Report for 2004DC56B: The Development of a MEMS-based Integrated Wireless Remote Biosensors

There are no reported publications resulting from this project.

Report Follows

The Development of a MEMS-based Integrated Wireless Remote Biosensors

Phase I: The Development of Instrumentation and Data Acquisition System for Bioelectric Signals Monitoring

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The Development of Instrumentation and Data Acquisition System for Bioelectric Signals

Introduction

Over the past decade, research has been active in developing methods for measuring the levels of stress in aquatic animals for the purpose of monitoring water pollution. This research proposes, in two phases, the design and implementation of an integrated wireless, low-power embedded biosensor monitoring system for the acquisition and transmission of biological functions from aquatic animals. These signals can be used to measure the stress induced in aquatic animals due to water pollution.

The minimization of power consumption is a critical issue in the design of electronic systems for portable battery-operated applications or remotely powered applications as employed in biomonitoring systems. In this study, a MEMS-based biosensor was integrated with a mixed-mode ASIC chip comprising of preamplifier, band-pass filter, analog amplifier, D/A module, modulator, transmitter, and a digital controller. The design integrated MEMS, wireless communication, VLSI, and system-on-chip (BioSilico) technologies in the design of a low power environmental monitoring device. The system will be designed as a solar/battery-powered device.

Techniques for analyzing the acquired data were developed. The embedded integrated sensors were used in the on-line acquisition of myoneural signals from bivalve mollusks. This design is expected to miniaturize several discrete modules and eliminate coaxial cables used in existing biomonitoring setups, and in a significant reduction in the overall system power consumption. A receiver system will be used to receive the signal transmitted from the sensor device. The receiver system will be designed and built using off-shelf components. When completed, the design will be able to automate the process of in situ environmental data gathering needed to monitor the safety of the drinking water resources.

Phase I Objectives:

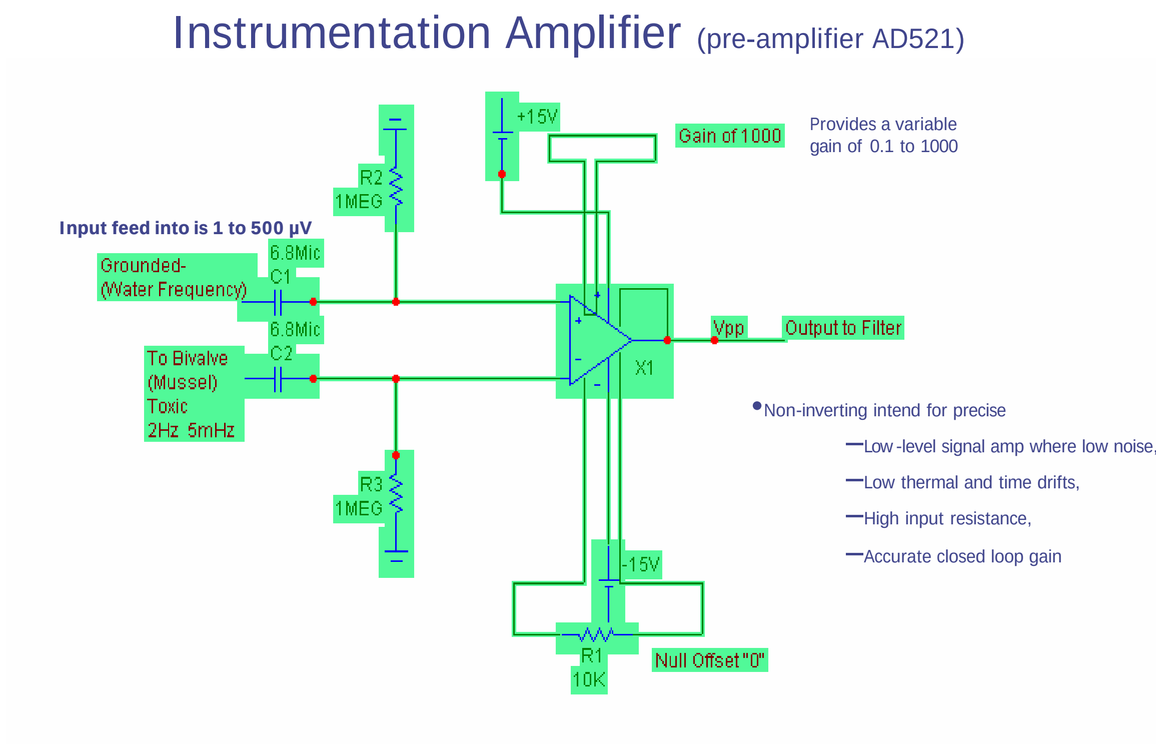
- To design instrumentation system for Bio-monitoring
- To identify toxins in estuaries
- To initialize research to determine types of toxins

