the subject to raise and lower his or her lower leg to demonstrate the type of EMG that occurs during quadriceps contraction and relaxation. Click AutoScale on the EMG Quad channel. Click Stop to halt the recording.

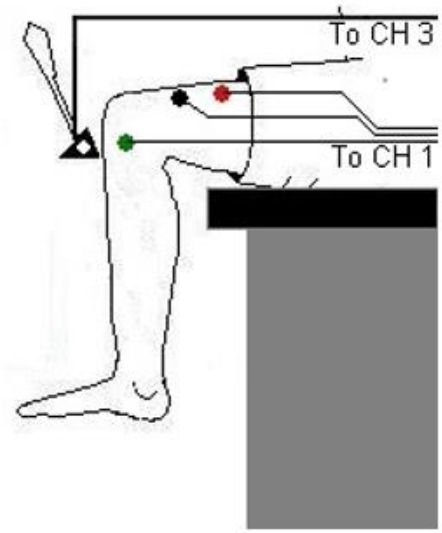


Figure NP-2-L5: Circuit diagram for recording EMGs from the thigh muscles.

6. Type "Patellar Tendon Reflex" in the Mark box that is to the right of the Mark button.
7. Click Record. Press the Enter key on the keyboard to mark the recording.
8. Instruct the subject to relax his or her quadriceps muscle and that the exercise has begun.
9. Tap the subject's patellar tendon to elicit the stretch reflex. Record a total of ten trials using the same tapping force.
10. After the tenth trial, click Stop to halt recording.
11. Select Save in the File menu.
12. Repeat this exercise on the same subject while the subject is voluntarily contracting his or her quadriceps.
13. Repeat this exercise on the same subject while the subject is performing Jendrassik's Maneuver. To perform this muscle activity:
    - The subject should curl the fingers of each hand toward its palm form a cup-shaped grip.
    - The subject should hold his or her hands and arms in front of his or her chest so that elbows are pointed out.
    - The subject should interlock his or her hands using the cup-shaped grip.
    - While the subject's patellar tendon reflex is recorded, the subject attempts to pull his or her hands apart. Jendrassik's Maneuver is an isometric contraction, in which motor activity that may affect reflex responses, occurs in another part of the body (the arm and shoulder muscles)

Data Analysis

1. Use the same technique explained in Exercise 1 to measure and record the conductions times of the subject's patellar reflex, patellar reflex with quadriceps muscle tension, and patellar reflex with Jendrassik's Maneuver.
2. Enter the mean reflex conduction times and velocities for this exercise

Observation

Reflex	Mean Reflex Conduction Time (ms)	Reflex Conduction Velocity (m/s)
Achilles Tendon - Light Tap		
Achilles Tendon - Medium Tap		
Achilles Tendon - Heavy Tap		
Patellar Tendon - Quads Relaxed		
Patellar Tendon - Quads Tensed		
Patellar Tendon - Jendrassik's Maneuver		

References:

LabVIEW manual

Experiment. 10 - Electromyogram (EMG) Activity and Muscle Strength

I. Objective:

In this experiment, students will use a hand dynamometer to measure a subject's grip strength as the EMG activity of the forearm muscles used to generate the subject's grip are recorded. The EMG activity will be related to the grip strength by plotting the maximum grip strength as a function the area under the absolute integral of the EMG activity during the muscle contraction. Data recordings will be made from the subject's dominant and non-dominant forearms, and the relative strength and electrical activity of each forearm will be compared to its diameter. Recordings of prolonged grip strength and forearm EMG activity will also be made to determine the rate of fatigue in the dominant and non-dominant forearms.

II. Test Standard:

EEE C37.14-1979 - IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

III. Theory:

A motor unit is composed of a motor neuron and all the muscle fibers that are innervated by that motor neuron. In a persistent muscle contraction, multiple motor units are firing repetitively throughout the contraction of the muscle. The strength of a muscle contraction is related to the number of motor units in the muscle that are activated during the same time period. The electromyogram (EMG) recorded during the muscle contraction is seen as a burst of spike-like signals, and the duration of the burst is about equal to the duration of the muscle contraction. The strength of a striated muscle contraction is directly proportional to the amount of electrical activity in the muscle. However, it is difficult to quantify the amount of electrical activity in a muscle unless the raw EMG data is mathematically transformed. One of the most common transformations used is the integration of the absolute values of the amplitudes of the EMG spikes. Through this transformation, it has been found that the area under the graph of the absolute integral of the EMG is linearly proportional to the strength of the muscle contraction.

