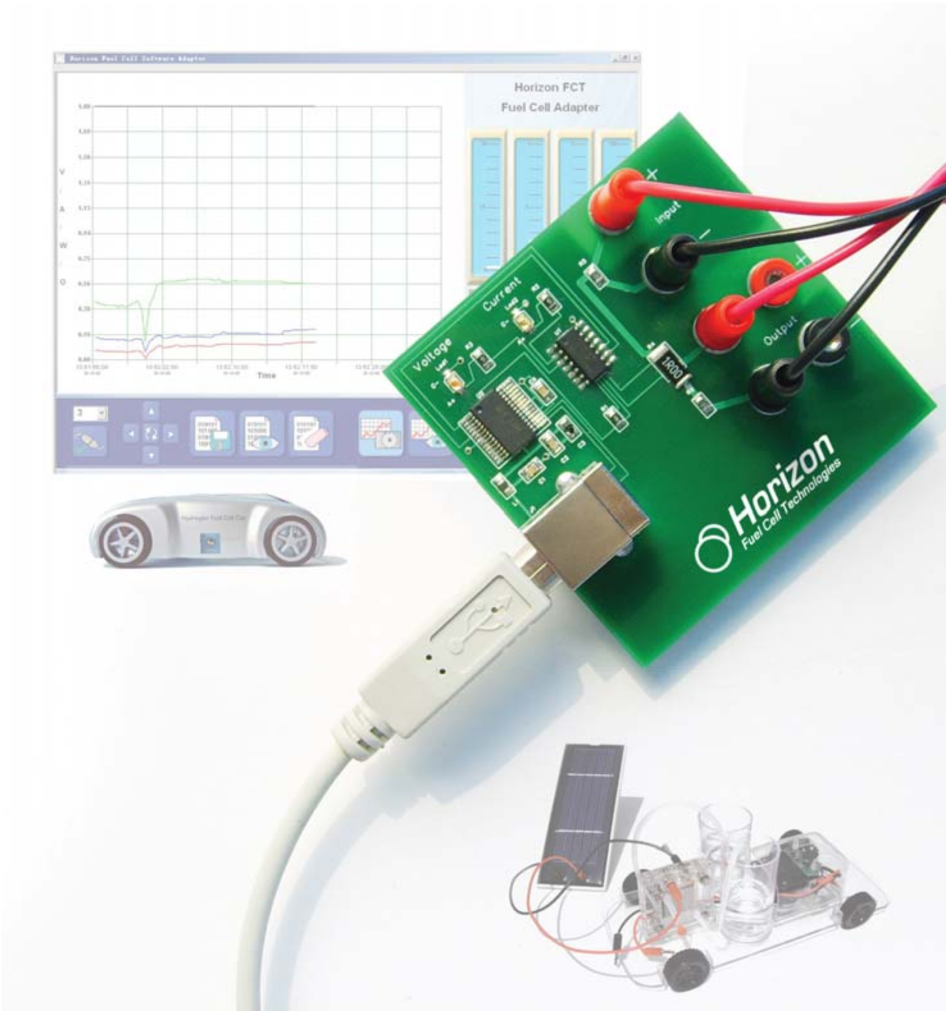
Horizon Fuel Cell Software Adaptor

User Manual



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1. Introduction

Diminishing resources, more severe environmental impacts and the ever- increasing demand for energy force us to re-evaluate the structure of our energy supply system. Automobile and oil companies increasingly invest in hydrogen technology because it offers solutions to some of these concerns. This fascinating technology combines a sound energy supply with minimal impact on our natural resources.

In order to learn more about how hydrogen fuel cells can power everything from cell phones to cars, the ***Fuel Cell Software Adapter*** allows you to directly peer into the electrical operation of a fuel cell in order to observe how it produces hydrogen from plain water and then uses this hydrogen to create electricity.

The ***Fuel Cell Software Adapter*** takes your regular desktop or laptop PC and turns it into a laboratory instrument where you can “graphically” observe the electrical relationships among voltage, current, resistance and power. Meters are fine for static electrical measurements, but when it comes to seeing what happens in real time – all at once - nothing beats a graphic display!

This is what you have in the ***Fuel Cell Software Adapter*** – a laboratory instrument that is specifically designed to test fuel cells. And the following experiments will teach you more in one minute than you can experience in hours of tedious laboratory measurements with a meter. A picture is worth a 1000 words and nothing is more appropriate for this comparison.

The ***Fuel Cell Software Adaptor*** provides a facility for automatically recording and evaluating the voltage, current and power values of fuel cells. It includes PC software for recording measurements, as well as a Data Acquisition Card for connecting to a computer's USB interface.

Horizon’s ***Fuel Cell Software Adaptor*** has been especially developed for fuel cells in the lower power range. The PC software and the Data Acquisition Card are designed for measuring and recording voltage, current, load resistance and power values for fuel cells with a power capacity of up to 5 watts.

The following measurement ranges are possible:

- Voltage measuring range:
  0 volts to 5 volts

- Current measuring range:
  0 amps to 1 amp

- Power measuring range:
  0 watts to 5 watts

- Resistance measuring range:
  0 ohms to 99.999 ohms

For best results, please review each experiment before performing it. This will avoid misunderstandings and provide you with knowledge of what is about to happen.

We wish you many enjoyable hours learning about fuel cell technology and how it can benefit our world with the ***Fuel Cell Software Adaptor.***

2. Intended Use

- Measurements can be carried out and evaluated on fuel cells in the power range up to 5 watts with the ***Fuel Cell Software Adaptor's*** external Data Acquisition Card and the associated software.

- The hardware and software were developed exclusively for educational teaching and demonstration purposes. Any other use is prohibited!

3. General Safety Precautions

In order to avoid any risks, you must follow the following General Safety Precautions when carrying out measurements with the ***Fuel Cell Software Adaptor*** and fuel cells.

- The system may only be set up and operated by a competent person. Students require adult supervision at all times.

- Read the Operating Instructions before setting up the system. Follow them during use and keep them readily available for reference. This also applies to the Operating Instructions for the fuel cells and, if appropriate, any electrolyzer used in the experiments.

- The system is not a toy. Operate the equipment and keep it and the gases produced out of the reach of small children.

- Unless specified otherwise, do not short-circuit or reverse the polarity of the terminals.

- Remove inflammable gases, vapors and fluids from the vicinity of fuel cells and electrolyzers. The catalysts contained in the system can trigger spontaneous combustion.

- Hydrogen and oxygen may escape from fuel cells and electrolyzers. To prevent the gases collecting and forming explosive mixtures only use the system in well ventilated rooms.

- Fuel cells and electrolyzers may only be operated where there is sufficient ventilation at all times. The operator is obliged to prove this by means of appropriate measurements.

- Remove from the vicinity of fuel cells and electrolyzers anything that could ignite the hydrogen such as a naked flame, materials that can become charged with static electricity, substances with a catalytic action, etc.

- Remove from the vicinity of fuel cells and electrolyzers all substances that could spontaneously ignite with increased oxygen concentration.

- Do not smoke in the vicinity of fuel cells and electrolyzers.

- Only use the gas storage tanks Horizon provides to store gas. Never connect other alternatives.

- Horizon will not accept any responsibility for injuries or damage sustained in the event of these Safety Precautions not being followed

4. Related Issues

4.1 Reverse Engineering

You are not entitled to reverse engineer, decompile or disassemble the software product in whole or in part.

4.2 Errors and Omissions

Horizon has made every effort to supply the software and hardware without errors; however, we are not responsible for any unintentional errors or omissions in the design, construction or operation of the product. If you should notice undiscovered errors, please contact us.

Horizon Fuel Cell Technologies
www.horizonfuelcell.com

4.3 System Requirements

The following operating systems are supported - Windows 2000, Windows 98, Windows ME, Windows NT, Windows XP, Windows Vista. MACs with INTEL processors can use Parallels **"Desktop 3.0 for Mac".**

4.4 Minimum Computer Requirements

The minimum requirements are the same as those of the respective operating systems. In addition, the Microsoft .NET Framework run-time environment is required for running the ***Fuel Cell Software Adapter,*** which can be found on the installation CD in German and English.

4.5 Software Installation

You will need administrator rights for software installation under Windows 2000, Windows NT, Windows XP or Windows Vista.

4.6 Supplied Materials

- Data Acquisition Card
- USB Cable
- One 1 ohm, two 10 ohm resistors.
- Capacitor
- CD-ROM with FCA graphics software, USB Driver Software, user manual and PDF installer
- Connection cables

4.7 Other Required Materials Not Supplied

- Windows PC – MACs must have Parallels “Desktop 3.0 for Mac”
- Fuel cell
- Solar panel
- Table fan for wind turbine
- Small DC motor and propeller
- Battery Holder (two AA batteries not included)
- Wind Turbine

5. Hardware Installation

1. Connect one end of the USB cable to the computer and the other end to the Data Acquisition Card.

2. The green and blue LEDs on the Data Acquisition Card should flash to indicate that the connection is made and power from the computer is applied to the circuit board.

6. Software Installation

1. Insert the Horizon ***Fuel Cell Software Adaptor*** CD-ROM into your computer’s disc drive and close the door.

2. On the Desktop, right-click on “Start” then click “Explore”. Find your CD-ROM drive (D, E or higher) then click it to bring up the folder’s contents.

3. Double click on the USB driver software (USB Driver Installer.exe) to install it.

4. Double-click on the **Horizon FC Installer** file and follow the instructions to install it.

5. Next, minimize all applications until the Desktop reappears again. A Horizon FCA icon like that shown here should appear:

6. Click the Horizon FCA icon. You can choose either English or German.

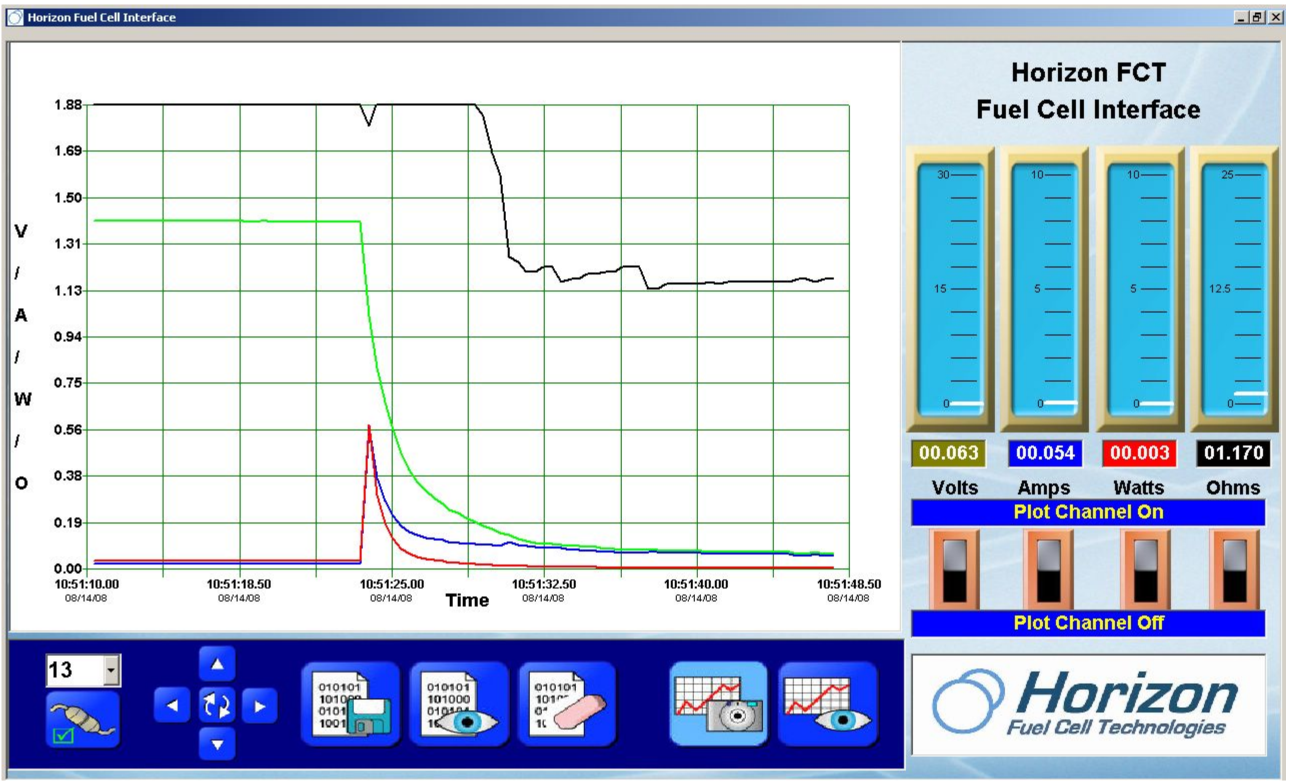
7. You have successfully installed the hardware and software. Now proceed to **Section 7** on **“Learning to Use the Graphics Software”** to understand what to do next.

7. Learning to Use the Graphic Software

The PC graphic software screen is divided into several regions that control how electrical quantities such as voltage, current, power and resistance readings are displayed.

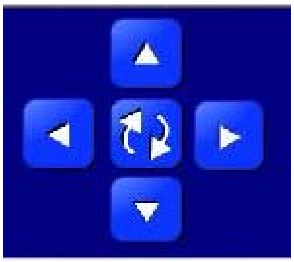
The large grid area continuously displays four plotted lines in four colors. The colors match the voltage, current, power and resistance values below the vertical meters.

- **Green – Voltage in volts**
- **Blue – Current in amperes**
- **Red – Power in watts**
- **Black – Resistance in ohms**



Before any plots can occur, the graphic software must connect with the attached circuit board that is transmitting data. To do so, first select the correct Comm port number then click on the Connect icon. You can type over the number displayed if it is not correct. To find the correct Comm port go to Control Panel --> System --> Hardware Manager --> Device Manager then click on the Comm port. This is the correct Comm port to type into the number area. Then click the connector icon – the one with the red x.

If correct, the Connect icon will show that the connection is made. If the Comm port is not correct an error message will be displayed, which is usually due to a Comm port already in use.

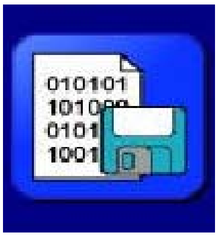


The plot area can be zoomed in and out of a time range (horizontal axis) or a voltage, current, power or resistance range (vertical axis).

The up and down arrows will zoom the plot in a vertical direction. Up to increase and down to decrease.

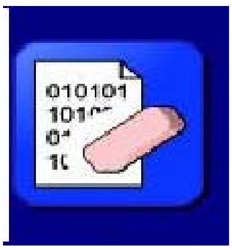
The left and right arrows will zoom the plot in a horizontal direction - left for more time and right for less time.

Click the center double-arrow icon to clear the screen and reset the plot. If the plot does not immediately start, click the double-arrow icon again.



To begin data logging, click the data log icon. A file will automatically open to record the data being sent by the circuit board.

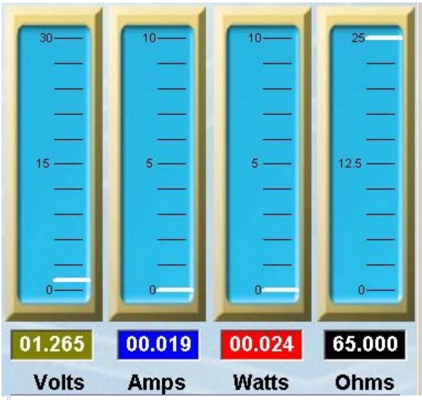
To view the logged data, click on this icon. The logged data will be displayed over the plot area where it can be examined. This same file can be ported to a spread sheet program like Excel for further analysis and plotting. To find the path to the logged data go to **Program Files → Horizon FCA → Data** on your hard disk.



Click this icon to close the data log file and erase all logged data.

Click this icon to capture the plot image on the screen.
These images are automatically saved to a file with a unique name and can be extracted and included in reports or printed out. To find the path to these images go to **Program Files → Horizon FCA → Data** on your hard disk. You will find the captured screen shots as .jpg files, which you can extract and use in reports or print out directly. You can also rename the files, as well.

Click this icon to view the captured images.



The four meters display the voltage, current, power and resistance. Their scales are fixed and unlike the grid plot area, cannot be changed.

The resistance reading of 99.999 ohms is maximum even if the actual resistance is more.

The other electrical measurements are consistent with their actual values.

To reduce screen clutter in the plot area, the individual switches can be clicked to turn ON or turn OFF the selected plot line.

If your computer is connected to the Internet, clicking on the Horizon icon will take you to their website.

8. Data Acquisition Board

The Data Acquisition Board is the electronic interface between devices such as a fuel cell, solar panel and wind turbine. When connected to a computer via a USB cable, it measures and computes voltage, current, resistance and power then transmits these electrical quantities 3 times a second to the computer. The computer software displays these quantities as both numbers and colored line plots as they are transmitted.

Input and Output Connectors

There are two (2) Input connectors. One is colored red, which indicates positive or plus (+) polarity and the other is colored black to indicate negative (–) polarity. In the following experiments, power sources such as a battery, solar panel, wind turbine or fuel cell will be connected to the Input connectors.

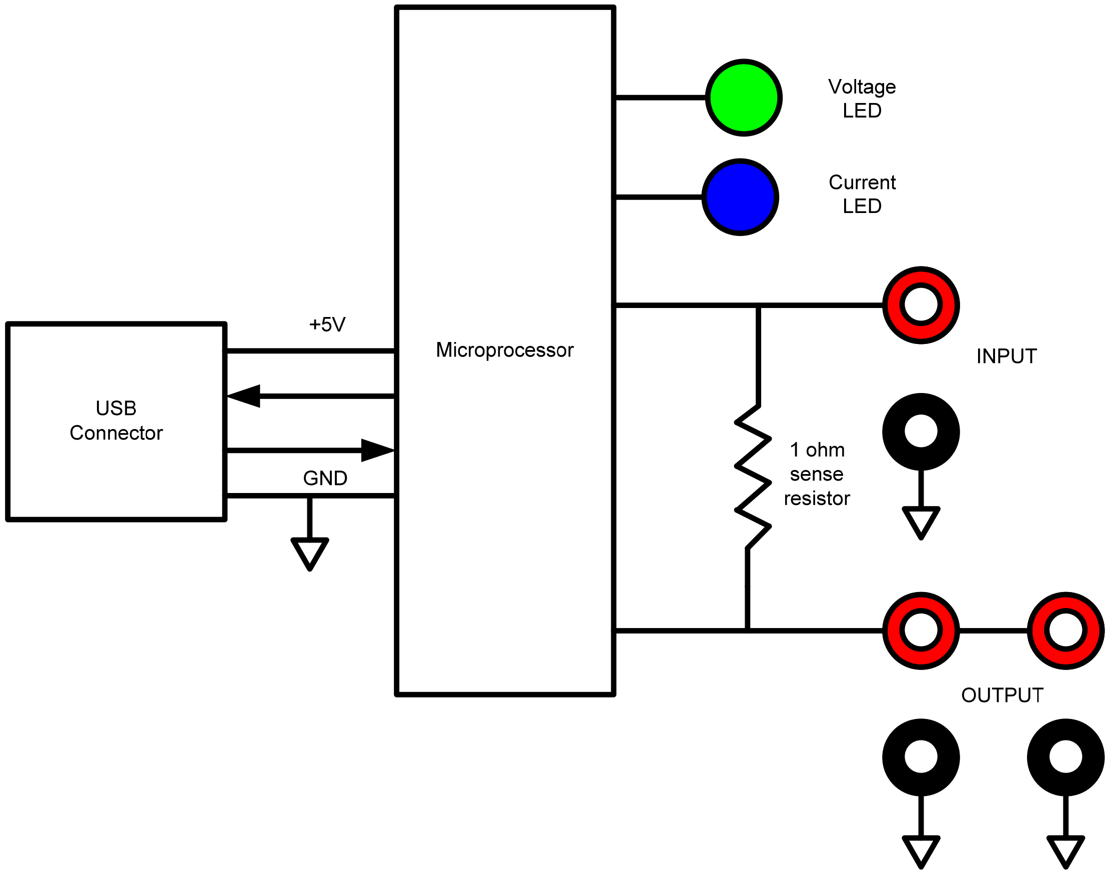
There are four (4) Output connectors, but they are actually two sets of positive and negative connectors arranged in parallel - meaning that the two positive (red) terminals are connected together and the two negative (black) terminals are connected together (but not to each other; i.e., positive to positive and negative to negative). In the following experiments loads such as a resistor, capacitor, motor and fuel cell are used. (a fuel cell can be both a power source as well as a load).

