

Lab 1: Introduction to Electronics Measurement Equipment

INTRODUCTION:

The purpose of this lab exercise is to introduce and give practice with the measurement equipment we will be using this semester. By the end of this lab you should be familiar with the basic functions of the function generator, oscilloscope, multimeter, and power supply. You will also gain experience with a biosignal amplifier and biosensors including a pulse plethysmograph heart rate monitor.

REQUIRED PARTS AND MATERIALS:

This lab assignment is performed using:

Hardware:

- 1) Philips PM 3365 Oscilloscope
- 2) HP 33120A Function Generator
- 3) Fluke 8840A Digital Multimeter
- 4) HP 6216C DC power supply
- 5) iWorx ETH-256C Combination Bridge Amplifier
- 6) BNC to BNC cable
- 7) Oscilloscope probe
- 8) Biomedical sensors (iWorx FT-325 Hand Dynamometer, PT-104 Pulse Plethysmograph)

Parts list:

- 1) 1 resistor of any resistance between 1 k Ω and 500 k Ω
- 2) 2 banana to banana cables

PRELAB:

1. Read the INTRODUCTION TO BIOINSTRUMENTATION section.
2. Read the LAB EQUIPMENT BACKGROUND section below to familiarize yourself with the lab equipment you will be using.
3. Read the PULSE PLETHYSMOGRAPH BACKGROUND section.
4. Read the ECE lab policy at https://www.egr.msu.edu/eceshop/labs/general_lab.php.
5. Read the ECE safety policy at <https://www.egr.msu.edu/eceshop/labs/safety/safety.pdf>.
6. Print the Prelab Grading Sheets and answer all of the questions. ***The Prelab Grading Sheet must be turned in to the TA at the beginning of lab, before beginning your lab assignment.***
7. Read through the LABORATORY PROCEDURE before coming to lab.

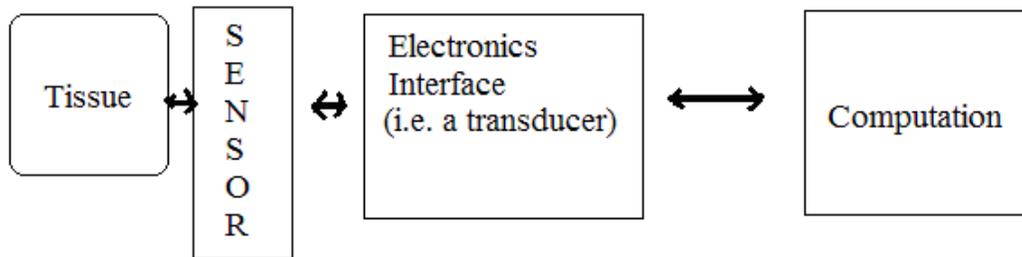
INTRODUCTION TO BIOINSTRUMENTATION

Biomedical instruments encompass a wide range of products such as electrocardiogram (EKG) machines or medical imaging systems. The current estimate for use of biomedical instruments totals over \$200 billion. Every biomedical instrument interfaces with biological materials through direct (i.e. an electrode) methods or indirect (i.e. induced fields) methods. In this class, we will deal primarily with biosensors, a branch of biomedical instrumentation. Biosensors can be modeled by the simple diagram shown below, where each part of the system must have specific characteristics to be a good instrument.

A sensor must:

- detect biochemical, bioelectrical, or biophysical parameters
- reproduce the physiologic time response of these parameters
- provide a safe interface with biological materials

Biosensor System



The electronics interface must:

- match electrical characteristics of the sensor with computation unit
- preserve signal to noise ratio of sensor
- preserve bandwidth (i.e., time response) of sensor
- provide a safe interface with the sensor
- provide a safe interface with the computation unit
- provide secondary signal processing functions for the system

The computation unit must:

- provide primary user interface
- provide primary control for the overall system
- provide data storage for the system
- provide primary signal processing functions for the system
- maintain safe operation of the overall system

Biomedical sensors study the changes of a system by taking precise measurements of that system. Some examples of measurements taken include body temperature, breathing flow and rate, even anatomical shapes and sizes. In order to process these measurements into quantifiable signals, some form of electrical interface is implemented. A popular element for this is a transducer. A transducer is a device that transfers power generated from one system to another system, either in the same form or a different one. A measurable parameter of the transducer changes under a change in the studied system. The measured variable could be mechanical, electric, thermal, optic, chemical or magnetic. The transducer influences the characteristics of the measurement system. A transducer is characterized by its accuracy, precision, and sensitivity. Other transducer parameters like repeatability and linearity may be required to fit a particular application.