IV. Apparatus:

- PC or Macintosh Computer
- IX-ELVIS USB cable
- Power supply
- Red, black, and green EMG leads
- Disposable electrodes
- FT-220 Hand dynamometer
- A-BT-220 Tubing
- GPSN-100 Pressure transducer
- Alcohol swabs
- Bathroom scale
- 5 or 6 textbooks or a 5-10 kg barbell weight String
- Metric ruler

V. Procedure:

IX-ELVIS Setup

1. Place the IX-ELVIS unit on the bench, close to the computer.
2. Connect the IX-ELVIS to the computer with the supplied USB cable.
3. Insert the power plug into the rear of the IX-ELVIS and plug the transformer into the electrical outlet. Turn on the power switches on the rear and on the upper right side of the top of the unit and confirm that the LEDs are illuminated.

Start the Software

1. Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program opens.
2. On the Main window, pull down the Settings menu and select Load Group.
3. Locate the folder that contains the settings group, ELVISNI.iwxgrp. Select this group and click Open.
4. Pull down the Settings menu again. Select the EMG-MuscleStrength-LS2 settings file.

5. After a short time, LabScribe will appear on the computer screen as configured by the EMGMuscleStrength-LS2 settings.
6. The settings used to configure the LabScribe software and the IX-ELVIS unit for this experiment are programmed on the Preferences Dialog window which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

EMG Cable and Hand Dynamometer Setup

1. Locate the red, black, and green electrode lead wires (Figure MP-1-S1).
2. Locate the FT-220 hand dynamometer, the A-BT-220 tubing, and the GPSN-100 pressure sensor, and assemble them as illustrated in Figure MP-1-S2.

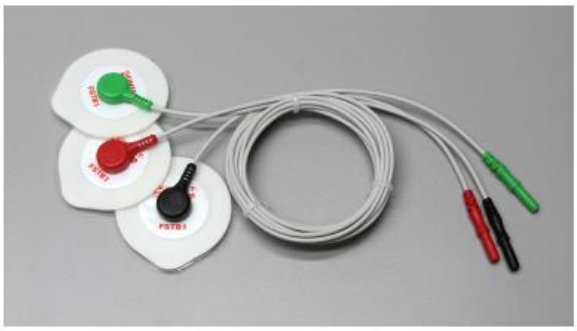


Figure MP-1-S1: EMG lead wires with disposable electrodes attached.

Figure MP-1-S2: Assembled FT-220 hand dynamometer, A-BT-220 tubing, and GPSN-100 pressure sensor.

3. Plug the mini-DIN connector to the GPSN-100 pressure sensor into the Channel 3 input of the

IX-ELVIS (Figure MP-1-S3).

4. Plug the red, black, and green EMG lead wires into their respective sockets of Channel 1 of the
   IX-ELVIS (Figure MP-1-S3).

Figure MP-1-S3: The EMG lead wires and the hand dynamometer assembly connected to an ETH/256.

5. The subject should remove all jewelry from their wrists. For the first exercises in this lab, record EMGs and muscle forces from the subject's dominant arm, the arm used most often.
6. Use an alcohol swab to clean and scrub three regions on the inside of the subject's dominant forearm where the electrodes will be placed (Figure MP-1-S4). One area is near the wrist, the second is in the middle of the forearm, and the third area is about 2 inches from the elbow.
7. Let the areas dry before attaching the electrodes.
8. Remove the plastic disk from a disposable electrode and apply it to a scrubbed area. Repeat for the other two areas.

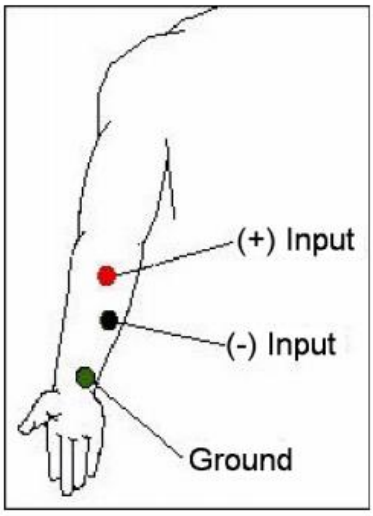


Figure MP-1-S4: Placement of EMG electrodes on the forearm.

9. Snap the lead wires onto the electrodes, so that:
    - the red "+1" lead is attached to the electrode near the elbow.
    - the black "-1" lead is attached to the electrode in the middle of the forearm.
    - the green "C" lead (the ground) is attached to the electrode on the wrist.