The diagram in the next subject line shows how these connectors are arranged.

1 Ohm Sense Resistor

A 1 ohm sense resistor (labeled R4 on the circuit board) is connected between the Input and Output connectors. Its main purpose is to measure the current flow from the power source on the Input connectors going into the load on the Output connectors. The sense resistor, R4, is also attached to the microprocessor (U1), which does the work of “sensing” current and load resistance.

Since the loads in the following experiments tend to be of small resistance values, generally 10 ohms, or less, the 1 ohm sense resistor must be considered in current and resistance calculations (as will be shown later). An equivalent circuit is shown on the following page:



Flashing LEDs

The two flashing LEDs represent the relative strength of the voltage and current being measured. The green LED indicates voltage and the blue LED indicates current - - the brighter the LEDs, the greater the relative voltage and current being measured (and visa versa). To enhance the understanding between the circuit board and the computer display software, these are the same colors used on the computer display software to display voltage and current.

USB Connector

The USB connector is the cube-like part on the left side of the circuit board. When a USB cable is attached to it and to a computer, power for the circuit board is delivered from the computer and data is transmitted by the circuit board to the computer for display and analysis.

9. Power Sources and Loads

The experiments use the following power sources and loads.

Power Sources
- Battery
- Solar Panel
- Wind Turbine
- Fuel Cell

Loads
- Resistors
- Capacitor
- Motor – Propeller
- Fuel Cell (a fuel cell can be both a power source and a load)

What is a Power Source?

For these experiments a power source is a device that produces both electrical voltage and current (in effect, power). The power sources use chemical energy (battery, solar panel), magnetic energy (wind turbine) or hydrogen (fuel cell) to generate voltage and current.

The equation for power is shown below:

$$P = E*I$$

Where P = Power in watts
E = Voltage in volts
I = Current in amps

What is a Load?

A load is a device that accepts the power coming from a power source and (may) use the power to do work, like spin a motor. Other loads like resistors and capacitors serve to dissipate or store power (respectively). In all cases, loads are used to both consume and regulate the power being produced.

Generally speaking, a load is measured as resistance whose units are in ohms.

In relative terms, a “light” load has a “large” resistance and a “heavy” load has a “small” resistance. This may be counter intuitive, but it is the case, nevertheless. For example, a 100 ohm resistor presents a “lighter” load to a circuit as compared with a 10 ohm resistor.

The equation for computing the association among voltage, current and resistance (load) is as follows:

$$E = I*R$$

Where E = Voltage in volts
I = Current in amps
R = Resistance in ohms

What is a Resistor?

A resistor is an electrical device (usually composed of a passive material like carbon) that limits the flow of current and voltage from a power source. Resistors are important components in any electrical circuit, since other components that are connected to the resistors depend on the limited current and voltage they produce to operate correctly.

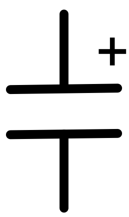
The physical part and electrical symbol for a resistor are shown below:

What is a Capacitor?

A capacitor is a device that stores energy from a power source and then releases the stored energy when it is no longer available. It is somewhat like a rechargeable battery, but quite different in terms of its construction and use in circuits. Depending on the size of the capacitor (its value, in units called Farads), it can store and release energy many times faster as compared with a battery. The experiments will use the capacitor to “filter” or smooth out the voltage “ripples” produced by the wind turbine.

Capacitors come in two basic types – polarized and non-polarized. A polarized capacitor requires that you connect the positive lead to the red terminal on the circuit board and the negative lead to the black terminal. Non-polarized capacitors can have either lead connected to positive or negative. The experiments only use a polarized capacitor.

The physical part and electrical symbol for a polarized capacitor are shown below:

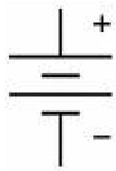


The longer lead of a polarized capacitor is positive (+) while the shorter lead is negative (-). The negative lead is also identified by a series of bar-and-arrow symbols on the part itself. In the experiments that follow, be sure to observe the positive and negative portions of the capacitor.

What is a Battery?

A battery stores chemical energy, which can be converted into electrical energy.

The physical part and electrical symbol for a battery are shown below:



Primary batteries are ready to produce current as soon as they are manufactured. Primary batteries are generally used in flashlights and must be replaced when they go “dead”.

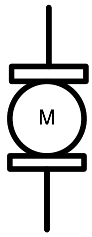
Secondary batteries can be recharged by applying an electrical current, which reverses the chemical reactions that occur during its use. All car batteries are secondary batteries that need constant recharging by the car’s alternator.

The capacity of a battery depends on the discharge conditions, such as the magnitude of the current and the duration of the current. The Battery Capacity (AH, Ampere Hour) is defined as the maximum constant current that a fully charged battery can supply for 20 hours at 68°F (20°C) down to a predetermined terminal voltage. Thus a 1000mAH (milliamp hour) battery will deliver 50mA over a period of 20 hours at room temperature. However, if it is discharged at 100mA, it will run out of charge within 10 hours.

What is a Motor?

There are many types of electrical motors, but the one used in the experiments is a small DC motor that attaches to a propeller. Normally constructed with spinning magnets (rotor) that surround a coil of wires (stator), a motor converts electrical energy into mechanical energy by taking in electrical power and then spinning a shaft using magnetic energy. The shaft can be connected to a "load" such as a propeller to do work; i.e., spinning the propeller to generate wind energy.

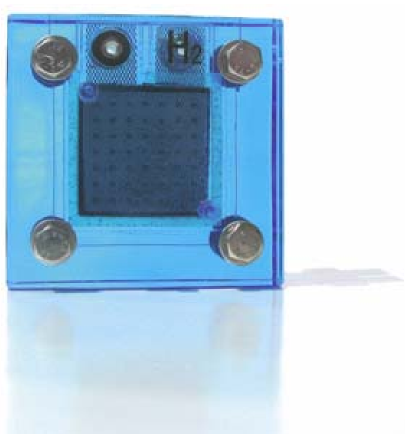
The physical part and electrical symbol for a DC motor are shown below:

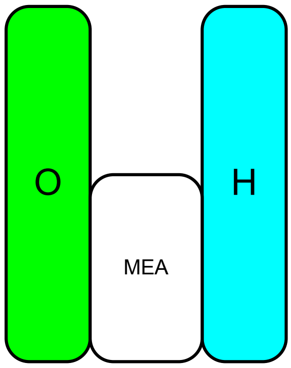


What is Electrolysis?

For our purposes the term electrolysis defines splitting water into its two main components – hydrogen and oxygen. This is what a "reversible" fuel cell does; it splits water (H2O) into hydrogen and oxygen gases in electrolysis mode and then recombines hydrogen and oxygen in fuel cell mode to create electricity, which is why it is called "reversible". It doesn't take much voltage (about 1.5 volts) to split water into hydrogen and oxygen as one of the experiments will demonstrate.

The physical part and symbol for a reversible fuel cell are shown below:



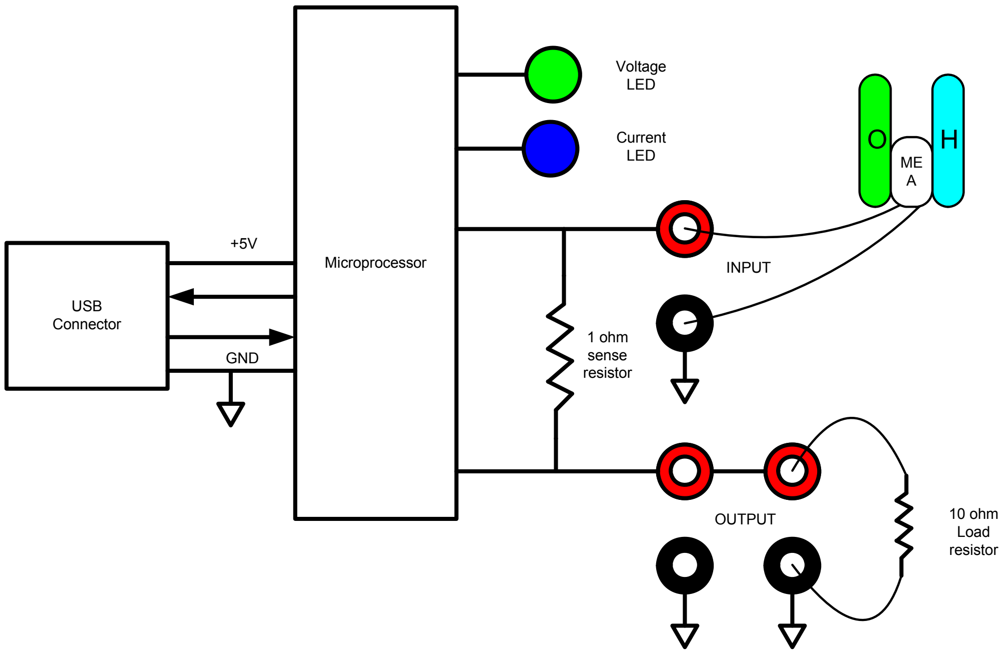


10. Measuring Resistance

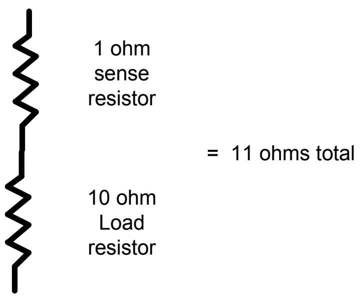
When measuring resistance both the external load resistor as well as the 1 ohm sense resistor built into the circuit board must be taken into consideration.

Example 1:

The illustration below shows a 10 ohm load resistor placed across one set of the OUTPUT terminals. The total resistance is really 11 ohms (10 ohm load resistance + 1 ohm sense resistance). While the fuel cell is shown as the power source, a battery, solar panel or wind turbine can also be substituted.

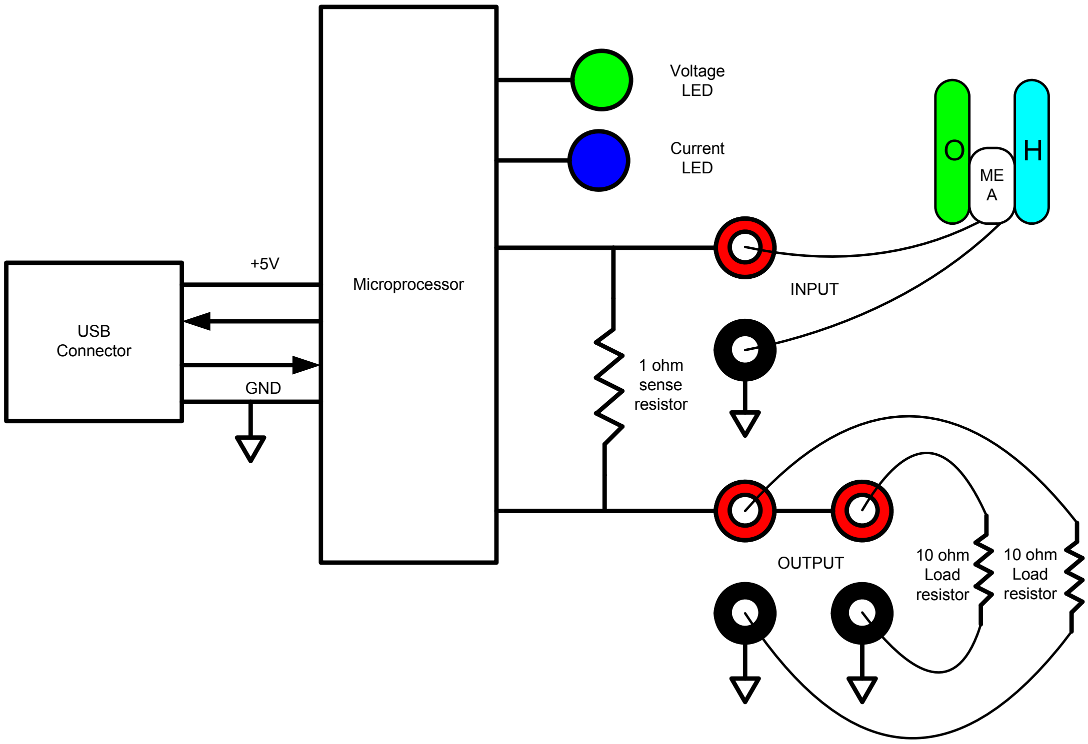


The equivalent circuit is shown below:

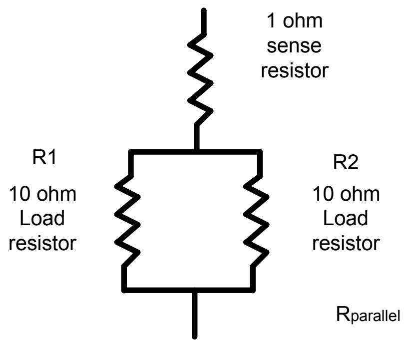


Example 2:

The illustration below shows two 10 ohm load resistors, in parallel, placed across both sets of the OUTPUT terminals. The total resistance is really 6 ohms (5 ohm “parallel” load resistance + 1 ohm sense resistance). While the fuel cell is shown as the power source, a battery, solar panel or wind turbine can also be substituted.



The equivalent circuit is shown below:

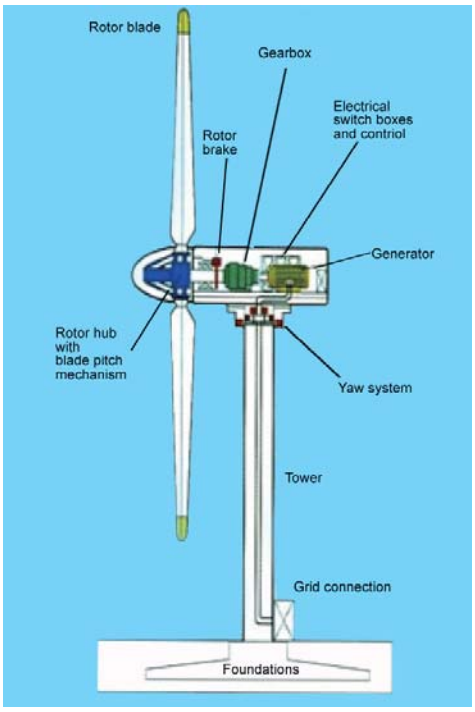


= 6 ohms total

$$R_{parallel} = \frac{R1 \times R2}{R1 + R2} = 5 \text{ ohms}$$

11. Basic Knowledge of Wind Power Technology

A wind turbine is a device that uses rotor blades connected by a mechanical shaft to an electrical alternator to generate electricity. When the wind blows across the rotor blades, the propeller shaft rotates the alternator and the alternator makes electricity (much the same when your car's engine spins the alternator to charge the car's battery).



The amount of power that is produced by a wind turbine depends on many factors – one of which is the rotor blades. The power that can be harvested in the area swept by the wind turbine rotor blades can be described as follows:

$$P = 0.5*\rho*A*V^3$$

Where:
P = Power in Watts
ρ= Air Density in Kg/m^3 (about 1.225Kg/m at sea level, less higher up)
A = Rotor Swept Area in $m^2 = \pi r^2$ (r= radius of the rotor)
V = Wind Speed in m/s

You should notice that the power is proportional to the cube of the wind speed and the square of the radius of the rotor blades. If the radius of the rotor blades is doubled, the swept area is quadrupled.

If the wind speed is reduced by half (1/2), the power is reduced to 1/8 of the original power. Thus, a light wind contains little power, so remember to use a larger table fan for the experiments. It will produce much better results.

Albert Betz was a German Physicist and a pioneer of wind turbine technology. Betz found out that we can only harvest, at maximum, 16/27 or 0.593 of the power from the wind. This number is called the Betz coefficient and is the theoretical maximum efficiency that a wind turbine can harvest from the wind.

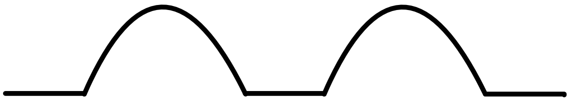
In real world, we have to take into account many other factors that affect the wind power being converted into electrical power by the wind turbines. The efficiency of wind turbines is affected by the blade parameters, generator efficiency and the mechanical losses in the gear box, etc. But there is ample wind to make clean, renewable energy for decades to come.

12. The Differences between a 3-Phase Motor Generator and a DC Motor Generator

The wind turbine used in the following experiments uses a 3-phase motor generator, also called an alternator that is much more efficient at producing electrical power as compared with a conventional DC motor. The following will point out these differences.

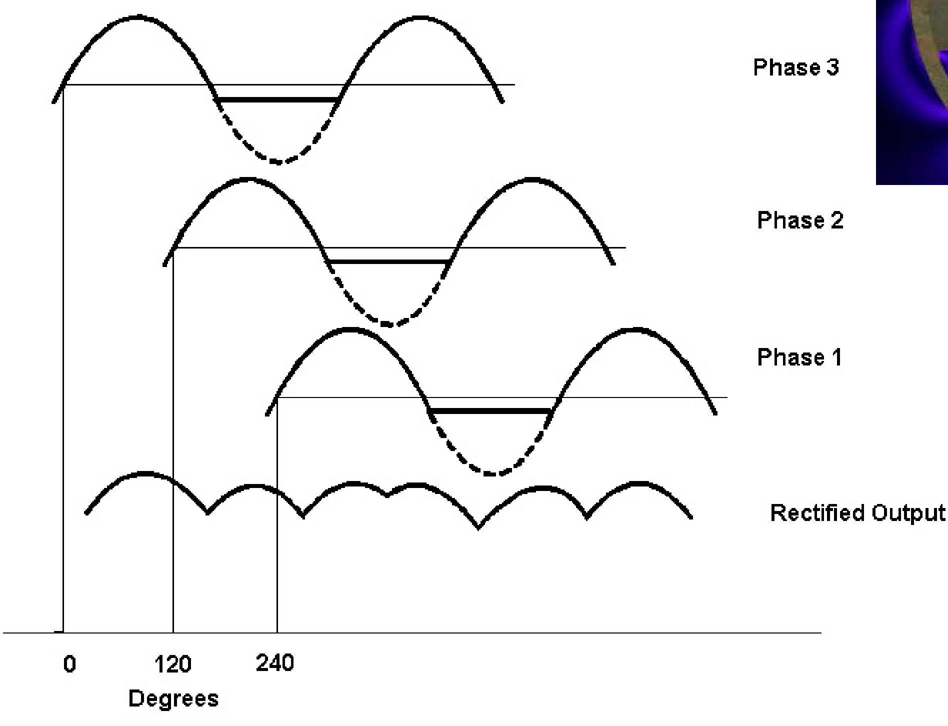
The main difference between a DC motor and a 3-phase motor is the number of coil windings inside the motor. A DC motor has 1 coil winding whereas a 3-phase motor has 3 coil windings.

The rotor of a DC motor consists of a coil wound around it, but not touching it. This coil is connected to the motor terminals with a brush type commutator. The function of the commutator is to switch the polarity of the coil as the rotor rotates every half cycle. Since the brushes are in contact with the rotating rotor, they will eventually wear out.