Accuracy is how close to the measured value is to the true value. It provides a confidence level within a certain percentage of the real value. Any discrepancy between the true value and the measured value is the error. The formula for calculating the accuracy of any instrument is usually given by:

$$Accuracy = \frac{True_Value - Measured_Value}{True_Value}$$

Precision is the instrument's ability to give the same reading under the same conditions. It is necessary but not sufficient for accurate readings because it does not take into account any coincidence or difference between the result and the true value.

Sensitivity describes changes in system output for a given change in a single input. It is quantified by holding all inputs constant except one. This one input is varied incrementally over the normal operating range, producing a range of outputs needed to compute the sensitivity.

Repeatability is the ability to reproduce the same output readings when the same measured value is applied repeatedly under the same conditions and in the same direction in short time intervals. Quantitatively, it is the minimum value that exceeds, with a specified probability, the absolute value of the difference between two successive readings obtained under the specified conditions (if not stated, is assumed 95%).

The computational part of the instrument model can be a variety of things. In this class, we will see in future labs different ways to interface with a system.

LAB EQUIPMENT BACKGROUND:

A) *The Oscilloscope*

The oscilloscope used in this course is a two channel digital storage oscilloscope that allows the observation of low frequency repetitive signals and transients over a wide range of frequencies. In this lab we will be covering most of the available features.

The oscilloscope, or scope for short, is divided into five blocks: the Display Block, the Vertical Amplifier Block, the Sweep Block, the Trigger Block and the Storage Block. The Display Block consists of the cathode ray tube (CRT) and associated controls. The CRT is a device which provides a visual display of a voltage. This voltage is applied to the scope at the Vertical Amplifier Block. The scope creates a CRT display by capturing and overlaying successive windows of time. These windows begin at the same trigger point on the voltage being examined and end at a specific increment of time. The trigger point is controlled by the Trigger Block and the time increment is controlled by the Sweep Block. The Storage Block allows us to save the wave form for future reference or hard-copy.

In measuring any circuit we will need to connect the measuring instrument to our circuit. This changes the original circuit by connecting the equivalent circuit of the instrument into the circuit. We will always need to know what the equivalent circuit of the instrument is, so that we can either neglect loading effects or include loading effects in the calculations of the circuit's response. The equivalent circuit for the **A** and **B** input terminals are shown in Figures 1-3 for the three settings of the **AC/DC** and **GND** buttons. This is the load seen by our circuits.

In the **DC** position the measured signal is **Directly Coupled** to the vertical amplifier and we see displayed the actual wave form. In the **AC** position, a blocking capacitor is inserted in series with the measured signal. This blocks any dc signal in steady-state and we see displayed only the time varying component of our measured signal. This is useful for measuring transistor amplifier circuits where the time varying signal is very small compared to the dc level. In these cases displaying the actual wave form makes it difficult to see the characteristics of the time varying signal. In the **GND** position the load seen by our circuit is an open circuit but the vertical amplifier, internal to the scope, sees a short and displays 0 volts. This feature is useful for setting a reference line.

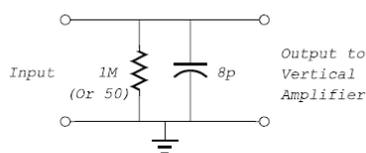


Figure 1. DC position

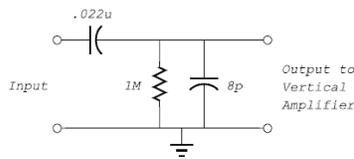


Figure 2. AC position

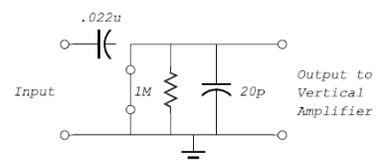


Figure 3. GND position

B) *The Function Generator*

The function generator is a precision source of sine, triangle, positive and negative ramp, haversine, square, positive pulse and negative pulse wave forms plus dc voltage. The frequency of the wave forms is manually and remotely variable from 100Hz to 50MHz. The equivalent circuit for the **OUTPUT** terminal is shown in Figure 4.