Calibrating the Hand Dynamometer

1. Collect 5 textbooks or use the barbell weight. Weigh the stack of books on the bathroom scale.
2. Record the weight of the stack in kilograms (kg) in the Journal. To open the Journal, click on the Journal button in the LabScribe toolbar. Use the keyboard to type the weight of the stack in the Journal window. Note: Remember that 1 kilogram is equal to 2.2 pounds.
3. Lay the hand dynamometer down on the bench top. Click the Record button on the LabScribe Main window and record for ten seconds.
4. Continue to record as you stack the textbooks on the bulb of the hand dynamometer. Record for an additional ten seconds after the last book is placed on the stack. Click the Stop button.
5. Click the AutoScale button on the Muscle Force channel. Use the Double Display Time icon to adjust the Display Time of the Main window to display the force recording before and after the books were placed on the hand dynamometer.

6. Click on the Double Cursors button on the LabScribe toolbar. Place one cursor on the force recording made before the books were placed on the bulb. Place the other cursor on the recording after the books were placed on the bulb.
7. Open the Channel Menu of the Muscle Force channel by clicking on the down arrow to the left of the channel's title. Select Units from this menu and Simple from the submenu to open the Simple Units Conversion dialogue window (Figure MP-1-L1).
8. Put check marks in the boxes next to Apply Units to new data and Apply Units to all blocks. Click on the Units Off button to remove any prior units conversion from this channel.
9. In the middle of the window is an array of four boxes. For each cursor, the value in the box on the left is the voltage at the position of the cursor on the recording window. In the box on the right, enter the value of the unit that equals the voltage on the left:
   - For Cursor 1, type zero (0) in the box on the right. This cursor is on the portion of the recording when no weight was placed on top of the hand dynamometer.
   - For Cursor 2, type the weight of the stack of books or the barbell weight in the box on the right
   - Type the name of the unit, kilogram or kg, in the Unit Name box. Click the OK button.

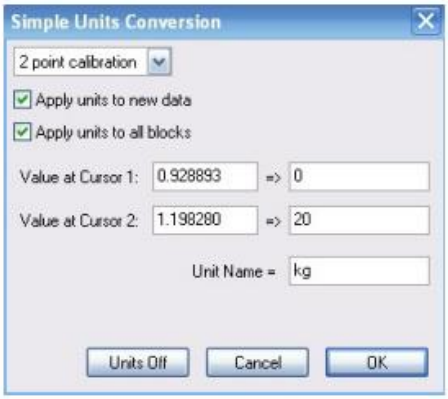


Figure MP-1-L1: The Simple Units Conversion dialogue window.

VI. Experimental Work:

Exercise 1: EMG Intensity and Force in Dominant Arm

Aim:

To determine the relationship between the intensity of EMG activity and the force of a muscle contraction in the subject's dominant arm.

Procedure

1. The subject should sit quietly with his or her dominant forearm resting on the table top. Explain the procedure to the subject. The subject will squeeze his or her fist around the hand dynamometer four times, each contraction is two seconds long followed by two seconds of relaxation. Each successive contraction should be approximately two, three, and four times stronger than the first contraction.
2. Type Increasing Grip Force-Dominant in the Mark box to the right of the Mark button. Click the Record button to begin the recording; then, press the Enter key on the keyboard to mark the beginning of the recording. After the recording is marked, tell the subject to begin squeezing the hand dynamometer following the procedure outlined in the step above.
3. In the relaxation period after the last contraction, click the Stop button.
4. Click the AutoScale buttons for the EMG, Muscle Force, and EMG Integral channels. The recording should be similar to Figure MP-1-L2.
5. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file, like your lab group folder). Designate the file type as *.iwxdata. Click on the Save button to save the data file.

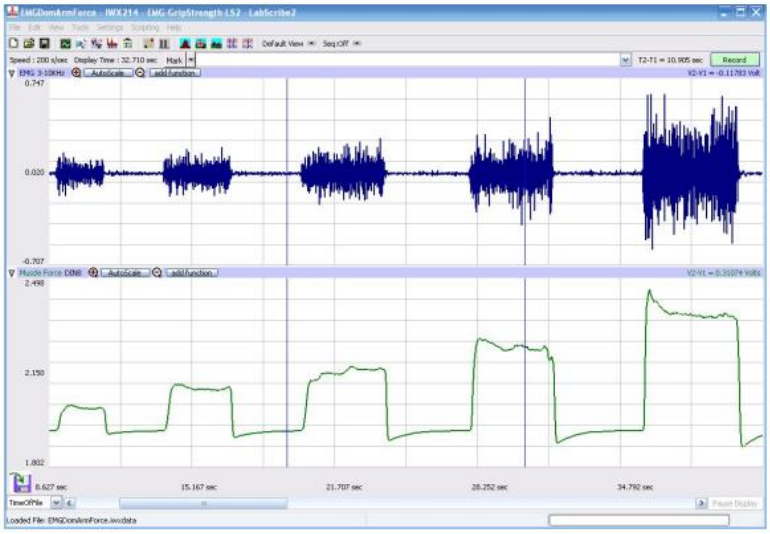


Figure MP-1-L2: The EMG (upper) and muscle force (lower) for four progressively stronger contractions displayed in the Main window.