The rectified output of a DC motor generator outputs 2 half cycle positive waveforms as shown here. Notice that the power drops to zero on every half cycle, which makes DC motors (like the ones Thomas Edison developed) very inefficient and unreliable.

In contrast to a simple DC motor, there are 3 coils wound on the stator of the 3-phase motor and they are spaced 120 degrees apart. There is no commutator in the motor. The three rectified phases and rectified DC output waveforms are shown below:



The important concept to realize is that since the 3 coils are spaced equally apart, each of them reaches its instantaneous peak at different times. When the individual phases are combined by rectifiers, the voltage and, thus the power never goes to zero like in a DC motor.

The 6 half cycles overlap each other at every 1/6 of a rotation (every 60 degrees). The effect of these 6 half cycles per rotation delivers more constant power to the load than that of the 2 half cycles per rotation from a DC motor.

Thus a 3-phase motor generator delivers more output than a DC motor generator. Since a 3-phase motor generator does not have a commutator, its usable life is also much longer than that of a DC motor generator.

The tradeoff is that a 3-phase motor consists of more materials like copper windings. However, not having to worry about replacing commutator brushes makes up for the extra amount of materials. Nicola Tesla, a student of Thomas Edison, developed the 3-phase AC motor and revolutionized electricity as we know it today. All industrial motors are 3-phase.

13. The Experiments

The following experiments demonstrate how various power sources, like a battery, solar panel and wind turbine can electrolyze water using a fuel cell. Multiple loads like resistors, capacitors and a small DC motor are used to provide loads.

The fuel cell acts as a both a power source and a load in the experiments.

The following is a listing of each of the experiments. For best results, the user is encouraged to perform these experiments in the order that they are presented.

Experiment #1 – Purging the Fuel Cell to Optimize Its Performance

Experiment #2 – Electrolysis Using a Battery

Experiment #3 – Understanding Ohm's Law

Experiment #4 – Electrolysis User a Solar Panel

Experiment #5 – Powering a Motor Load

Experiment #6 – Electrolysis Using a Wind Turbine

Experiment #7 – Powering a Capacitor Load

Experiment #8 –Create electricity from ethanol and water

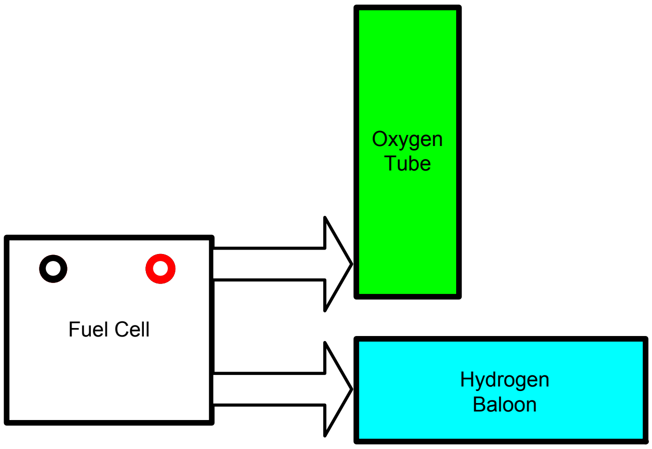
Experiment #9 – Exploring the effects of temperature

Making the Most of Your Experiments

The conditions created in performing the following experiments are considered nearly ideal, since great care was taken to produce valid, observable results. Your results can equal and even exceed those shown if sufficient care and attention are paid to the setup and procedures. In any event, your results will vary from those here due to variations in equipment setup and environmental conditions like sun and wind.

Fuel Cell Assembly

The following experiments assume that the user is familiar with setting up the fuel cell assembly and hydrating the fuel cell.



Near Real Time Measurements

The electrical data displayed as graphic plots and numbers on the computer are said to be in "real time"; however, bear in mind that the Data Acquisition Card requires a finite time to process the electrical data and then transmit it to the computer for display. When the data is finally displayed, it will "not" be "time tagged" as exactly when it was captured. There will be several milliseconds of delay between data capture and display.

The Data Acquisition Card is not an oscilloscope; however, the data presented in near real time will certainly provide a much better observation of the experimental results as compared with a simple meter.

Where the Data is Stored

Plot images and logged data can be found on the computer's hard disk at the following location:

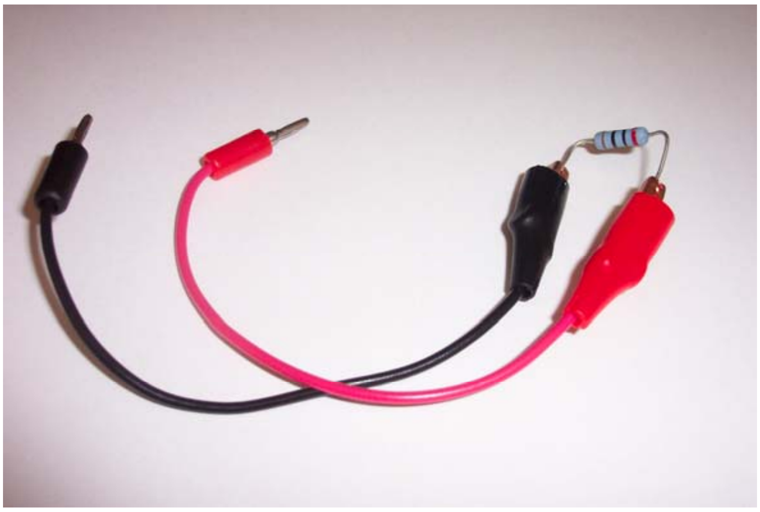
Program Files → Horizon FCA → Data

The Proper Way to Hookup Components

You are provided with leads that have banana plugs on one end and alligator clips on the other end. The banana ends plug into the Data Acquisition Card while the clip leads attach to small components like resistors and capacitors.

Note how the clip ends attach to the component leads with the alligator clips clamping down on the component leads. This makes a good connection and, also, prevents the alligator clips from touching each other.

Make certain that you use good practice in hooking up components this way.



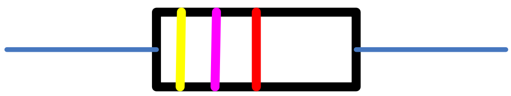
Understanding Resistor Color Codes

The following experiments use three resistors; however, since the value of the resistor is not stamped on the device, another method is used to identify its value. This method is called "color coding" and refers to the round bands that surround the resistor's cylindrical surface. The following is the number and corresponding color convention for identifying color codes.

0 – Black
1 – Brown
2 – Red
3 – Orange
4 - Yellow
5 – Green
6 – Blue
7 – Violet
8 – Gray
9 - White

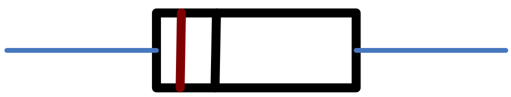
For example, a 4,700-ohm resistor would have the following color codes (stripes) beginning at the far end of the device.

4,700 ohms = Yellow (4) – Violet (7) – Red (2)

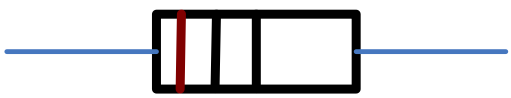


The last stripe (Red = 2) is a multiplier of 10 raised to the power of the stripe value, as in 10^2 which equals 100. Therefore, we get 47 x 100 = 4,700 ohms. Our three resistors have values of 1 ohm, 10 ohms and 20 ohms with the corresponding color codes…

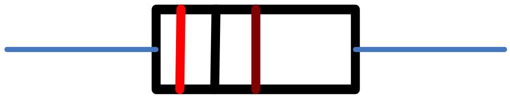
1 ohm =Brown (1) – Black (0) (A multiplier of 10^0 = 0)



10 ohms = Brown (1) – Black (0) – Black (0) (A multiplier of 10^0 = 0)



20 ohms = Red (2) – Black (0) – Black (0) (A multiplier of 10^0 = 0)



There are other bands after these; however, they should be ignored. They are generally there to indicate the accuracy of the resistor (1%, 5%, 10%, etc.). The supplied resistors are within 5% of their rated value.

Experiment #1 – Purging the Fuel Cell to Optimize Its Performance

Purpose:

This experiment is done to ensure that the fuel cell is purged of all gasses except pure hydrogen. By performing this experiment first, it will allow the fuel cell to deliver maximum power for the remaining experiments.

Equipment:

1	Fuel cell assembly
1	Data Acquisition Card
1	USB cable
1	Battery Holder with 2 AA batteries (battery holder has its own leads)
1	Red test lead
1	Black test lead
1	1 ohm resistor
1	PC computer with graphic software

Setup:

Setup the equipment as shown below:

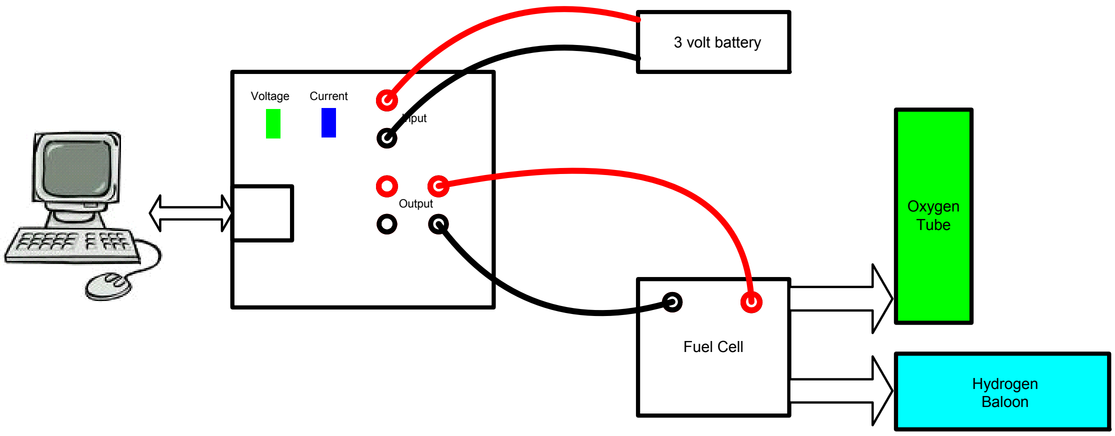


Figure 1.1 – Experiment #1 Setup

1. Make sure that the fuel cell is fully hydrated.

2. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

3. Make sure the graphic software is running on the computer.

4. On the computer display, click on the Connect button at the lower-left on the screen and verify the red plot line is slowly moving across the bottom of the grid display.

5. Adjust the voltage scale to 7.5 volts.

Note: Please read through this procedure first before performing the experiment, as the process goes fast and requires prior knowledge of what is about to happen.

Procedure:

1. Set the battery ON-OFF switch to ON.

2. Verify that the hydrogen balloon is beginning to expand and that a plot similar to the one in Figure 1.2 below is beginning to be displayed.

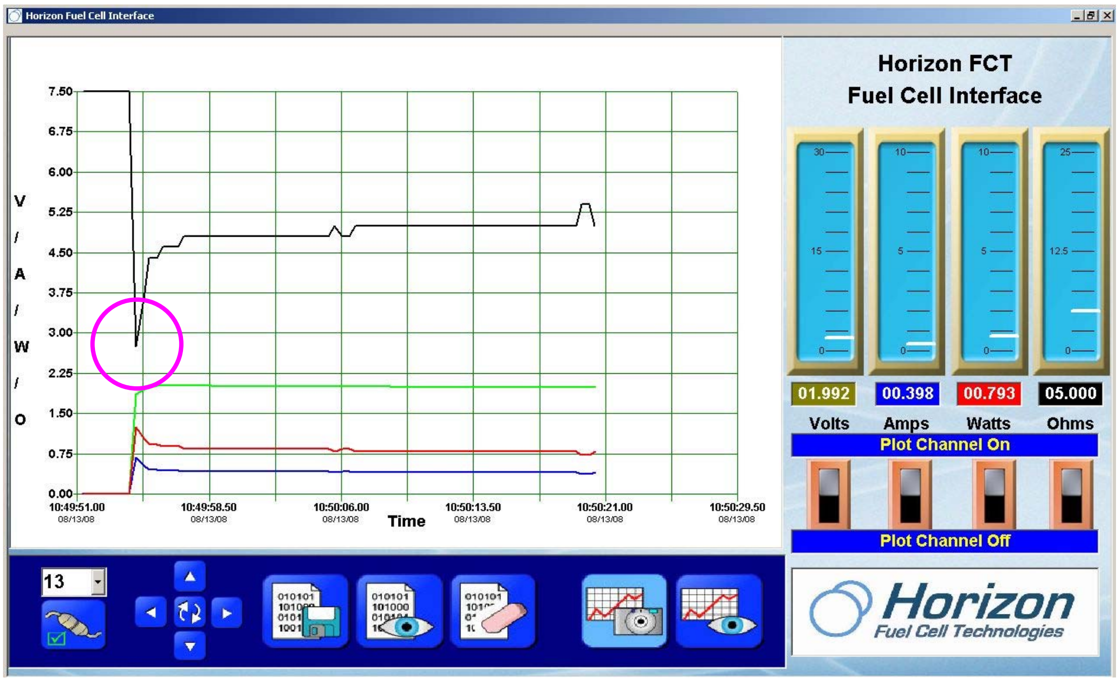


Figure 1.2 – Fuel Cell Electrolysis

3. Set the battery ON-OFF switch to OFF when the hydrogen balloon is filled.

4. Next, remove the battery from the Input terminals on the Data Acquisition Card and move the fuel cell to the Input terminals. Be careful to maintain the correct polarity. Refer to Figure 1.3 below for the new setup.

5. On the computer adjust the voltage scale to 1.88 volts.

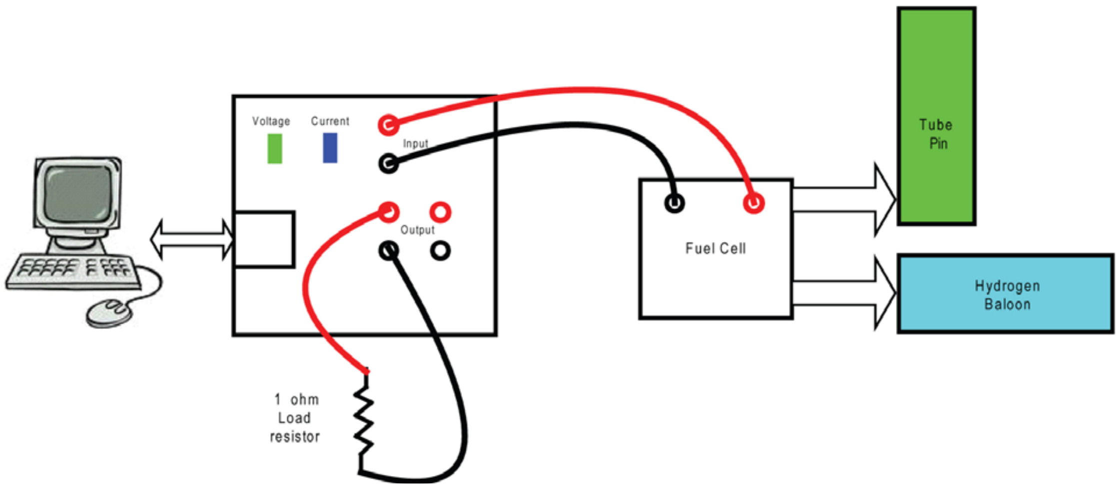


Figure 1.3 – Setup to Purge the Fuel Cell of All Gasses

6. Now add the 1 ohm resistor across the Output terminals and witness a plot similar to the one below in Figure 1.4. Allow the voltage to decrease to zero thus purging all the hydrogen and other gasses from the balloon.

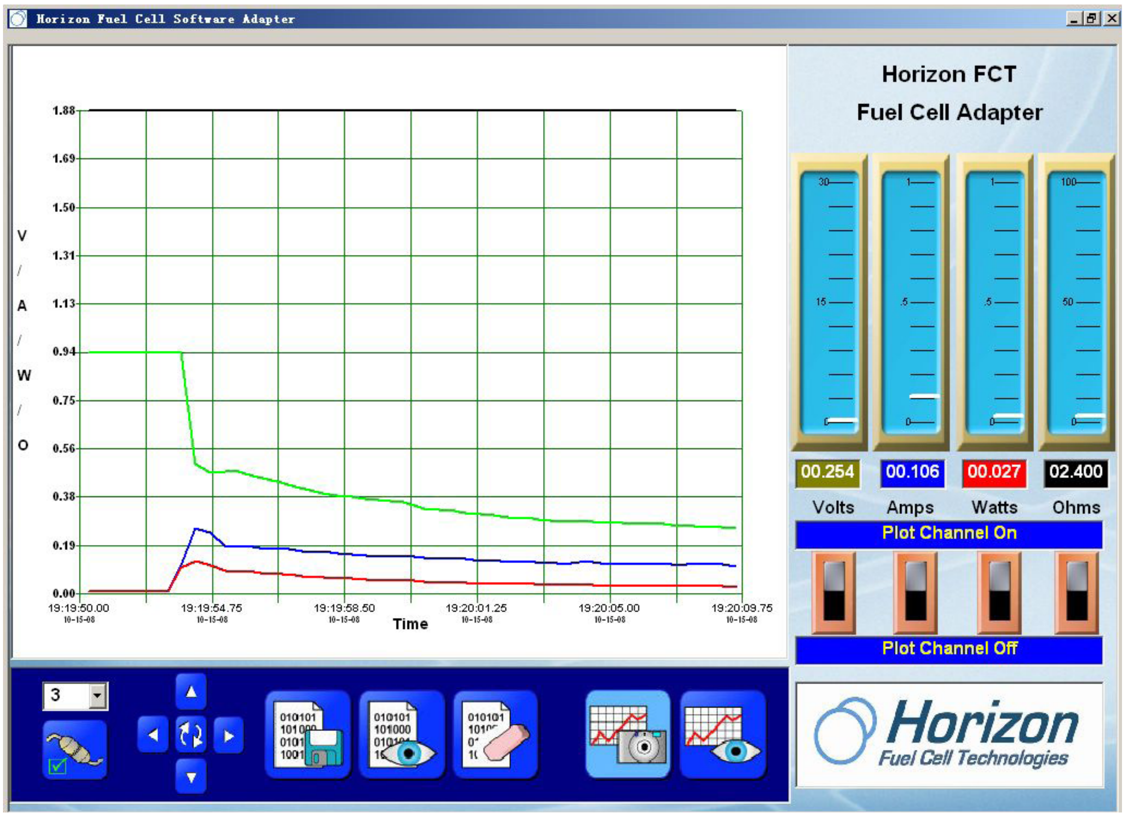


Figure 1.4 – Discharge across a 1 ohm Load

7. Next, disconnect the connecting tube to release a little hydrogen into the air and verify a similar plot as shown below in Figure 1.5. Notice that the resistance reading is 2.4 ohms – not 1 ohm as you might expect. More about this in the Analysis section below.