C) Digital Multimeter

The Fluke 8840A Digital Multimeter is a precision, manual ranging, multi-function multimeter. For the manual range selection, the number on these buttons indicates the maximum number displayed. If the measured quantity exceeds these limits an **OVER**range value of 1___ is shown. The measurement functions of the 8010A are DC and AC voltage, 2-Wire Resistance, and DC and AC current.

1) Resistance Measurement

The **k Ω 2 WIRE** measurement of the 8840A, shown in Figure 5, is done by forcing a precise dc current to flow through the device which we wish to measure. This creates a dc voltage which is sensed and converted to display a value which corresponds to the unknown resistance. The equivalent circuit of the meter in this mode is a current source. The value of the current depends on the range selected either manually or automatically. Since the meter is establishing its own currents for measurement, it is important to **never** use the Ω feature in a circuit with power applied. Resistors should always be completely disconnected from a circuit when measured.

2) Resistor Color Codes

The resistance value of carbon composite resistors can be determined by reading the color code on the resistor, as described in Figure 6

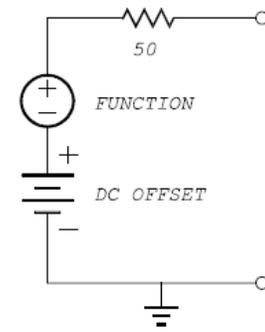


Figure 4. Function Generator.

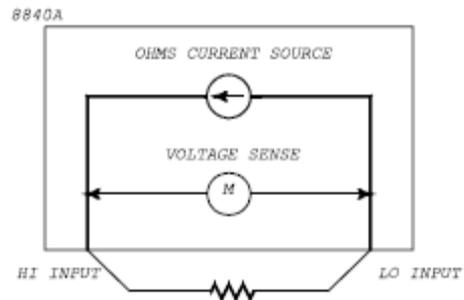


Figure 5. 2-Wire resistance measurement.

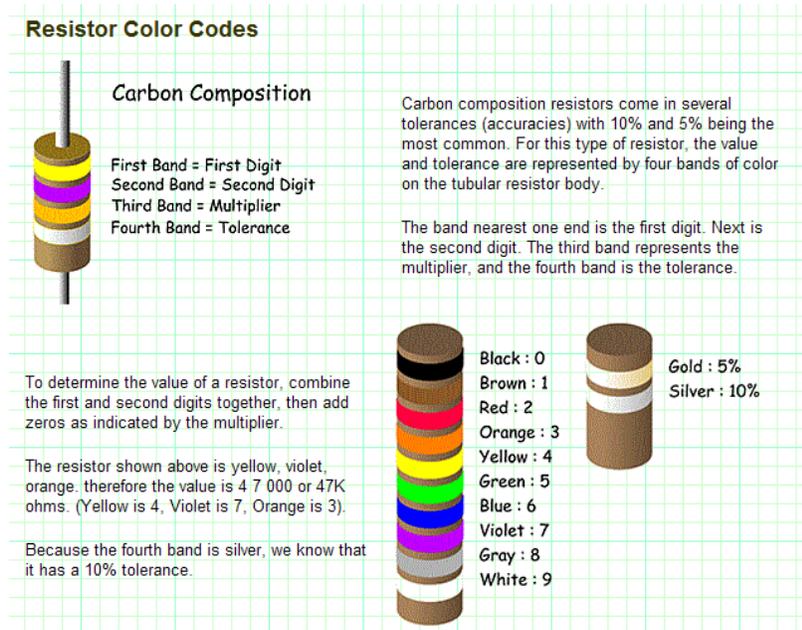


Figure 6. Resistor color codes

(http://www.reprise.com/host/circuits/resistor_colorcodes.asp).