Data Analysis

1. Use the Display Time icons to adjust the Display Time of the Main window to show the four progressive muscle contractions on the Main window. The four contractions can also be selected by:

- Placing the cursors on either side of a group of four contractions; and
- Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the segment with the four contractions to the width of the Main window.

2. Click on the Analysis window icon in the toolbar (Figure MP-1-L3) or select Analysis from the

   Windows menu to transfer the data displayed in the Main window to the Analysis window

   (Figure MP-1-L4).

3. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions, Abs. Area, V2-V1, and T2-T1 should appear in this table. The values for Abs. Area, V2-V1, and T2-T1 on each channel are seen in the table across the top margin of each channel.
4. Once the cursors are placed in the correct positions for measuring the absolute areas under the muscle contraction and the corresponding EMG activity, the values for the areas can be recorded in the on-line notebook of LabScribe by typing the names and values directly into the Journal.
5. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the absolute areas to the Journal. To use these functions:
   - Place the cursors at the locations used to measure the absolute areas.
   - Transfer the name of the mathematical function used to determine the absolute areas to the Journal using the Add Title to Journal function in the EMG channel pull-down menu.
   - Transfer the values for the absolute areas to the Journal using the Add All Data to Journal function in the EMG channel pull-down menu.
6. Use the mouse to click on and drag the cursors to the beginning and end of the first muscle contraction (Figure MP-1-L4). The values for Abs. Area on the EMG and

Muscle channels are the relative amount of the electrical activity causing the contraction and relative strength of the muscle, respectively. Record the values for these areas in the Journal using the one of the techniques described earlier in this exercise, and on Table MP-1-L1.

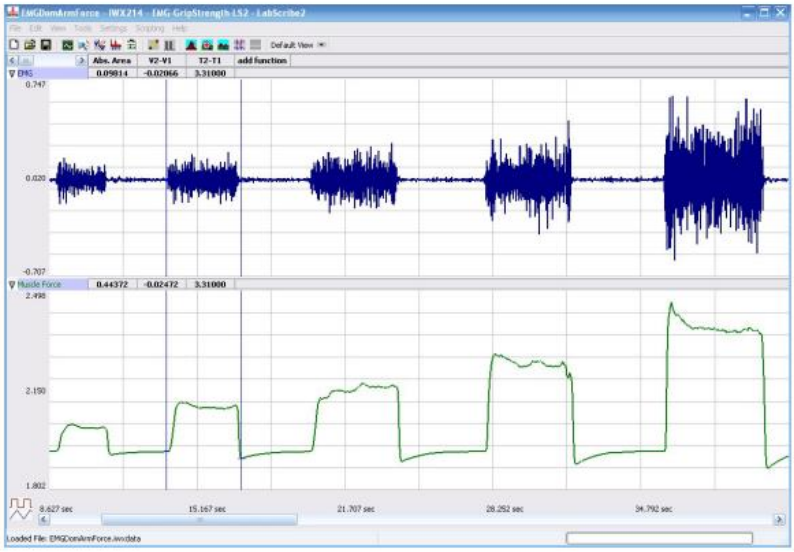


Figure MP-1-L4: The EMG and muscle force recordings displayed in the Analysis window. The cursors are placed on the margins of the first muscle contraction and the absolute area function is used to measure the area under the EMG spikes and the area under the force recording.

7. Repeat Steps 4, 5, and 6 for the other three muscle contractions recorded in this exercise.
8. Use a piece of string and a metric ruler to measure the circumference of the dominant forearm at approximately 3 centimeters below the elbow. Record this value in the Journal and on Table MP-1-L1.
9. Select Save from the File menu.

Observation

Dominant Forearm Diameter (mm):_____		
Relative Grip Strength	Absolute Area of EMG Activity	Absolute Area under Force Curve
Lowest		
Higher 1		
Higher 2		
Highest		

Observation:

References:

LabVIEW manual