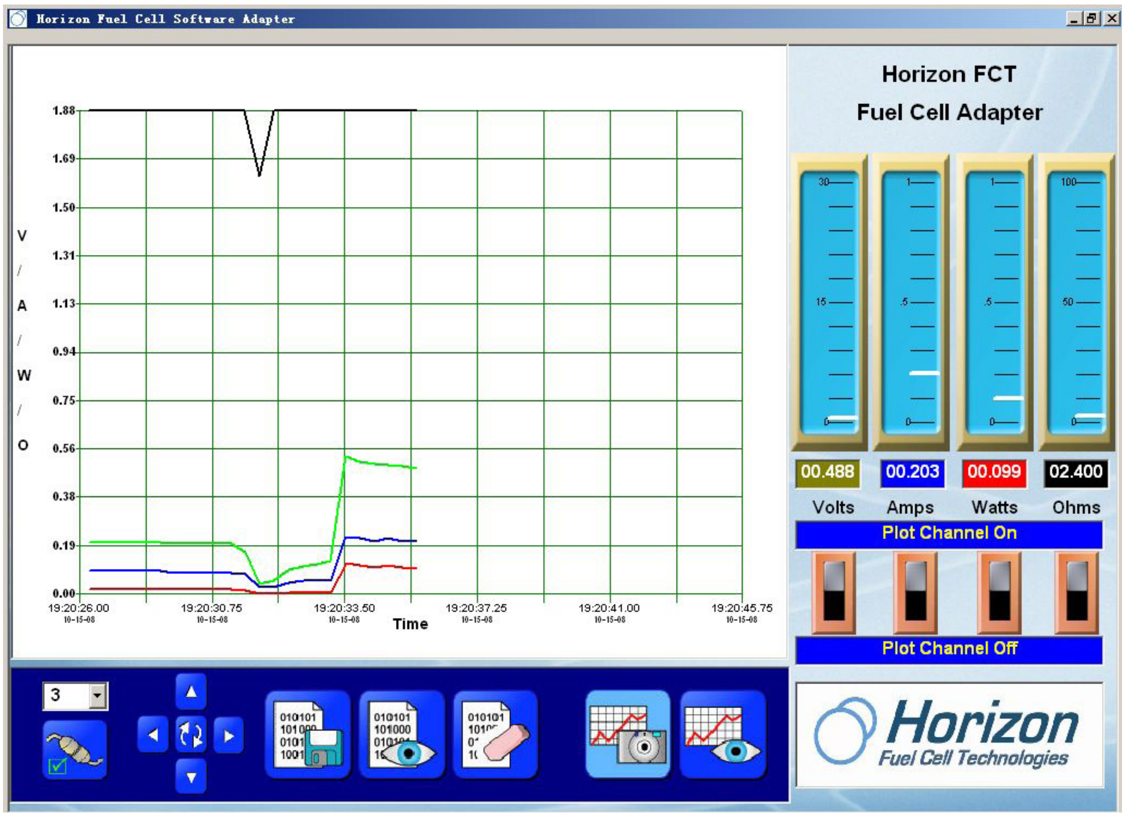


Figure 1.5 – Purging the Hydrogen Tube of Gasses

Analysis:

As the plot in Figures 1.4 and 1.5 illustrates, the fuel cell's voltage, current and power rapidly increase with the fuel cell purging process. When the fuel cell system is first setup, there is a small amount of air in the tubes and the hydrogen container, so the fuel cell consumes impure hydrogen. As a result the fuel cell cannot reach its optimum performance.

However, when the tube is removed, impure gasses along with some water vapor are expelled and, thus, clear the tube for pure hydrogen production the next time the fuel cell is electrolyzed.

This is why the procedure should be repeated at least one more time in order to clear the connecting tubes and balloon of impure gasses.

Now to the 2.4 ohm reading….

The experiment used a 1 ohm resistor to act as a load in order to quickly discharge the hydrogen from the fuel cell's balloon. But the reading indicated 2.4 ohms. So where did the extra resistance come from?

Recall that there is another 1 ohm sense resistor in the circuit that adds to the total resistance. So the 1 ohm load added to the 1 ohm sense resistor is 2 ohms.

But what about the extra 0.4 ohms – where did it come from?

This inaccuracy is caused by the fact that the load resistor is not exactly 1 ohm…it could be a little more or less depending on how it was made at the factory. Plus, the way it is connected to the Data Acquisition Card could add a little more resistance to the circuit. If it was attached loosely (like it was in this experiment) the connection could add some resistance.

You will experience more readings like this in the other experiments, so pleased be prepared for it.

Experiment #2 - Electrolysis Using a Battery

Purpose:

This first experiment in electrolysis uses the 3 volt battery as the power source and the fuel cell as the load in order to quickly split water into hydrogen and oxygen and to store the hydrogen for our first load experiment (Experiment #3).

Equipment:

1	3 volt battery holder and 2 AA batteries
1	Fuel cell assembly
1	Data Acquisition Card
1	USB cable
1	Red test leads
1	Black test leads
1	PC computer with graphic software

Setup:

Setup the equipment as shown below:

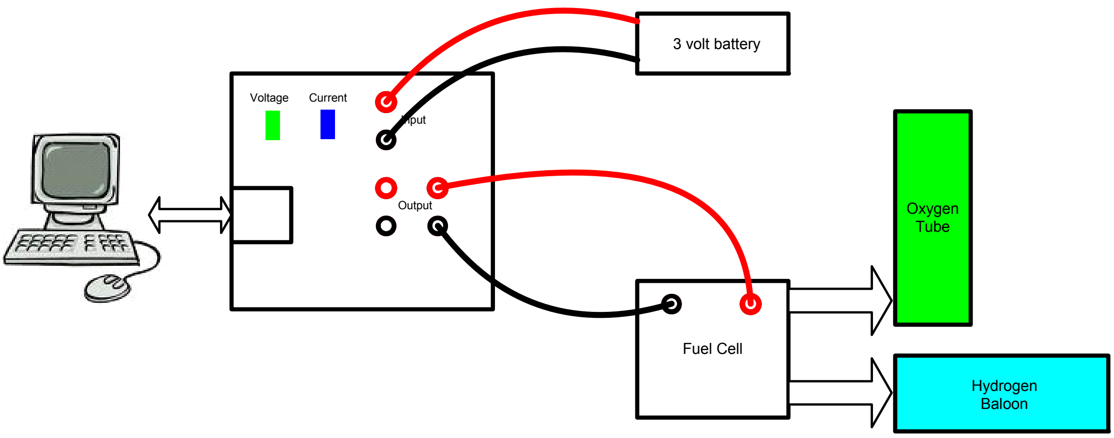


Figure 2.1 – Experiment #1 Setup

1. Set the battery ON-OFF switch to OFF.
2. Make sure that the fuel cell is fully hydrated and that no hydrogen is left in the hydrogen balloon.
3. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.
4. Make sure the graphic software is running on the computer.
5. On the computer display, click on the Connect button at the lower-left on the screen and verify that a red plot line is slowly moving across the bottom of the grid display.
6. Adjust the vertical scale to 7.5 volts.

Procedure:

1. Set the battery ON-OFF switch to ON.
2. Verify that a plot similar to the one below is beginning to develop.
3. Set the battery ON-OFF switch to OFF when the hydrogen balloon is filled.

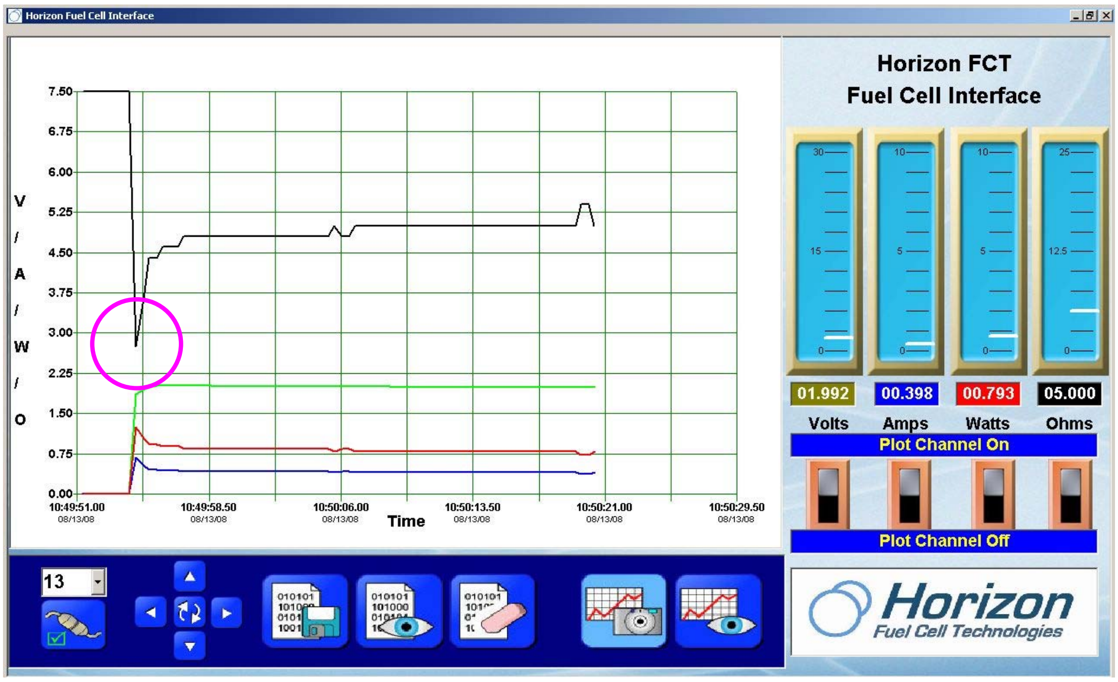


Figure 2.2 – Plot #1

Analysis:

In Figure 2.2 as the electrolysis process begins, the battery voltage (green line) starts at 0 volts then rises quickly to about 2.00 volts. This is due to the fuel cell (the load) presenting a relatively low resistance (heavy load) in the very beginning; in this case about 3 ohms as can be seen at the very left of the plot (black line in circle).

As the electrolysis process continues the fuel cell's load resistance increases (gets lighter) allowing the battery voltage to increase as it does not have to supply as much current into the load.

The current (blue line) and power (red line) also peak at the beginning in response to the heaver load presented by the fuel cell. They then level off as the fuel cell's load stabilizes.

The load stabilizes at 5.00 ohms as the fuel cell continues to create hydrogen and oxygen from water. As can be seen on the meters, the battery is supplying over ¾ amp (0.793 amps) to electrolyze the water. For these experiments, the 3 volt battery supplies the most power for electrolysis.

Experiment #3 – Understanding Ohm's Law

Purpose:

This experiment demonstrates one of the basic laws of electronics - the relationship of voltage, current and resistance called Ohm's Law. It uses the hydrogen that was created in Experiment #2, so if you are not following Experiment #3 directly from Experiment #2, please repeat Experiment #2 to create the hydrogen for this experiment.

Equipment:

1	PC computer with graphic software
1	Data Acquisition Card
1	Red test lead with alligator clip
1	Black test lead with alligator clip
2	10 ohm resistors

Setup:

Setup the equipment as shown below:

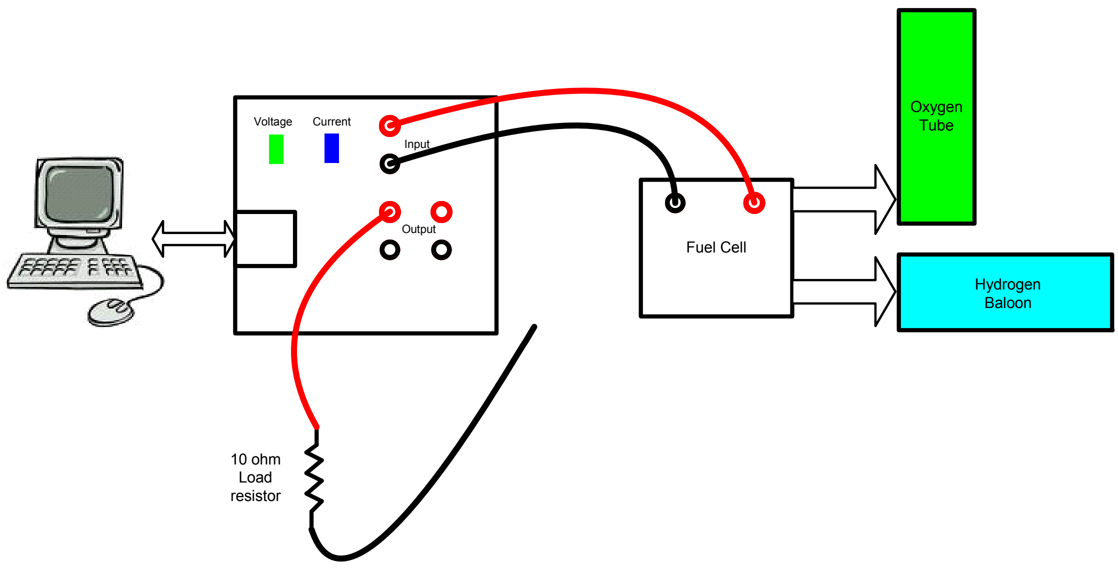


Figure 3.1 – Initial Test Setup

1. Make sure that the fuel cell is fully hydrated with hydrogen stored from the previous experiment in the hydrogen balloon.

2. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

3. Make sure the graphic software is running on the computer.

4. On the computer display, click on the Connect button at the lower-left on the screen and verify the red plot line is slowly moving across the bottom of the grid display.

5. Adjust the voltage scale to 1.88 volts.

Note: Please read through this procedure first before performing the experiment, as the process go fast and requires prior knowledge of what is about to happen.

Procedure:

1. Attach the black lead of the 10 ohm resistor to the black OUTPUT terminal and verify a similar plot as shown below. Notice that the resistance reading is at 10 ohms on the meter below.

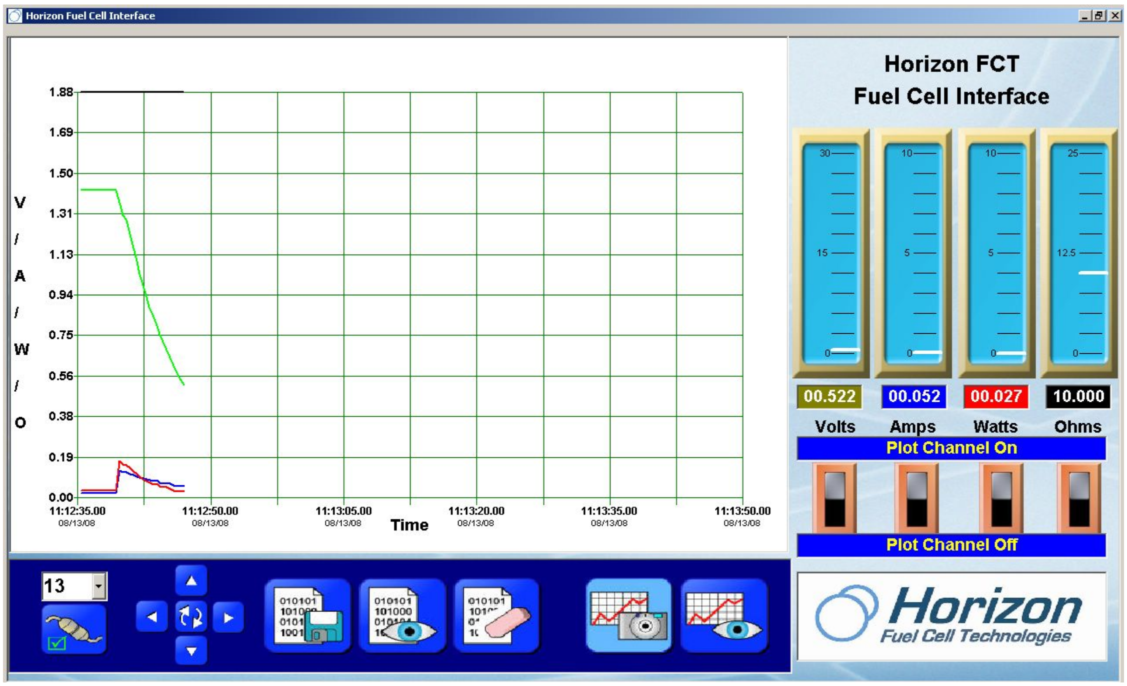


Figure 3.2 – 10 ohm Resistor Discharge Curve

2. Next, attach a second 10 ohm resistor across the other set of OUTPUT terminals (red and black) and verify a similar plot as shown below. Notice that the resistance reading is 5.7 ohms. This is consistent with the two 10 ohm resistors in parallel along with the 1 ohm sense resistor in series with them.

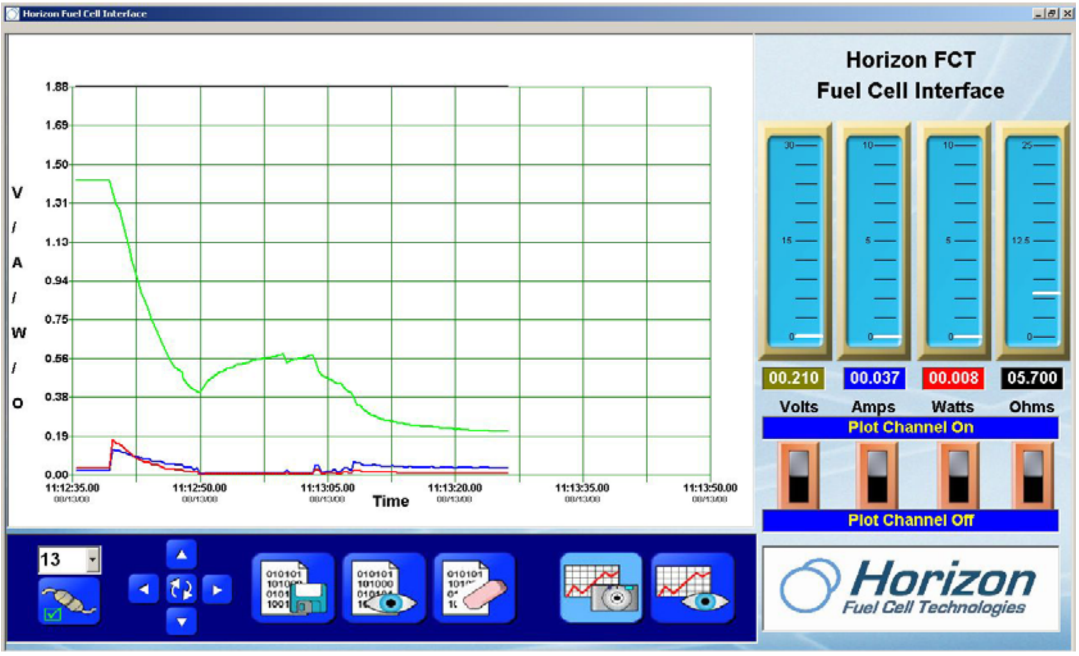


Figure 3.3 – 5 ohm Resistor Discharge Curve

Analysis:

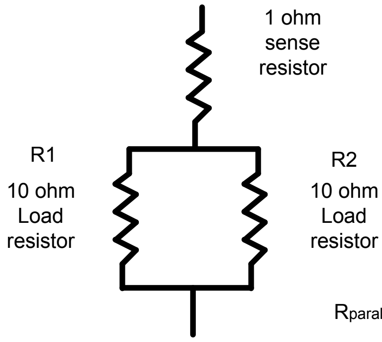
As the two plots show, the fuel cell's voltage rapidly decreases with one 10 ohm resistor applied and decreases even more rapidly as the second 10 ohm resistor is attached. Also, the formula for Ohm's Law is obeyed, which is:

$E = I*R$

Where E = Voltage in Volts
I = Current in Amps
R = Resistance in Ohms

With a single 10 ohm resistor applied as a load, the fuel cell attempts to supply current into it; however, the supply of hydrogen that creates the voltage and current quickly begins to dissipate under such a relatively heavy load. As such, the voltage (green line) and current (blue line) decrease as the hydrogen is consumed.

Applying a second 10 ohm resistor in parallel with the first 10 ohm resistor creates even a heaver load of 5 ohms as shown by the formula below:



= 6 ohms total

$$R_{parallel} = \frac{R1 \times R2}{R1 + R2} = 5 \text{ ohms}$$

Because the 1 ohm sense resistor on the circuit board is in series with the parallel resistors, the resultant resistance should be 6.00 ohms. However, due to inaccuracies in the value of the resistors (the actual resistance of each resistor in this particular experiment is less than 10 ohms – your results may vary), the measured resistance on the computer display is 5.7 ohms.