PULSE PLETHYSMOGRAPH BACKGROUND:

[source: http://www.picotech.com/experiments/calculating_heart_rate/]

When the heart beats, a pressure wave moves out along the arteries at a few meters per second (appreciably faster than the blood actually flows). This pressure wave can be felt at the wrist, but it also causes an increase in the blood volume in the tissues, which can be detected by a plethysmograph. This word comes from the Greek "plethysmos" for increase and is a term for a "fullness" (i.e. change in volume) measuring device. For this lab you will use a photoelectric pulse plethysmograph which will allow the beating of the heart to be recorded without the need to make direct electrical connections to the body.

In lab you will monitor your heartbeat using a sensitive, rugged, non-magnetic accelerometer pulse sensor finger clip that will be provided. In an alternative photoelectric sensor that we will use later, a finger clip plethysmograph consists of an emitter and photodetector, where light is emitted by the infrared (IR) emitter and passes through the tissue of your finger or earlobe to a matched wavelength photodetector. Variation in blood volume alters the amount of light incident on the detector, and hence the measured voltage.

In hospitals and in other biomedical instrumentation applications these sensors often look like the ones shown in Figure 7. The sensors shown may often also include red LEDs and matched detectors, in addition to the IR emitter and detector. The red LEDs are used to measure the fluctuations in reflection of the hemoglobin in blood, which allows the oxidation of the blood to be measured. The "redder" the blood is, the more red LED light is reflected, and hence the higher the measured level of blood oxidation. Recall that when blood is oxidized it turns bright red, but when the oxygen is absorbed by the tissues it turns a duller, darker red, and hence reflects less of the incident red light. Some of the sensors shown are designed to be disposable, and are adhesive so that they can be quickly put on patients' fingers in the emergency room. Blood oxidation is also an important vital sign for infants, and many pulse plethysmograph and blood oxidation sensors have been designed specifically for this application.



Figure 7. Pulse plethysmograph and blood oxidation sensors.

LABORATORY PROCEDURE:

The following tasks should be completed in lab, during your lab session.

General Guidelines !! IMPORTANT!!

When possible, work in 2-person teams. Each team should complete and turn in a single grading sheet (write both names on the top of the grading sheet). Try to divide the work load and take turns doing different connection, measurement, and data recording tasks. The TA will ask questions when he checks off various parts of your lab and if you don't know answers he will reduce your grade for the lab. Try to complete the assignment with the lab period; all the labs are full so there is no opportunity to work outside of your lab section. Do not leave lab without turning in your Lab Grading Sheet.

A) First Time Operation of the Philips PM 3365 Oscilloscope

1. Before actually turning on the oscilloscope, there are a few controls you can preset to facilitate the startup procedure. On the right side there are two columns of 4 round knobs. The outermost column are labeled **Y POS**, **Y POS**, **X POS** and **TRIG LEVEL**. These knobs should be pointing straight up. The other column of knobs are labeled **VAR**, **VAR**, **VAR** and **HOLD OFF**. These knobs should be turned fully clockwise and pointing to **CAL**, **CAL**, **CAL** and **MIN**, respectively.
2. Check that the power cord is plugged into the AC receptacle. Press in the **POWER** switch found in the upper left corner. If the trace that appears is extremely bright, turn the **INTENS** control counter-clockwise.

CAUTION: If the cathode ray tube (CRT) is left with an extremely bright dot or trace for a very long time, the fluorescent screen may be permanently damaged. If a measurement requires high brightness, be certain to turn down the **INTEN** control immediately afterward.

3. Turn the **INTENS** control to adjust the brightness to the desired level.
4. Turn the **FOCUS** control for a sharp trace.

B) The HP 33120A Programmable Synthesizer/Function Generator

1. The laboratory function generator is a precision source of sine, triangle, positive and negative ramp, haversine, square, positive pulse and negative pulse wave forms plus dc voltage.
2. Check that the power cord is plugged into an AC receptacle. Press the **POWER** switch found in the lower left corner to the on position.
3. Change the impedance to High Z: Press Shift > Press Enter to enter menus. Press "right" button till you see **SYS MENU**. Press "down" button twice to see 50 OHM. Press "right" button to get **HIGH Z**. Press Enter. **ENTERED** will be displayed. Repeat these steps every time you turn on the function generator.