This experiment points out how resistors in parallel generate more of an electrical load to the power source as compared with just a single resistor of the same value.

You are encouraged to repeat this experiment and, this time, look more closely at the current and power plots rather than the voltage plot. In order to this reduce the vertical setting so that the current and power plots are better visible.

Experiment #4 – Electrolysis with a Solar Panel

Purpose:

This experiment uses the solar panel to electrolyze water into hydrogen and oxygen using the fuel cell. Plus, it demonstrates the minimum voltage required to achieve electrolyzation.

Equipment:

1	Fuel cell assembly
1	Solar panel
1	Data Acquisition Card
1	USB cable
2	Red test leads
2	Black test leads
1	PC computer with graphic software

Setup:

Setup the equipment as shown below:

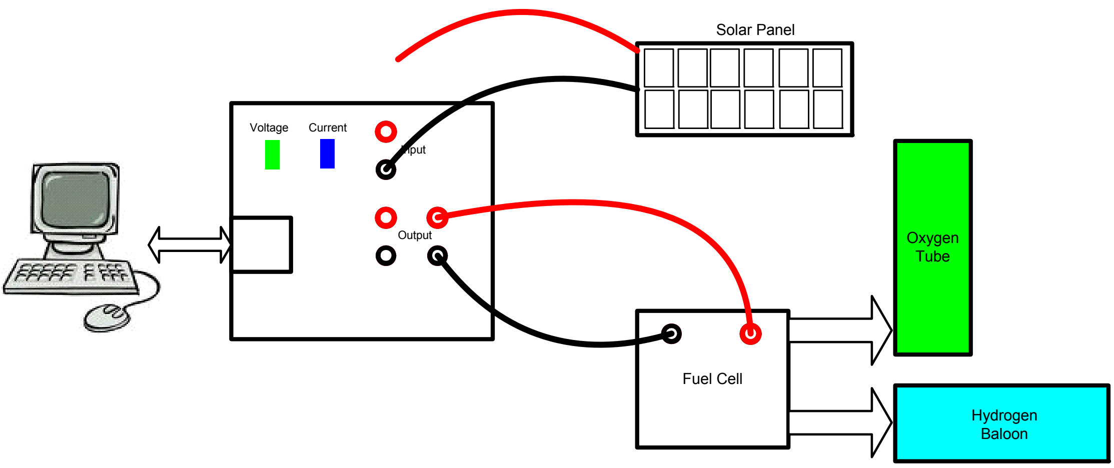


Figure 4.1 – Experiment #4 Setup

1. Remove the red wire lead from the solar panel to the Data Acquisition card for now.
2. Make sure that the fuel cell is fully hydrated and that no hydrogen is left in the hydrogen balloon.
3. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.
4. Make sure the graphic software is running on the computer.

5. On the computer display, click on the Connect button at the lower-left on the screen and verify that a red plot line is slowly moving across the bottom of the grid display.

6. Adjust the voltage (vertical) scale to 1.88 volts.

Procedure:

Note: Please read through this procedure first before performing the experiment, as the elements of the process go fast and require prior knowledge of what is about to happen.

1. Place the solar panel face down then connect the red wire lead to the red input connector.

2. Slowly rotate the solar panel towards the light until the voltage goes above 1.5 volts (green plot line) and the current (blue line) and power (red line) "jump" from nearly 0 to some positive value as shown in the plot below.

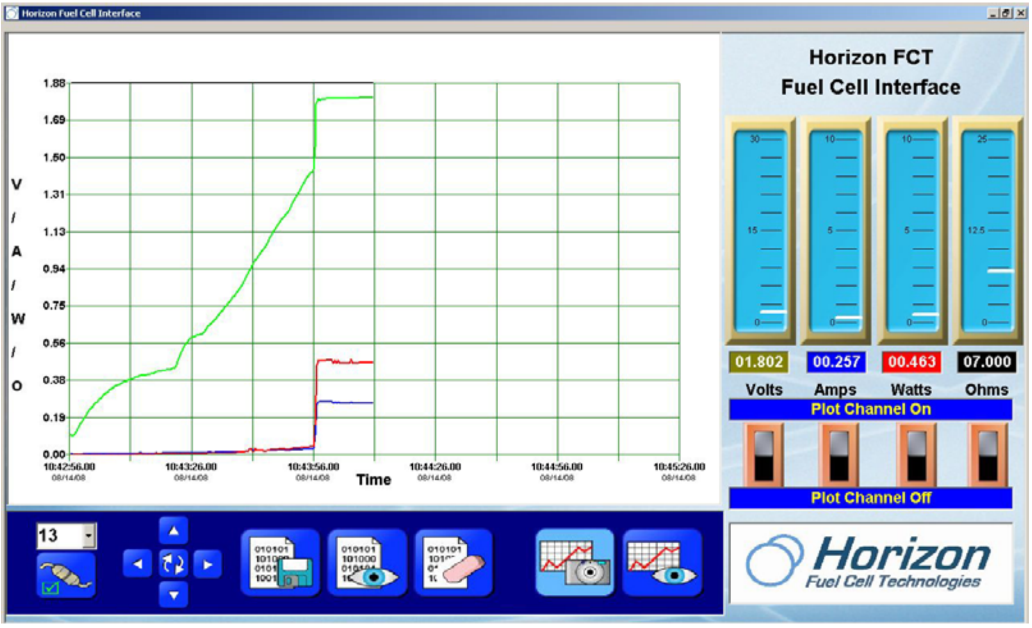


Figure 4.2 – Determining the Electrolyzing Voltage of Water

3. Next, rotate the solar panel facing down again until the voltage drops below 1.5 volts and observe that the current and power go back to zero as shown in the plot below.

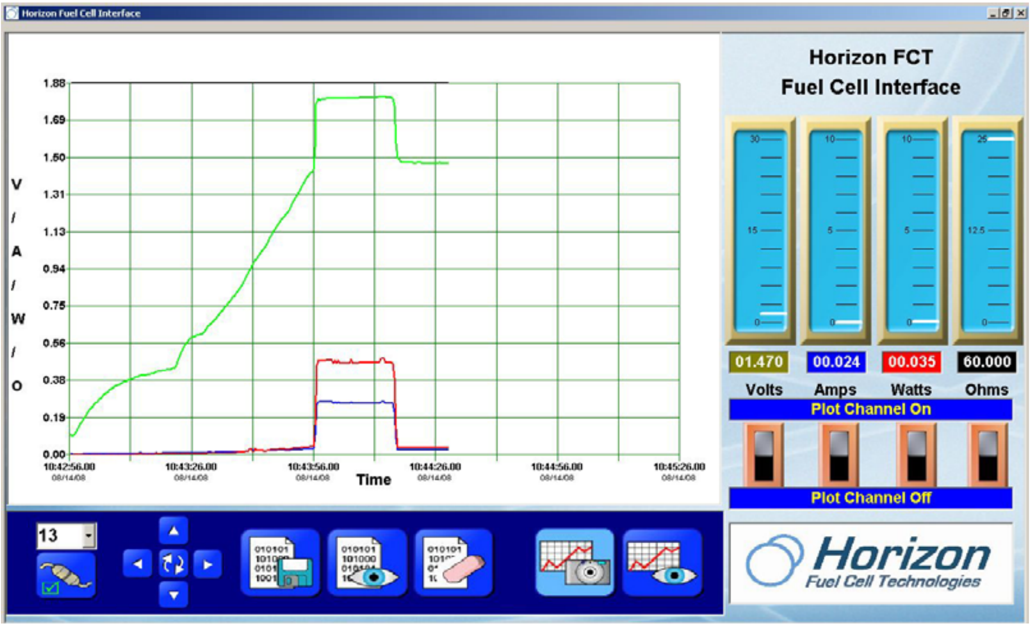


Figure 4.3 – Halting the Electrolysis Process

4. Finally, place the solar panel directly into the light source (sun is best) and observe that the voltage, current and power levels increase correspondingly. The solar panel will now electrolyze the water completely and fill the hydrogen balloon for the next experiment. Remove the solar panel from the circuit when the hydrogen balloon is filled.

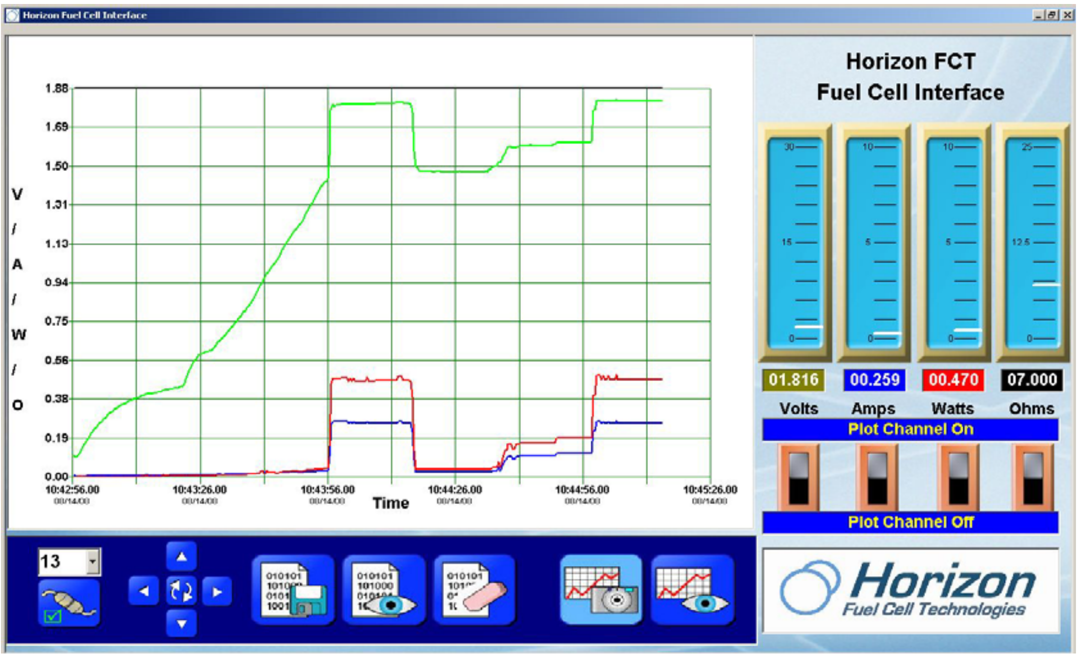


Figure 4.4 – Continuing To Electrolyze Water

Analysis:

Before going on to explain the electrolysis process, note that the solar panel is delivering nearly half a watt (0.470) into the fuel cell load. This is less than the nearly three-quarters of a watt delivered with the battery in Experiment #1. The reason for this decrease is due to the solar panel's inability to produce the same amount of power as compared with the battery. If sun was not used in this experiment to energize the solar panel, the actual power would be even less. If a larger solar panel were used, the power would certainly be increased.

In terms of the electrolysis process, the minimum voltage at which water can be split into hydrogen and oxygen is called the "decomposition voltage".

Scientists have determined that the theoretical decomposition voltage for water is 1.23 volts, which is lower than what this experiment shows. The difference between the theoretical decomposition voltage and the measured voltage is called "overpotential". Overpotential is a function of the fuel cell's inability to expel the hydrogen and oxygen gasses that form on the metal electrodes below a certain voltage; in this case, about 1.5 volts as compared with 1.23 volts. Many other factors are involved in this difference of decomposition voltage; however, the reasons for these differences are beyond the scope of this experiment.

What this experiment demonstrates is the relatively small amount of voltage necessary to split water into its component gasses of hydrogen and oxygen. This fact should be remembered when dealing with fuel cells in future experiments.

Experiment #5 – Powering a Motor Load

Purpose:

This experiment follows Experiment #4 in order to use the stored hydrogen that was generated by electrolysis. A motor-propeller is used to demonstrate the fuel cell's ability to power such a device, albeit for a short amount of time. The results of the experiment explain the reasons why the motor used in the experiment requires such a relatively large amount of power to operate.

Equipment:

1	Fuel cell assembly
1	Motor-propeller
1	Data Acquisition Card
1	USB cable
2	Red test leads
2	Black test leads
1	PC computer with graphic software

Setup:

Setup the equipment as shown below:

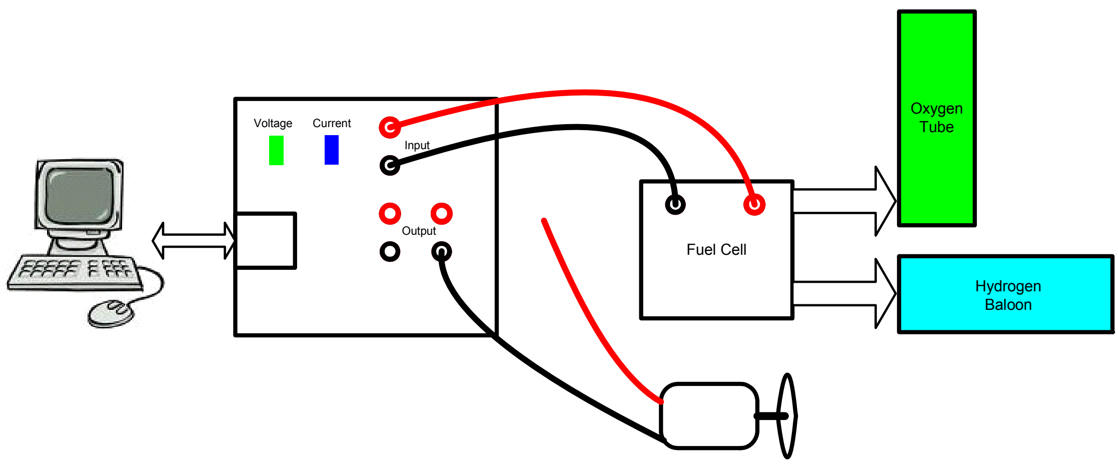


Figure 5.1 – Motor Experiment Setup

1. Remove the red wire lead from the motor to the circuit card for now.

2. Make sure that the fuel cell is fully hydrated and the balloon filled with hydrogen.

3. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

4. Make sure the graphic software is running on the computer.

5. On the computer display, click on the Connect button at the lower-left on the screen and verify that a red plot line is slowly moving across the bottom of the grid display.

6. Adjust the voltage (vertical) scale to 1.88 volts.

7. Adjust the time (horizontal) scale to about 30 or 40 seconds.

Procedure:

Note: Please read through this procedure first before performing the experiment, as the elements of the process go fast and require prior knowledge of what is about to happen.

1. Click on the plot restart button – the one with the double arrows in the center of the up, down, left and right arrows and verify a plot similar to the one shown below. This shows the fuel cell's voltage being plotted without the motor attached.

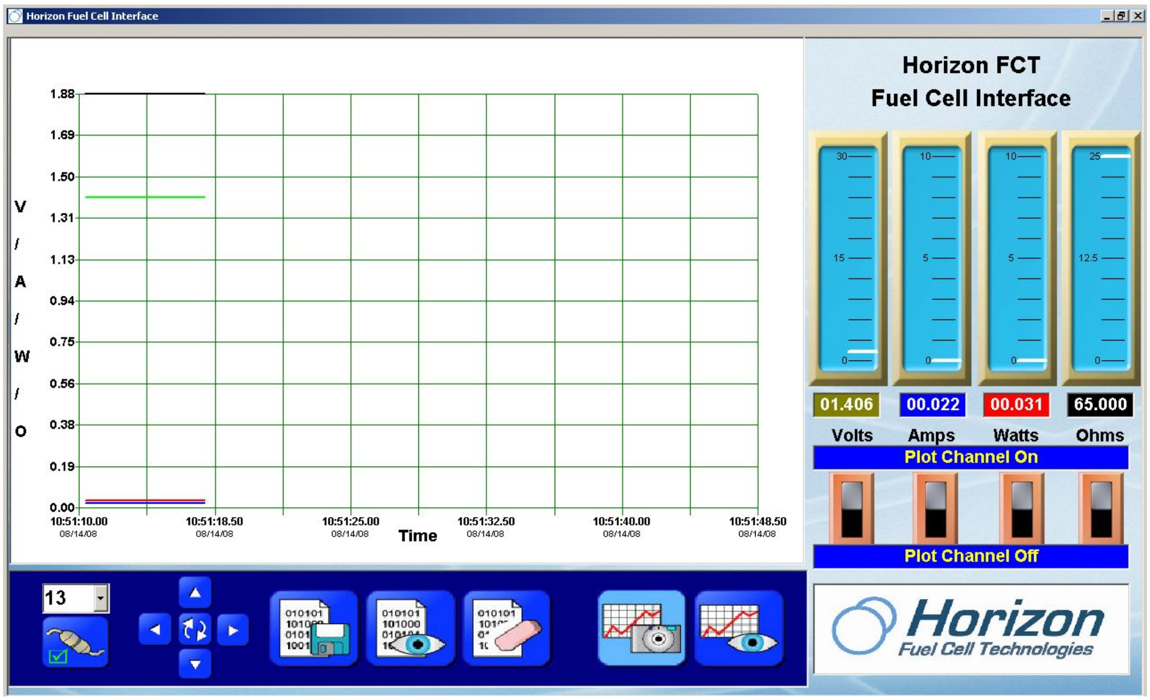


Figure 5.2 – Plot with no Motor Load

2. Next, attach the red wire lead from the motor and verify a plot similar to the one below. Notice the motor spins for only a few seconds and the hydrogen quickly flows out of the hydrogen balloon.