C) Waveform Measurement

1. Coaxial cable is the most common method of connecting an oscilloscope to signal sources and equipment having output connectors. The outer conductor of the cable shields the central signal conductor from hum and noise pickup. These cables are usually fitted with a BNC (Bayonet Connector) on each end.

Connect a BNC cable from the **OUTPUT** of the function generator found on the lower right side to the **A** input terminal of the scope found in the lower center. Our first task will be to generate a voltage equal to $1+0.5 \sin(2\pi 1000t)$.

2. Press the button with the sine wave.
3. We next need to set the frequency of the wave form. This is done with the **FREQ** button. The value is entered with the up/down arrows to the right or with the knob on the far right. Adjust to 1000 Hz (1 kHz). This value will appear on the digital display.
4. Push the button labeled **Amplitude**. Use the up/down arrows to change the units to Vpp. This is the peak-to-peak value of the wave form selected. Enter a value of **1** using the knob or arrows. You now have generated a voltage with the expression $0.5 \sin(2\pi 1000t)$.
5. To add a dc offset onto our wave form, we need to press Offset. Enter a value of **+1**. We now have a voltage of $1+0.5 \sin(2\pi 1000t)$.
6. If you make a mistake or want to change any of the above settings, just repeat the specific step.
7. A wave form should appear on your scope screen. If not ask your lab instructor for help.
8. The wave form on the screen may appear small or crowded. This is because of the setting selected by the scope during power-up. We will learn shortly how to change this. However we can quickly re-set the scope so that it will try to make our wave form easier to view by pressing the green **AUTO SET** button on the scope. Do this.
9. The scope has two different modes of operation. These are called analog and digital. In the analog mode the wave form is very smooth and continuous. In the digital mode the wave form is being sampled and displayed and may appear jagged on the screen. Press the white **DIGITAL MEMORY** button on the scope. You will see these two modes. Place the display in the analog mode.
10. The top number found in the menu window is the value for each of the vertical divisions. These are the large squares of the screen grid. Counting the number of these divisions from the highest to lowest point of your sine wave and multiplying this times the setting displayed in the menu window is the peak-to-peak value of your sine wave. This may be difficult depending on where your wave form is on the screen.
11. We can set and/or place the zero volt reference of the input. This is done by first pressing the **GND** button. There are two such buttons. The top one is for the **A** input and the second one two rows down is for the **B** input. Press the **A** input **GND**. This is zero voltage reference for this channel. Rotate the **Y POS** for this channel and place this line in the center of the screen. Now press the **A** input **GND** button again.

Detach the Lab Assignment section of this lab. You will hand this in at the end of lab. Calculate the measured peak-to-peak value of your sine wave using the setting of the scope, that is, the voltage per division times the number of divisions. Record this, and all data that follows, as indicated in the Lab Report. If your calculated peak-to-peak voltage is not 1, ask your instructor for help.

Note: If the function generator is checked and the signal is set properly then the issue is the oscilloscope calibration. To make it easier to visualize, change the function generator to output 2Vpp. On the oscilloscope, adjust Var until each division block is equal to the vertical increment value indicated in the top digital menu. If the menu says 1, then each block represents 1 volt. Hence the 2Vpp signal should stretch between two blocks. After calibrated, return the function generator to 1Vpp.

12. Press the **A** input **AC/DC** button. Now you should be in the **DC** mode. Your wave form still has a zero reference at the center line of the screen. Calculate the dc level of your wave form. If this is not 1, ask your instructor for help. What is the purpose of the **AC/DC** button? (Answer this and all questions in a complete sentence)
13. The other number in the menu window is value of the horizontal divisions. Count the number of divisions per cycle and calculate the period of your sine wave. The frequency of your sine wave is the reciprocal of the period. Calculate the frequency. If this is not the same as set in part 4, ask your instructor for help.
14. Switch to the digital mode of the scope by pressing the **DIGITAL MEMORY** button. Although this mode is not as smooth as the analog mode, it does allow us to do some very useful tasks with the data.
15. Below the scope screen there are five white buttons. Press the right most one several times and press it so that a row of text appears on the scope display. This is our path into a set of wave form operations. The first one we will investigate is how to display the settings found in the menu window.