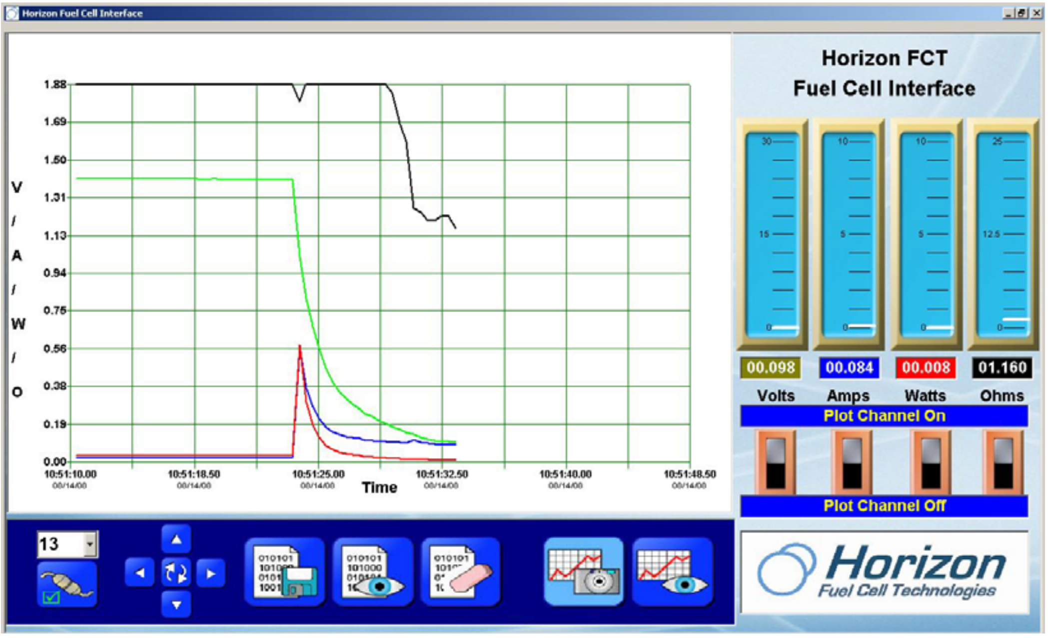


Figure 5.3 – Plot with Motor Load

3. Allow the motor to spin until the hydrogen is completely consumed. The plot should look like the one pictured below.

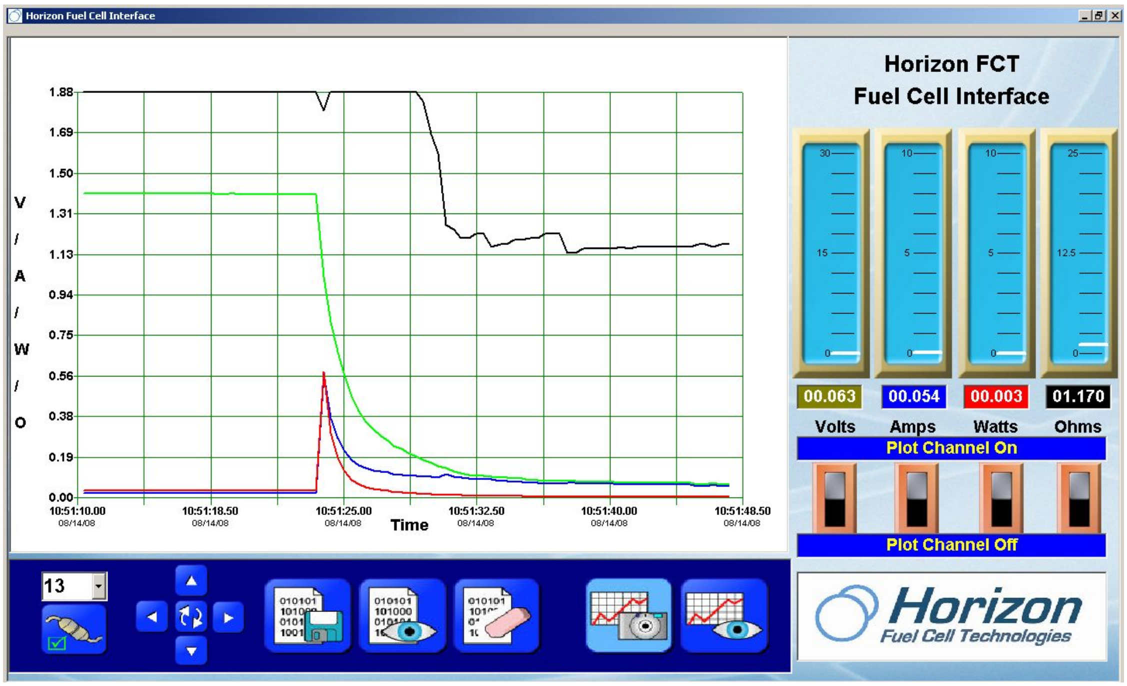


Figure 5.4 – Plot of Motor Load Dissipating Hydrogen

Analysis:

The motor presents a relatively heavy load to the fuel cell. This can be seen by observing the resistance readings below the meter of between 1.60 and 1.70 ohms. This is over 6 times as much as the 10 ohm load in Experiment #1, which accounts for the rapid decrease in voltage and, correspondingly, current and power.

Notice that at the very beginning of the plot, when the motor was first connected to the circuit board, that the voltage, current and power readings were at their maximum. This is indicated by the spike in the red and blue lines. However, as the voltage decreased, so did the power. This can be confirmed using the formula below for computing power – when voltage or current decrease, so does power:

$$P = E*I$$

Where P = Power in watts
E = Voltage in volts
I = Current in amps

As an exercise, plug in the observable units of voltage and current on the plots to confirm the formula's validity. For example,

$P = E*I$
$P = 0.063 * 0.054$ (taken from the meter readings on the last plot)
$P = 0.003$ watts

If data was being logged, the intermediate voltage, current, resistance and power readings could also be examined. As such, you are encouraged to re-perform this experiment with the data logging feature enabled.

Experiment #6 – Electrolysis Using a Wind Turbine

Purpose:

This experiment uses a unique wind turbine called the **WindCharge** tm as the power source to electrolyze water. This wind turbine is unique in that it is really a miniature model of the type of wind turbines that dot our landscape making clean, non-polluting energy. It uses the same 3-phase alternator technology used in commercial turbines. While not as powerful as a battery or solar panel as a power source, the wind turbine demonstrates yet another means for generating non-polluting power.

Equipment:

1	Fuel cell assembly
1	WindCharge tm Wind turbine
1	Table fan
1	Data Acquisition Card
1	USB cable
2	Red test lead
2	Black test lead
1	PC computer with graphic software

Setup:

Setup the equipment as shown below:

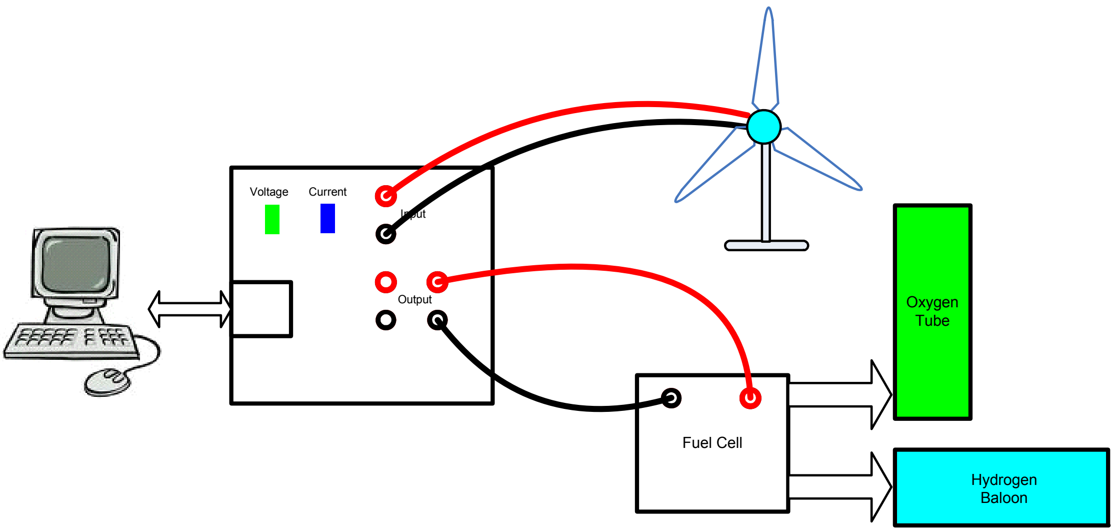


Figure 6.1 – Wind Turbine Experiment Setup

1. Make sure that the fuel cell is fully hydrated.

2. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

3. Make sure the graphic software is running on the computer.

4. On the computer display, click on the Connect button at the lower-left on the screen and verify that a red plot line is slowly moving across the bottom of the grid display.

5. Adjust the voltage (vertical) scale to 1.88 volts.

Procedure:

Note: Please read through this procedure first before performing the experiment, as the elements of the process go fast and require prior knowledge of what is about to happen.

1. Place the table fan directly in front of the wind turbine then switch it on to its highest (fastest) setting. A plot similar to the one below should begin to appear. Notice how the voltage quickly increases (but not as quickly as the battery or solar panel – more about this later).

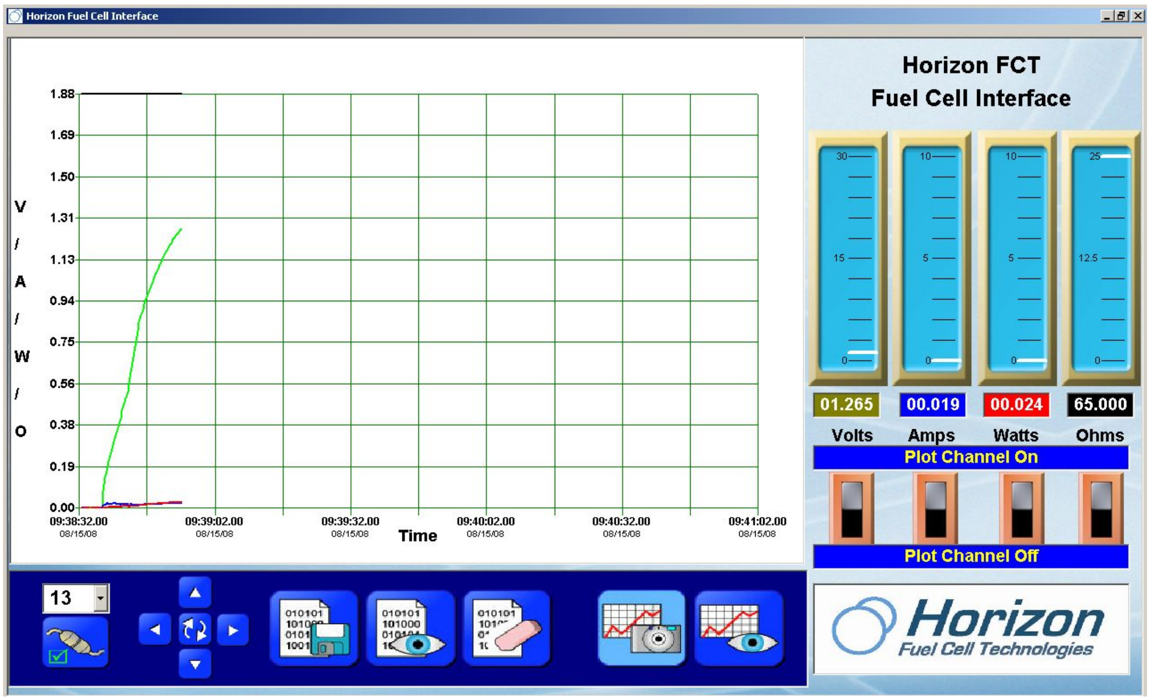


Figure 6.2 – Start of wind turbine electrolysis of fuel cell

2. Very soon the voltage will stabilize (level off) as shown below:

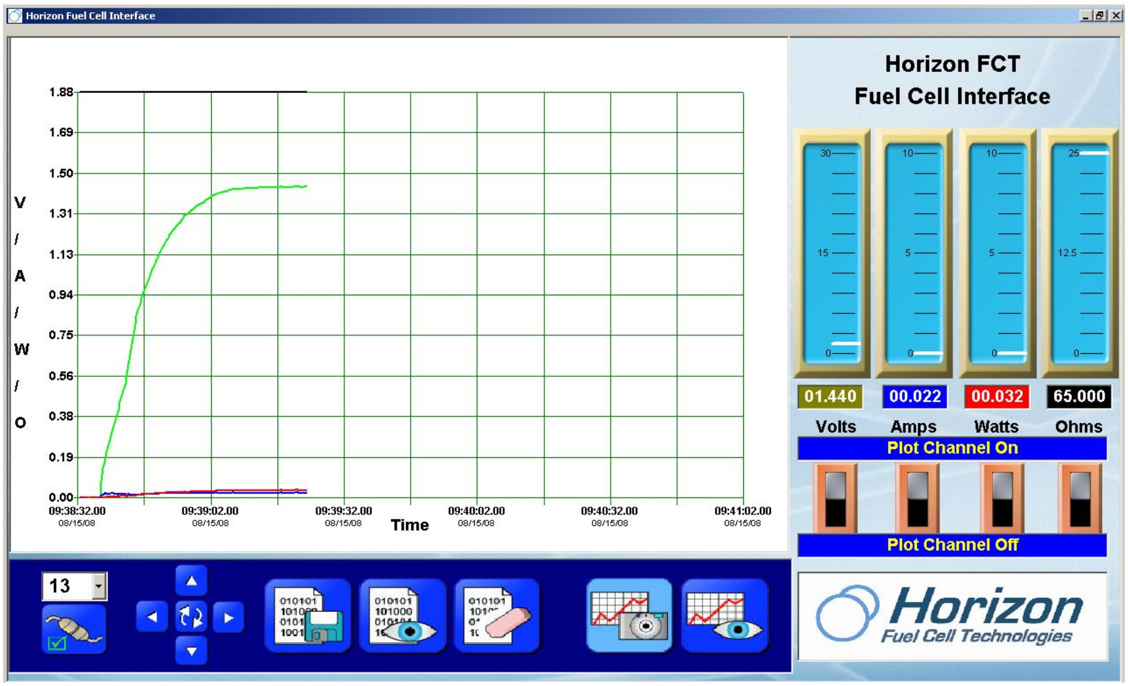


Figure 6.3 – Electrolysis voltage leveling off

3. Next, reduce the vertical voltage scale to 0.23.

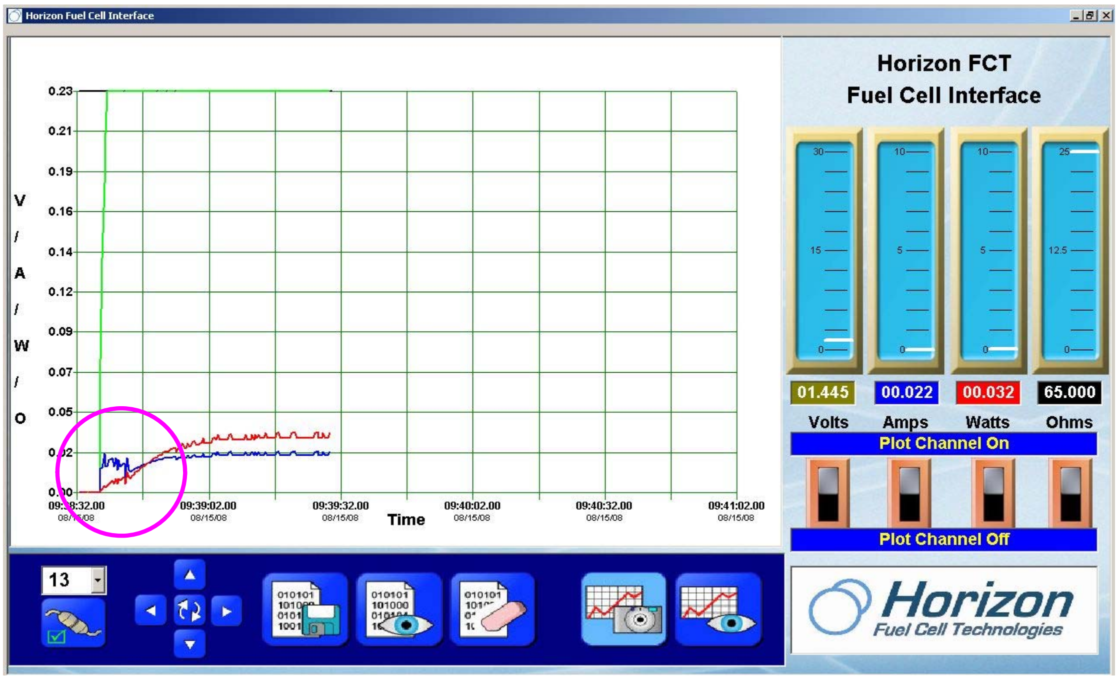


Figure 6.4 – Examining current and power in more detail

4. In the expanded view above, notice the change in current and power as the voltage climbs to its stabilized level of 1.440 volts. In the very beginning of the plot (in the circle) the current plot line (blue line) indicates an immediate rush of current from the wind turbine into the fuel cell; however, since the voltage is so low, almost no power (red line) is generated. Remember the formula for power is voltage (E) times current (I) …

$$P = E*I$$

   …so if E (voltage) is low or zero, very little or no power (P) will be generated.

   As the plot continues notice that the current, voltage and power all increase before leveling off. In this screen capture the voltage is 1.445 volts, the current is 0.022 amps (22 milliamps) and the power is 0.032 watts (32 milliwatts).

5. Now, disconnect the wind turbine red lead from the circuit board and notice that the voltage dips slightly (circle). The wind turbine is completely out of the circuit at this point, so the voltage is coming from the fuel cell load.

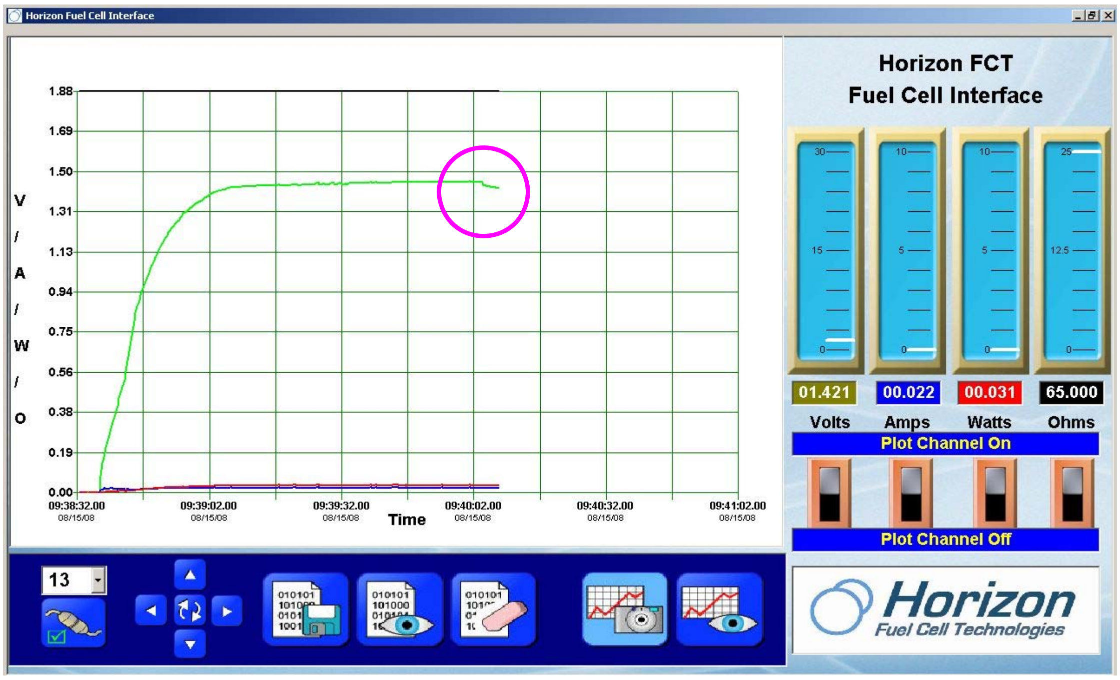


Figure 6.5 – Fuel cell voltage output

Analysis:

Although the WindCharge tm wind turbine can deliver the minimum amount of voltage to decompose water, it is very limited in the amount of current that it can produce to do the task quickly. As a result, the electrolysis process takes longer. However after a few minutes of electrolysis the wind turbine does generate a small amount of hydrogen, which is evident in the voltage displayed even after the wind turbine is disconnected from the circuit.

You are encouraged to repeat this experiment and, this time, allow the table fan to blow air for 15 minutes, or more. This should be enough time to fully inflate the hydrogen balloon. If this is done the 10 ohm load should not deplete the hydrogen so quickly allowing the voltage and current to remain at higher levels for a longer time, similar to the experiments with the battery and solar panel.

REMEMBER – the wind turbine generates its power based solely on the amount of air that reaches its blades. The faster the airflow, the faster the blades turn with more power generated. Therefore, use a larger, more powerful table fan to produce more power out of the wind turbine

More about Wind Turbines:

The important parameters surrounding a wind turbine's power generation ability are …

- wind speed
- wind direction
- blade size
- blade shape
- blade angle
- blade pitch and
- generator efficiency in relation to shaft rotation speed

The WindCharge tm wind turbine is designed to work with these parameters so that you, the experimenter, can see the effects when these parameters are changed. Also, the WindCharge tm wind turbine can align itself to the direction of the wind. This feature cannot be found in most small turbines for educational purposes.

Initially, the output voltage rises more slowly as compared with a solar panel, which is a solid state device whose voltage and current outputs are nearly instantaneous. A fuel cell is a heavy electrical load that makes the wind turbine work harder to power it. As the fuel cell starts to electrolyze water, the current drawn by the fuel cell is reduced. The output voltage will then stabilize at a voltage of about 1.5 Volts which is higher than the electrolyzing voltage of a fuel cell.