These next few steps show how to print a hardcopy of the screen of the scope. However, we do not have a printer hooked up in our lab.

16. Press the button under the word **SETTINGS**. To obtain a hard copy of the scope's screen turn on the printer. The on/off switch is on the back. Press the **PLOT** button on the scope. The scope should display a message indicating that it is plotting. In a minute or so your printer will start to plot. When the plot is finished, the paper will advance and you can tear off your plot. Make one copy for each student in your lab group. Mark your zero volt reference line with a pen or pencil.
17. Now that you are familiar with the generation of a sine wave, look at the other **WAVE FORMS**.
18. Press the **AUTO SET** button. The triggering mode is set by the scope so as to best display the wave forms. The mode selected is probably **TB** (time base); **AUTO**; **A**; **PP**. These four abbreviations should appear in your menu window, if not have your instructor help you to set it in this mode.

This provides a display where the triggering of the picture is initiated by the time varying signal applied to the **A** input. **B** is then displayed relative to **A**. This will show the phase angle relationship between the two measured signals.
19. Set the function generator for a 2Vpp 1 kHz sine wave with no offset.
20. Rotate the **TRIG LEVEL** knob. This knob selects the point on the trigger signal where the wave

form is to begin being displayed. In the **PP** mode the range is determined by the peak-to-peak value of the trigger signal.

The slope of the trigger signal is also used. In the / mode, the positive slope is used and in the \ mode, the negative slope is used. Press the slope button and rotate the **TRIG LEVEL** knob.

21. Return the scope to the positive slope mode and adjust the trigger level so that the input wave form is a sine wave with 0° phase shift.
22. If we are trying to capture a signal that is not repetitive, the auto trigger mode cannot capture the wave form. To do this we need to change to the single shot mode, where a single wave form is captured and displayed.
23. Press the **TB TRIG MODE** to display **SINGLE**. To arm the scope to prepare for an event, press the **RESET** button. You can now press the **DIGITAL MEMORY** button. The scope should display the waveform that you just captured. Change the scope back to analog mode and change the **TB TRIG MODE** to display **AUTO**.
24. The PM 3365 can also perform waveform measurement. Place the scope in the digital mode. Press the right white button on the screen bezel so that the words: **CURSORS SETTINGS SHIFT** and **TEXT-OFF** appear. Press the **CURSORS** button. A new menu appears on the bottom of the screen. Press the **CALC** button. A new menu appears. We can select the measurement of amplitude or time. Select **TIME**. Again a new menu appears. Select **FREQ**. The frequency of your sine wave should now appear in the upper portion of the screen. What is the value of the measured frequency?
25. Now press return and this time select **AMPL**. What is the peak-to-peak voltage measured by the scope? Go through these menus and observe the different measurements the scope will take. When finished return the scope to the analog mode.
26. Change your waveform to a 100 Hz sawtooth wave. Change the **TIMES/DIV** to .5mS. Your waveform now has less than one cycle on the screen. With the **TB VARIABLE** control and the **VAR** knob, adjust the time scale so that one cycle of you wave fits between 7.2 major divisions. You can adjust the point of initial triggering by using the **TRIG LEVEL** control. Since there are 5 minor divisions per (major) division then one cycle of 360° has $5 \times 7.2 = 36$ minor divisions. Thus each minor division corresponds to 10° .
27. Generate a 50 kHz 5V square wave with no offset. Use the digital mode of the scope to verify you created the correct signal. Experiment more with generating different waveforms with the function generator.
28. Disconnect the function generator from the scope.

D) Probe Compensation and Use

1. Locate the scope probe. Hold the base such that the set screw of the adjustment capacitance trimmer is face up. Connect the probe to the **A** input connector such that the set screw is still face up. Pull back on the probe flange to expose the hook on the tip of the probe and attach to the **CAL 1.2V** connector. In this circuit you do not need to connect alligator clip. Why?
2. Press the **AUTO SET** button. Measuring the peak-to-peak value of this wave form would be

easier if we could enlarge the picture on the screen. The setting of the vertical voltages per division can be changed by the user with the rocker switch marked **A**. Push on one end and then the other and watch what happens on the screen. Set the value to 0.2 Volts (per division). Now measure the peak-to-peak value of this and record this value. How does this compare with the value stamped on the scope?