In the first part of the experiment, you chose the best location for the wind turbine with the maximum wind energy source. The water can then be electrolyzed at the maximum speed. However, keep in mind that the speed of electrolysis depends largely on the output power of the fan – the larger the fan, the more power that gets produced.

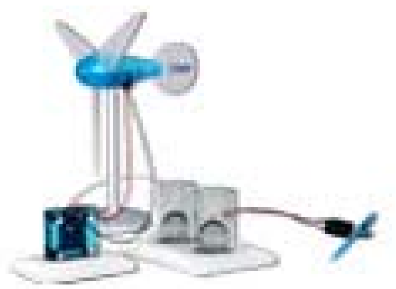
Another way to increase the output of the WindCharge tm wind turbine is to experiment with different blade designs. You are encouraged to create your own blades using cardboard or flexible plastic materials and then repeat this experiment. Polypropylene, balsa wood, post card or any sheet media can be used. See for yourself which material is more efficient. You may find that your efforts will produce more hydrogen in a faster time. Have fun!!

Experiment #7 – Powering a Capacitor Load

Purpose:

This last experiment uses the WindCharge tm wind turbine to show how another component, called a capacitor, can both smooth out the voltage produced by the wind turbine.

Equipment:



1	WindCharge tm Wind turbine
1	Table fan
1	Capacitor
1	Data Acquisition Card
1	USB cable
2	Red test leads
2	Black test leads
1	PC computer with graphic software

Setup:

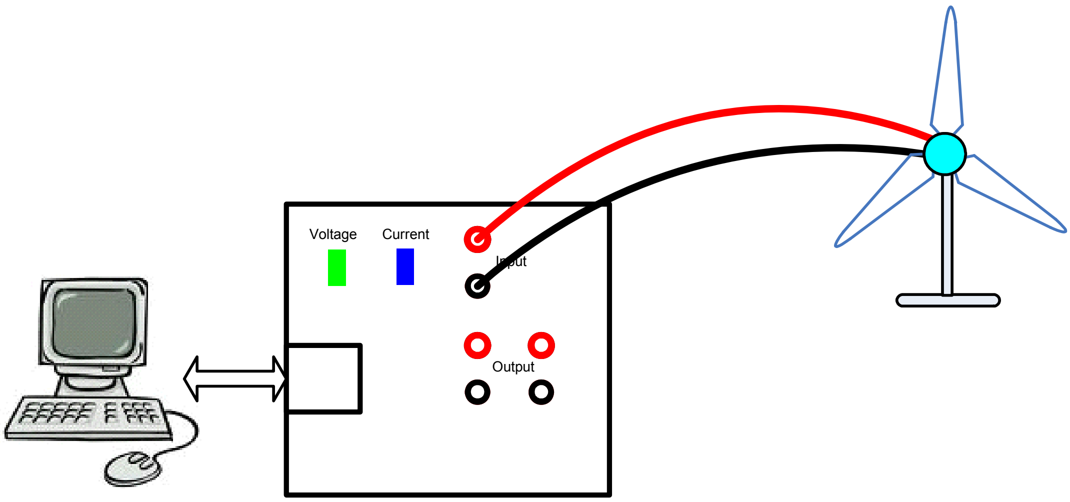


Figure 7.1 – Experiment #7 Setup

1. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

2. Make sure the graphic software is running on the computer.

3. On the computer display, click on the Connect button at the lower-left on the screen and verify that a red plot line is slowly moving across the bottom of the grid display.

4. Adjust the voltage (vertical) scale to 1.88 volts.

Note: Please read through this procedure first before performing the experiment, as the elements of the process go fast and require prior knowledge of what is about to happen.

Procedure:

1. Place the table fan directly in front of the wind turbine then switch it on to its highest (fastest) setting. A plot similar to the one below should begin to appear. Notice that the voltage (green line) increases to a maximum level almost instantly. The maximum voltage level may vary given your fan setup and speed of air movement. Also notice the ripples as the plot proceeds. This is due to the wind turbine's 3-phase output.

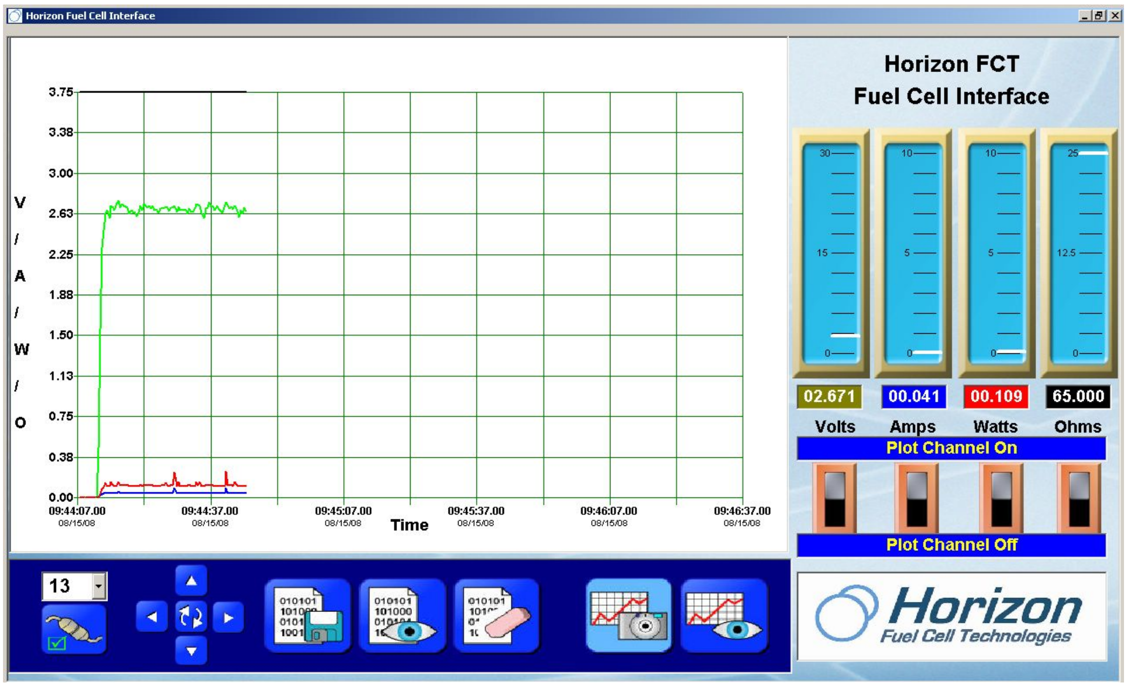


Figure 7.2 – Wind turbine's DC voltage with ripples

If the wind turbine output were to be measured with an oscilloscope (a professional graphic display device), the actual voltage waveform would look like that below:

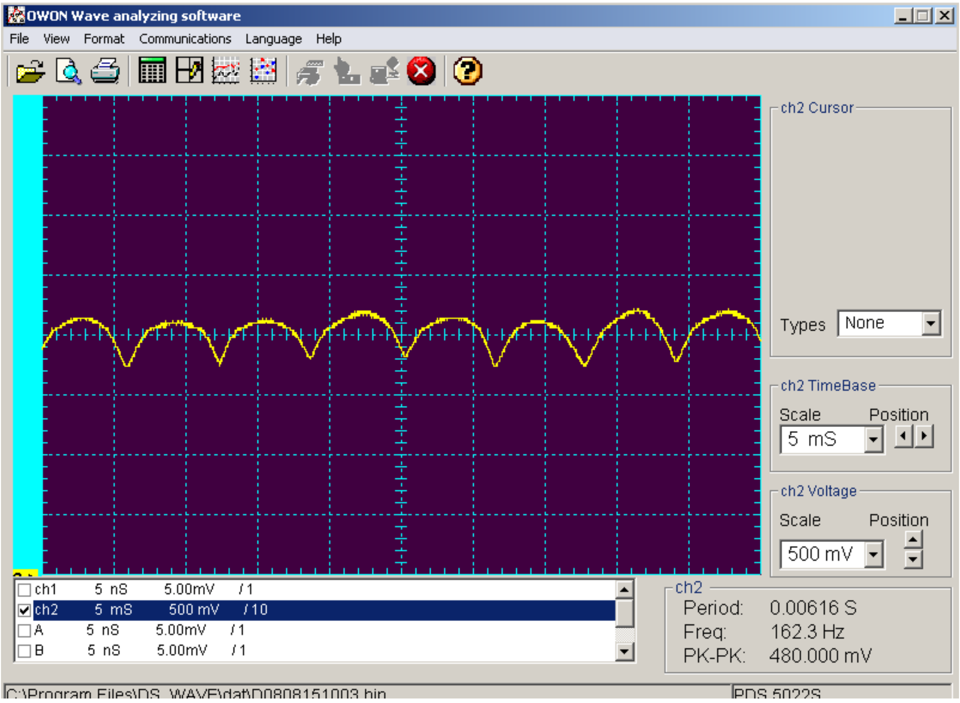


Figure 7.3 – Oscilloscope plot of wind turbine DC voltage without a capacitor

2. In order to smooth out these voltage ripples, a capacitor will be added to the circuit as in the setup below. **Make sure to hookup the capacitor with the positive (+) lead going to the red OUTPUT terminal and the negative (-) lead going to the black OUTPUT terminal.**

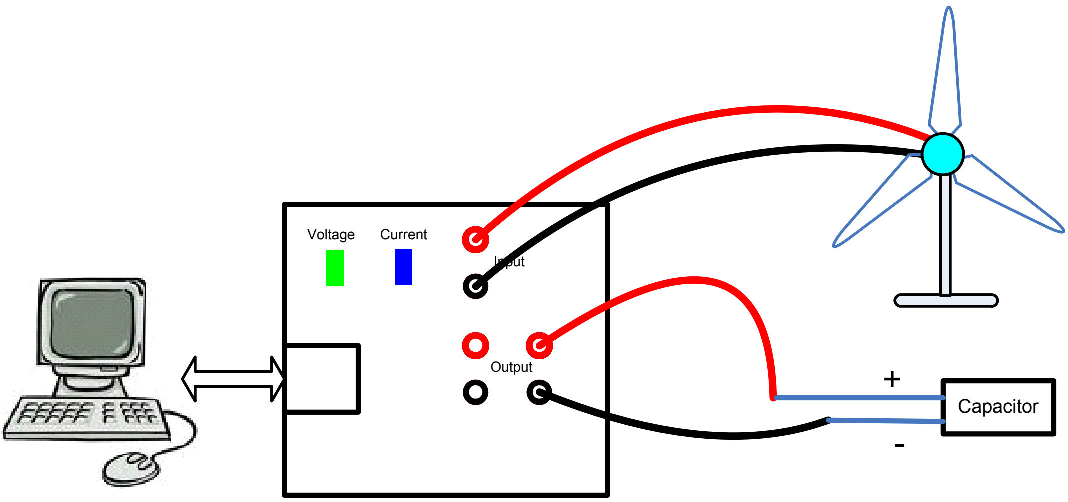


Figure 7.4 – Experiment #7 setup with capacitor load

3. With the capacitor attached to the OUTPUT terminals, continue to keep the wind turbine blades spinning and the following plot should be displayed. Notice that the voltage has increased and that it is somewhat smoother. Depending on the value of your capacitor, your results may vary. The basic result is that the waveform is much smoother with the capacitor in the circuit.

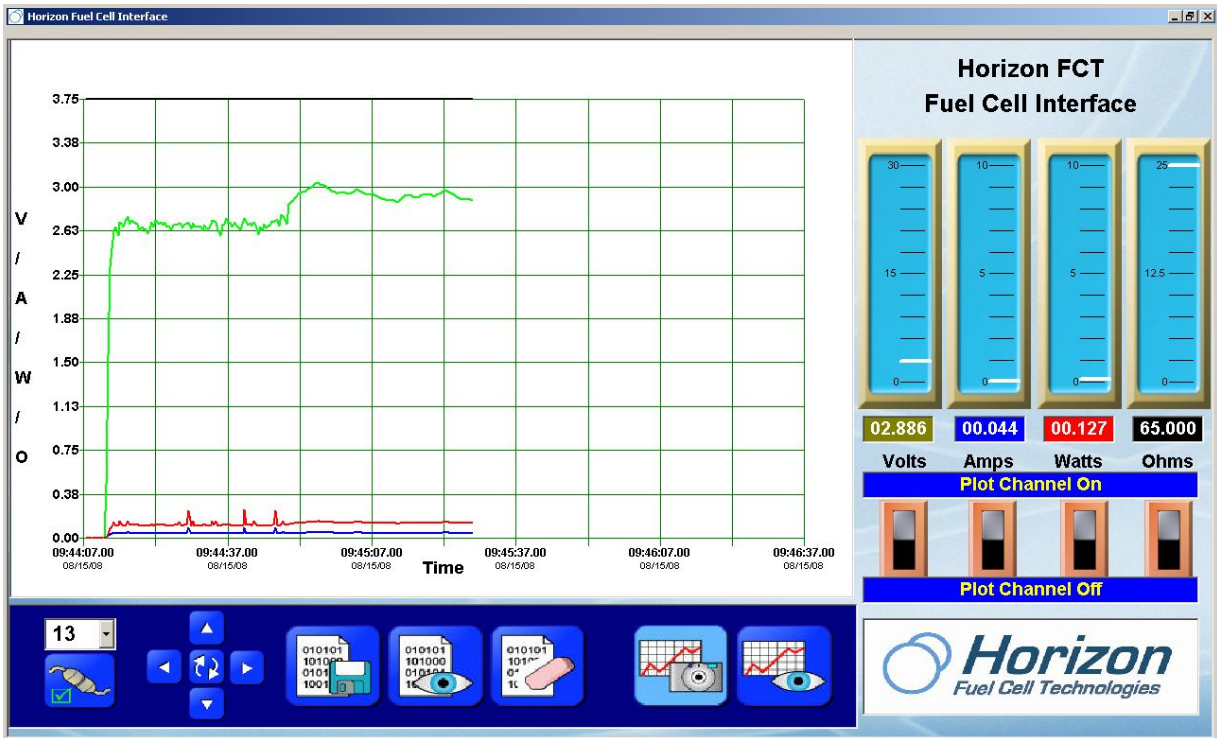


Figure 7.5 – Effect of capacitor on wind turbine DC output

If the wind turbine output were now to be measured with an oscilloscope the waveform would look much different. Notice the plot line is smooth and regular with no ripples – and that it is centered at the average output of the rippled waves in the previous view. This is due to the voltage smoothing effect of the capacitor.

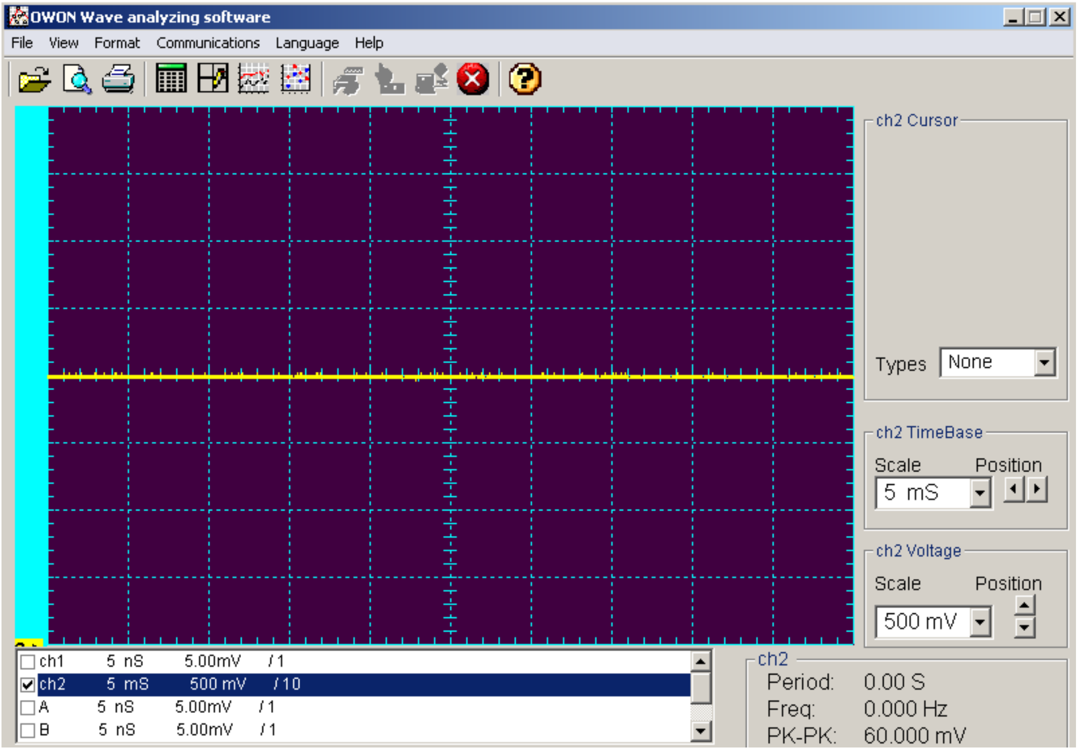


Figure 7.6 - Oscilloscope plot of wind turbine DC voltage with a capacitor

Analysis:

If voltage were like water coming out of a hose in spurts, and not a continuous stream, a capacitor acts like a water bucket with a hole in the bottom. As a water spurt enters the bucket it temporarily fills the bucket with water. Then when the spurt ceases, the partially filled bucket releases the water from the hole in the bottom. Repeating this spurt-stop sequence many times over, water will drain from the hole in the bucket's bottom in a regular, uninterrupted manner.

Compare this water analogy many times faster using electricity and the reasons for a capacitor (the water bucket) smoothing out the voltage begins to become clear.

Different values of capacitor are like larger and smaller water buckets. This is only one example of a capacitor that can hold enough charge when the voltage is rising, then release that charge when the voltage is falling, thus making the voltage a smooth, continuous value.

Even More about Wind Turbines

A wind turbine is a mechanical device and, as such, it takes time for the rotor to rotate from 0 rpm to whatever speed. And with a load is connected, the time to reach steady speed will be even longer. Thus the output voltage from the wind turbine rises slowly as compared to that of a Solar Panel. A solar panel is a semiconductor device whose response time is very fast.

When there is no load connected to the wind turbine, the output voltage is proportional to the average wind speed of the swept area. You may compare this result with an Anemometer – a device that uses small wind vanes to measure the speed of the wind.

You may notice that the output voltage fluctuates frequently and with many ripples on the plot. This is a characteristic of wind turbine which shows that the wind is never steady. Even though the output from the fan is very steady, the turbulence created by the wind still exists. A good wind tunnel can minimize this.

The voltage ripple exists as a result of the 3-Phase generator. For each rotation, there are 6 ripples generated (2 ripple for each phase). However, due to the time scale resolution of the system, this phenomenon cannot be demonstrated accurately.

The output voltage also changes with the distance between the wind turbine and the wind source. The output voltage decreases if the wind turbine does not align with the wind. However, the WindCharge ^{tm} will align itself automatically to face the wind.

Optimizing a Wind Turbine

A wind turbine cannot be efficient at all wind speed conditions. The blades have contradicting requirements at high and low wind speed. At low wind speeds, the size of the blades should be large and long, and with more blades. At high wind speeds, the size of the blades should be narrow and short, and with fewer blades. Therefore, you are encouraged to test the wind turbine with the supplied long and short blades. You may also create your own blades to see if they are more efficient.

Play around with the Wind Turbine

WindCharge ^{tm} is a realistic mini wind turbine that you can use to power your electrical devices apart from the experiment purposes. You may use it to charge rechargeable batteries, power water pumps, driving motor fan, lighting a bulb and much more. You can bring your WindCharge outdoor to experience the natural wind. However, you have to know that the voltage output from the wind turbine can be more than 10 Volts under strong wind. To protect your electronic devices from damage by the high voltage, always connect a rechargeable battery of suitable voltage rating to clamp the voltage and serve as a reservoir to filter the fluctuation from the wind.