CAUTION: Excessive turning of the adjustment trimmer screw will permanently damage the probe. The replacement cost of one probe is approximately \$100.

3. With a small screwdriver, adjust the set screw of the capacitance correction trimmer of the probe **no more than a 1/8 turn in either direction** to display an under-compensated wave form (rounded edges). Plot this wave form with the scope settings. Adjust the probe to display an over-compensated wave form (edges with peaks). Plot this wave form with the scope settings. Mark the zero volt reference line.
4. Adjust the probe so that the wave form is a correctly compensated square wave.
5. Determine the dc (average) value and period. Record and determine the frequency of this calibration signal.
6. Disconnect the probe from the scope.

E) Fluke 8840A Digital Multimeter and the HP 6216C DC Power Supply

CAUTION: Never turn on the power supply for the first time with anything connected. The voltage or current might be set too high and could potentially damage whatever you have plugged in.

1. The HP 6216C is a constant-voltage/current-limiting dual/single output 30V/0.5A power supply. Turn on the power supply (**LINE**) by pushing the power button in the lower left corner. If the supply ever becomes current limited (voltage won't go up any more) you may need to increase the current by turning the **CURRENT** knob clockwise, but we'll be working with relatively low power circuits in this lab.
2. Select **VOLTS** in the meter selection. Turn the **VOLTAGE** knob until the voltage reads 5.0V.
3. The Fluke 8840A multimeter has multiple functions and manually selectable ranges. You will need two banana-to-banana cable. Connect a banana-to-banana cable to the **LO** terminal and different cable to the **HI** terminal. Select **VOLTS** in meter selection. Press the **V DC** button to select voltage measurement and **20** to set the range (suitable for our 5V supply).
4. Connect the **HI** input terminal on the multimeter to the red + terminal on the power supply. Connect the **LO** input terminal to the red - terminal on the power supply.
5. Using the reading from the power supply, adjust the **VOLTAGE** knob to set the voltage to 5.0 V. What voltage does the multimeter display? Record this value.

F) Voltage, Current, and Resistance measurements.

1. Now we are going to explore the functions of the Fluke 8840A to take some measurements. Start by measuring the voltage output of the power supply. Adjust the power supply voltage until the multimeter reads as close to 5V as possible. Record this value.

2. Disconnect the cables to the multimeter. Configure the multimeter to measure current by connecting one banana cable to **LO** and a different cable to **2A Input**. Press the **mA** button to select current mode. Routing a node through the multimeter will now measure current. You will have to adjust the range to suit different situations.
3. Turn the power supply off and then connect the multimeter in series with the power supply and the resistor as shown in Figure 11 below. Several resistors should be provided on the lab bench; you can pick any of them. Double check your circuit connections. Turn on the power supply and observe the current. Record the current value. Calculate the resistance using ohms law.

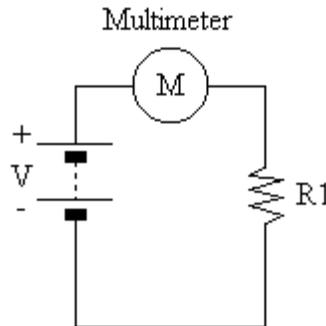


Figure 11. Current measurement setup

4. Use the information provided in the prelab to determine the resistance of your chosen resistor based on its color coding.
5. Measure the actual resistance using the multimeter as follows. Turn off the power supply and disconnect the cables from the power supply. Disconnect the multimeter cable from the **2A** input terminal and connect it into the **HI** input terminal. Connect the resistor between these two cables and then press **k Ω 2WIRE** button. Record the measured resistance value.

CAUTION: Never take a resistance measurement with power supplied to the resistor. This could damage the multimeter.

6. Now that you have measured the actual resistance, calculate the percent error of your calculated resistance. If your percent error is more than 3% make sure all your calculations and measurements were done correctly.
7. Turn off the multimeter and disconnect all cables.

G) Biosignal Amplifier Experiment

The iWorx ETH-256 Combination Bridge and ECG/EMG Amplifier is composed of two identical functional units. The inputs and settings for each of these units are on the front panel of the device. The first functional unit (Channel 1) is located on the left half of the front panel, and the second (Channel 2) on the right half. Each channel has two input connectors: one 8-pin DIN connector (used by many transducers), and one BNC connector for devices that are single-ended. Each channel also has settings for a High Pass Filter (HPF), Low Pass Filter (LPF), gain, and a DC offset. The HPF,

LPF, and gain are controlled by the small black buttons to the left of their LED displays, and the offset by the knob near the input connectors. The outputs for each channel are BNC type connectors located on the rear of the device.

Setup

1. Connect the ETH-256 as follows: Connect power to the rear of the ETH-256 using the supplied wall transformer to 3.0mm phono plug cable. Using a BNC cable, connect the Channel 1 output terminal on the rear panel of the amplifier to an oscilloscope. Turn on the ETH-256 (the switch is on the back) and then turn on the oscilloscope.

Dynamometer

2. Connect the iWorx FT-325 Hand Dynamometer (pressure sensor) to the Channel 1 8-pin DIN connector. Set the HPF for Channel 1 to the **DC** setting by pressing the small black button to the left of the HPF LED display until the LED labeled “DC” is lit. Set the gain for the channel to a value of 1 (no gain) by pressing the small black button to the left of the gain LED display until the LED labeled “x1” is lit.
3. Adjust the ground level of the scope signal to a position near the top of the display and ensure you are able to see the voltage signal (it should be a flat line) somewhere near the middle of the display. If you cannot, adjust the value of the vertical divisions such that each division accounts for more or less voltage. Use the offset knob on the ETH-256 to move the flat line to ground on the scope.
4. Squeeze the hand dynamometer pressure sensor and observe what happens on the scope. If it is not easy to see a change in voltage, you will need to adjust the scope so that each vertical division accounts for less voltage. Adjust the vertical divisions until the change in voltage when you squeeze the sensor is between 1 and 2 divisions. Calculate the change in voltage (ΔV) when you squeeze the sensor by subtracting the voltage when you are not squeezing the sensor from the voltage when you are. Record this value.
5. Now set the ETH-256 gain for the channel to a value of **x5** by pressing the small black button to the left of the gain LED display once. Repeat step 4 at this new gain.
6. Repeat step 5 with the ETH-256 gain set to **x10**. Comment on how well the recorded values compare at different gain settings. Is the ΔV you calculated for a gain of 10 what you would have expected? If not, give some possible reasons.
7. Repeat measurements at all 3 gains having the other member of your group squeeze the sensor. Are your ΔV ratios roughly the same?

Plethysmograph

8. Disconnect the hand dynamometer pressure sensor and connect iWorx PT-104 Pulse Plethysmograph to the Channel 1 input. Set the HPF to “**DC**,” the LPF to “**50**,” and the gain to “**x1**” by pushing the appropriate buttons on the front panel.
9. Move the ground line of the scope to a position near the middle of the display and ensure you are able to see the voltage signal (it should be a flat line) somewhere near the middle of the display. If you cannot, you may need to adjust the value of the vertical divisions such that each division accounts for more or less voltage. Use the offset knob on the ETH-256 to move the flat line to ground on the scope.

10. Wrap the sensor around your finger so that it is fairly tight. Adjust the value of the horizontal divisions to account for more or less time until you can see approximately three periods. You may also need to adjust your vertical divisions so that you can see the changing signal.
11. Use the store mode of the scope by pressing lock button to freeze the image on the scope display. Calculate the peak-to-peak period of your heart pulse by multiplying the value of each horizontal division by the number of divisions. Record this value and calculate your heart rate (frequency).
12. Repeat step 11 until you have 3 heart rate readings. Calculate the average heart rate.
13. Repeat step 12 for your other team member. Note the variations with one person's heart rate readings and the difference in heart rates for each team member.

H) Clean up

Make sure all equipment has been turned off. Please return all wires to the racks/box from which they were taken. Turn your assignment in to the TA.