You may like to customize the WindCharge ^{tm} with your imagination. The materials that you can use to make the blades and vane are readily available. Polypropylene sheet, Balsa wood, post card or any sheet media can be used. What you need are scissors and a punch. You can color your blades and vane to make them more attractive. You may also stick a picture on the vane and share the fun with your friends. It is nice to display the WindCharge ^{tm} on your desk or your friends. Use your imagination!!

Horizon Fuel Cell Technologies

Experiment #8 –Create electricity from ethanol and water

Purpose:

This experiment demonstrates the production of electricity of the Horizon Bio-energy kit. The direct ethanol fuel cell produces electricity while ethanol reacts at the anode side of the fuel cell. Hydrogen protons permeate from the ethanol solution through the DEFC's membrane, liberating electrons that are captured in an external circuit.

Equipment:

1	PC computer with graphic software
1	Data Acquisition Card
1	Red test lead with alligator clip
1	Black test lead with alligator clip
1	10 ohm resistors
1	Bio-energy discovery kit (not provided)

Setup:

Setup the equipment as shown below:

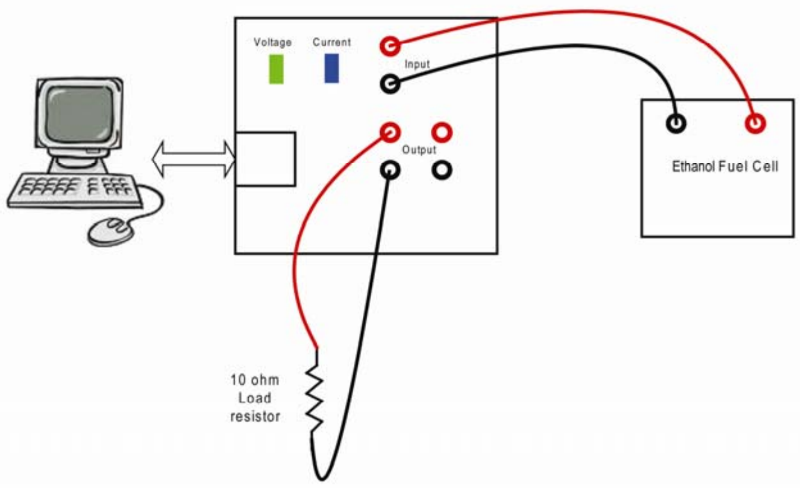


Figure 8.1 – Initial Test Setup

1. Make sure that the bio-energy discovery kit is filled with mixture of 10% ethanol, 90% water solution stored in the solution tank.

2. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

3. Make sure the graphic software is running on the computer.

4. On the computer display, click on the Connect button at the lower-left on the screen and verify the red plot line is slowly moving across the bottom of the grid display.

5. Adjust the voltage scale so you can see the data clearly.

Note: Please read through this procedure first before performing the experiment, as the process go fast and requires prior knowledge of what is about to happen.

Procedure:

1. Attach the black lead of the 10 ohm resistor to the black OUTPUT terminal and verify a similar plot as shown below. Notice that the resistance reading is at 10 ohms on the meter below.

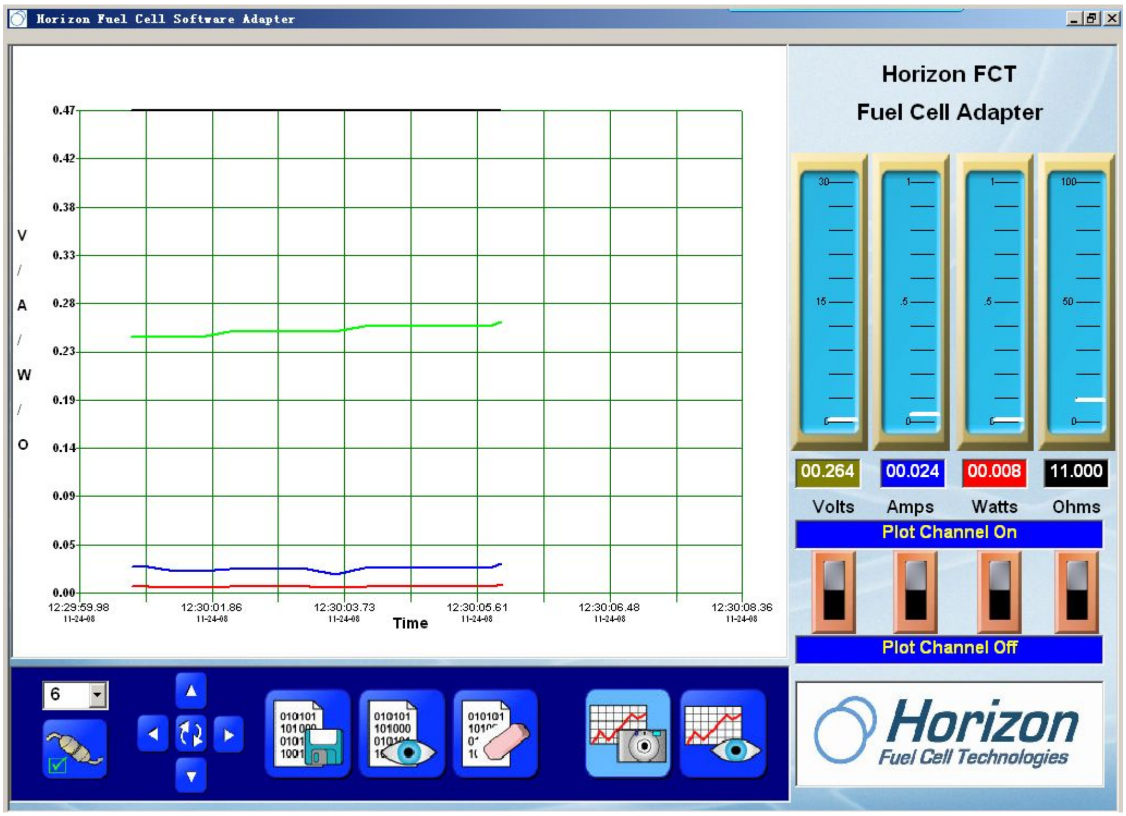


Figure 8.2 – 10 ohm Resistor Discharge Curve

Analysis:

On the cathode side, the catalytic reaction of hydrogen with oxygen from the ambient air forms water as a result.

Direct-ethanol fuel cells or DEFCs are a subcategory of Proton Exchange Membrane (PEM) fuel cells where, the ethanol fuel is not first reformed into pure hydrogen, but fed directly to the fuel cell's membrane.

The mechanism is as follows:

Anode:

(1) $C2H5OH \rightarrow CH3CHO + 2H^{+} + 2e^{-}$

(2) $C2H5OH + H2O \rightarrow CH3COOH + 4H^{+} + 4e^{-}$

(3) $C2H5OH + 3H2O \rightarrow 2CO2 + 12\ H^{+} + 12\ e^{-}$

Cathode:

$4H^{+} + 4e^{-} + O2 \rightarrow 2H2O$

During the reaction, some of the ethanol is oxidated completely and turns into CO2 (as in the reaction #3, while some of the ethanol is oxidated incompletely and turned into acetaldehyde and acetic acid (as in the reactions #1 and #2).

Conclusion:

The Direct Ethanol Fuel Cell produces electricity while ethanol reacts at the anode side of the fuel cell. Hydrogen protons permeate from the ethanol solution through the DEFC's membrane, liberating electrons that are captured in an external circuit.

Experiment #9 – Exploring the effects of temperature

Purpose:

This experiment demonstrates the relationship between temperature and the performance of the ethanol fuel cell. At higher temperatures, atoms tend to move faster and are more likely to interact with the catalysts located on the surface of the membrane. With more interactions, the reaction accelerates and more electricity is produced, which is demonstrated by the speed of the fan motor increasing.

Equipment:

1	PC computer with graphic software
1	Data Acquisition Card
1	Red test lead with alligator clip
1	Black test lead with alligator clip
1	10 ohm resistors
1	Bio-energy discovery kit (not provided)

Setup:

Setup the equipment as shown below:

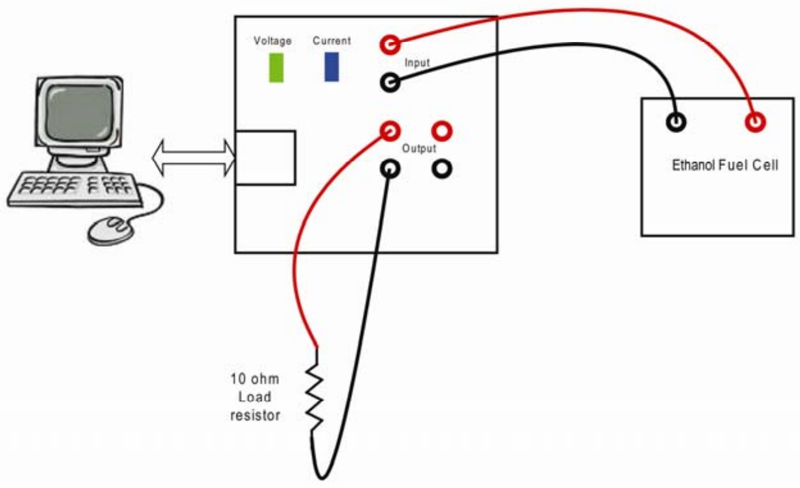


Figure 9.1 – Initial Test Setup

1. Make sure that the bio-energy discovery kit is filled with mixture of 10% ethanol, 90% water solution stored in the solution tank.

2. Connect the USB cable between the circuit board and the computer and verify that the green and blue LEDs on the circuit board are flashing.

3. Make sure the graphic software is running on the computer.

4. On the computer display, click on the Connect button at the lower-left on the screen and verify the red plot line is slowly moving across the bottom of the grid display.

5. Adjust the voltage scale so you can see the data clearly.

Note: Please read through this procedure first before performing the experiment, as the process go fast and requires prior knowledge of what is about to happen.

Procedure:

1. Attach the black lead of the 10 ohm resistor to the black OUTPUT terminal and verify a similar plot as shown below. Notice that the resistance reading is at 10 ohms on the meter below.

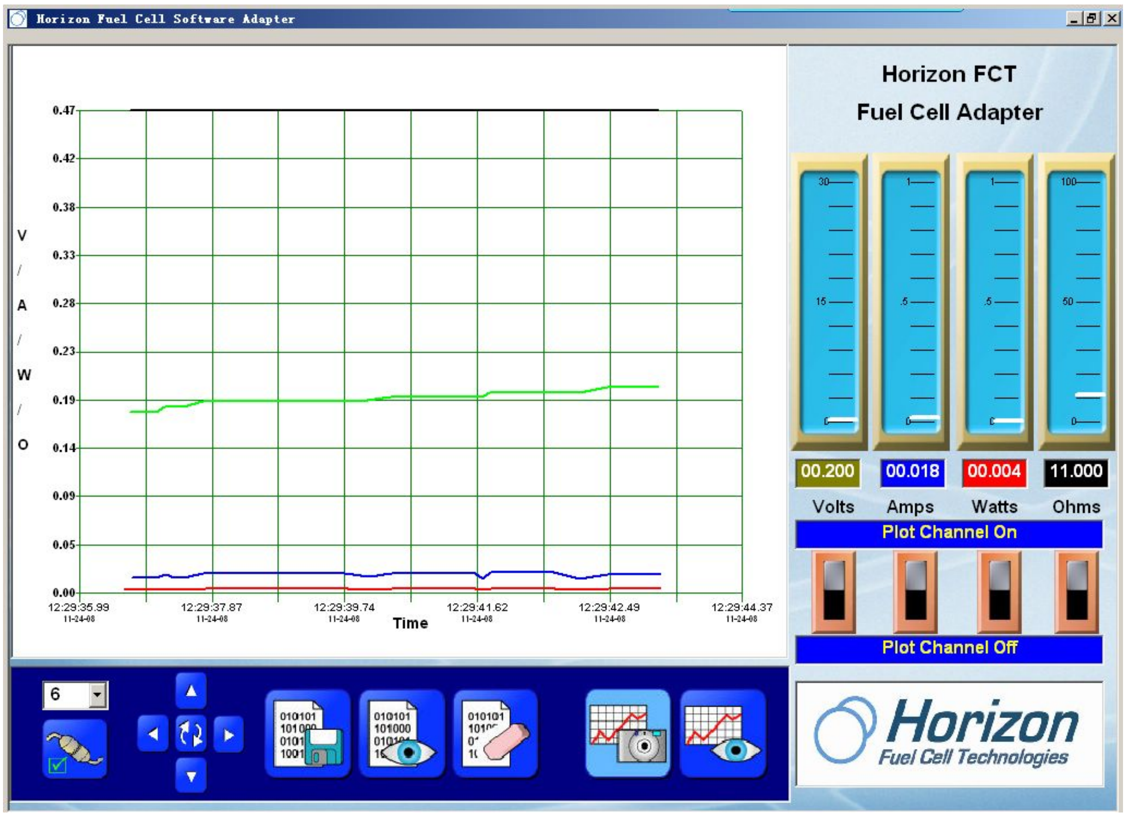


Figure 9.2 – 10 ohm Resistor Discharge Curve

2. Next, use a hair drier to create a flow of hot air directed towards the back of the fuel cell. After 30 seconds you should observe the data below and the motor and fan will be operating at a faster speed.

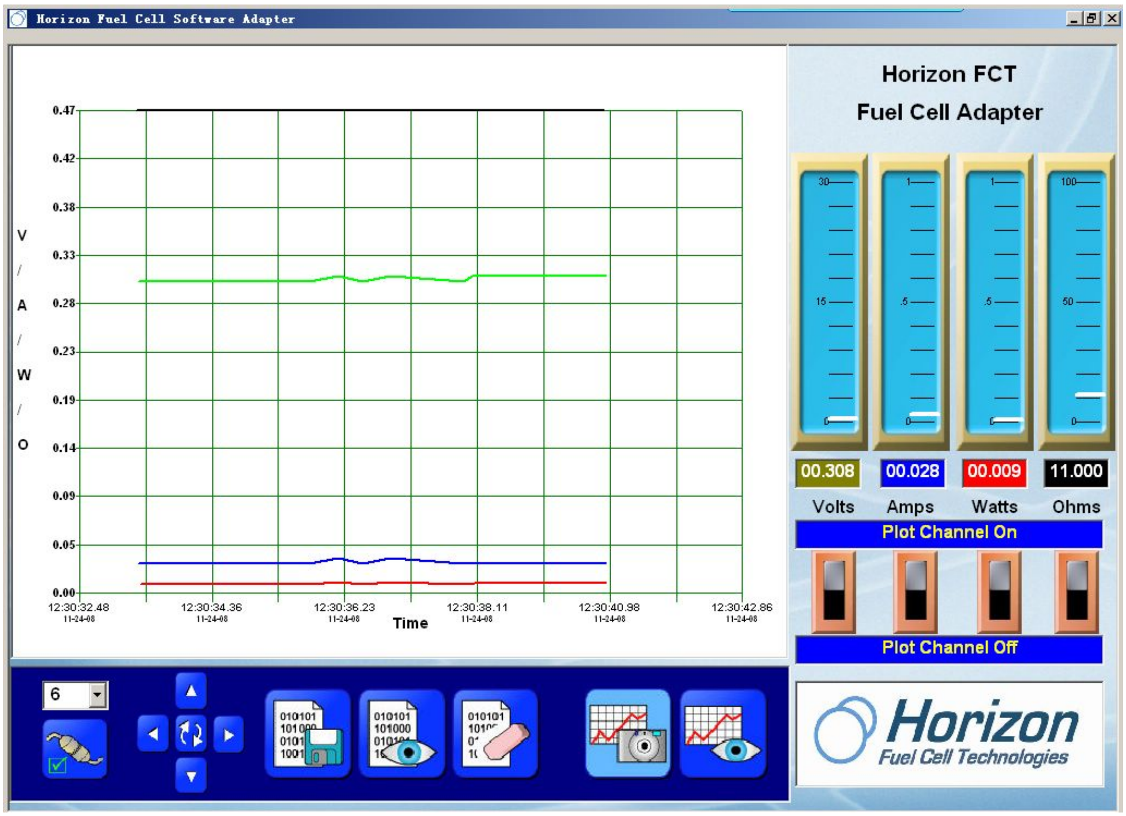


Figure 9.3 – The effects of temperature applied to the ethanol fuel cell

Analysis:

At higher temperatures, atoms tend to move faster and are more likely to interact with the catalysts located on the surface of the membrane. With more interactions, the reaction accelerates and more electricity can be produced, which is demonstrated by the speed of the fan motor increasing.

Note: Before you direct warm air towards the fuel cell, direct the airflow to your hands first to make sure the air is not too hot (Below 60℃ is preferred).

Conclusions:

(1) Higher temperatures will make it more likely for ethanol molecules to interact with the catalysts located on the surface of the membrane, which accelerates the speed of the chemical reaction.

(2) High temperature can also make the membrane more active, so it will demonstrate an increased ability of proton exchange within the membrane and an increase the speed of the fan motor. Increasing the power capability of ethanol fuel cells can be done by increasing their operating temperature, or the temperature of their fuel.

14. Fault Diagnostics

If the software does not respond after starting or if it should produce unexpected results, please check the following possible causes:

Connecting to the Data Acquisition Card

To find the correct Comm Port, do one or the other of these steps…

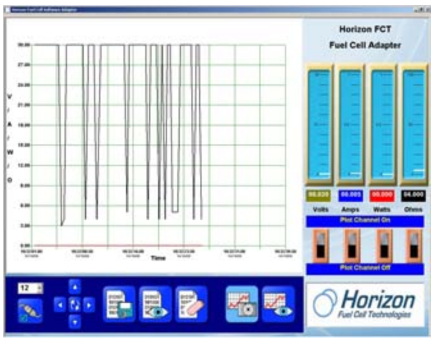
Click directly on the “arrow” next to the displayed port number. It may display another number that is the correct port number. Click on this number, and then click on the “X” in the icon below. If it is correct, the following icon will appear and the Data Acquisition Card will be connected to the plot display.

You can also use determine the correct icon number by using your computer’s Control Panel (PCs only).

Click on Start → Control Panel → System →Device Manager → Ports → USB Serial Port (x)

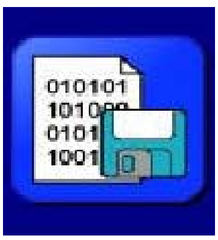
where x is the number that should be entered into the Comm Port select icon. Then go back to the Fuel Cell Adapter software and click on the number shown. Then (using the keyboard) enter the number of the USB Serial Port you found from the Control Panel. Then click on the “X” in the icon below.

False Readings



With no power source or load connected, you may experience false readings on the plots and meters as shown here. This is due mainly to the fact that the Data Acquisition Card has very sensitive electronics that react to stray electrical noise in the environment, such as from the power lines and even your computer. However, once a power source and load are connected to the Input and Output terminals, as in the experiments, these anomalies should disappear, since the electronics are now being driven correctly.

Finding the Data



After clicking on either the Capture Image icon (left) or Start Data Log icon (right), the captured data can be found on your hard drive by searching the following path:

Program Files → Horizon FCA → Data

15. Technical Data

Product Item No. FCJJ-24

Data Acquisition Card

- Dimensions 2.5” x 2.5”
- USB Interface
- Electrical Limits

  The following measurement ranges are possible:

  - Voltage measuring range:
    0 volts to 5 volts
  - Current measuring range:
    0 amps to 1 amp
  - Power measuring range:
    0 watts to 5 watts
  - Resistance measuring range:
    0 ohms to 99.999 ohms