This document gives a summary report on the Instrumentation system and the Solar Lab developed for remote biosensing in the summer of 2004 through the 2005 Spring semester. The instrumentation board captures myoneural (muscle-nerve) signals from fresh water bivalve mollusks. Typical signals are in the range 5mV to 20mV. The design was partitioned into 5 stages:

1. The Pre-amplifier stage with closed loop amplification gain of 10.
2. The Second-order Low-Pass Butterworth Filter which filters out High frequency noise and electronics noise.
3. The Butterworth High-Pass Filter which filters out the unwanted low-frequency noise.
4. The variable-gain main Amplifier stage with signal amplification gain of 100 to 1000.
5. The Voltage Detector which limits or attenuates signals to 5V.

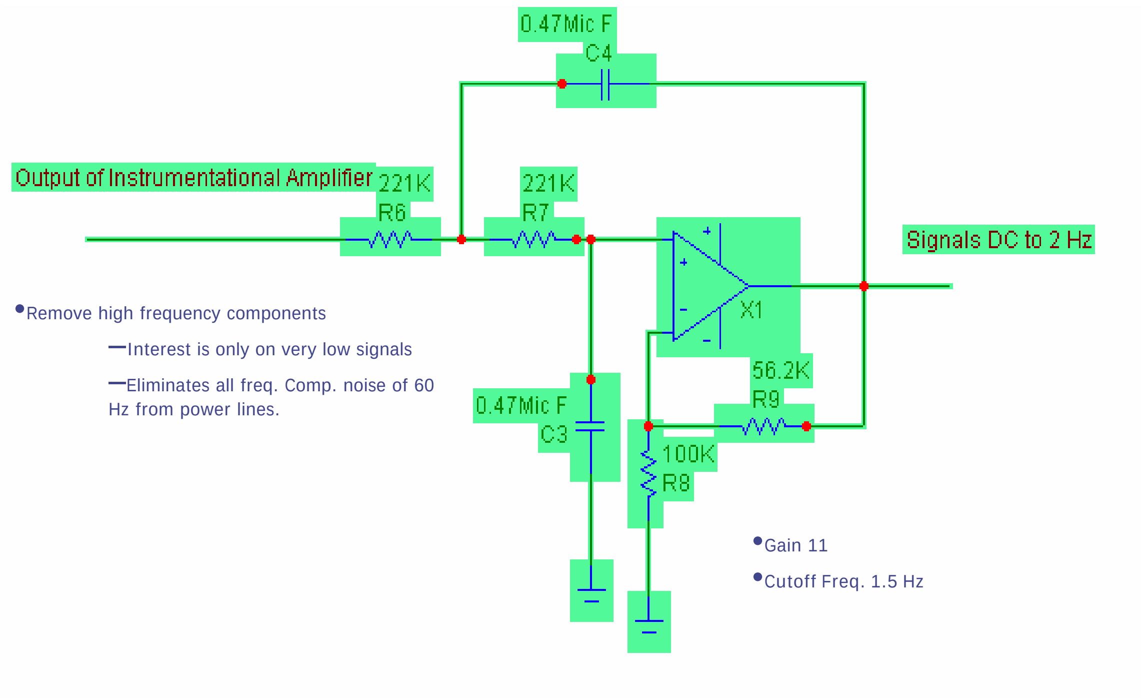
The instrumentation board was designed with discrete components and tested in the lab. The different stages of the design are shown below:

1. The Pre-amplifier stage



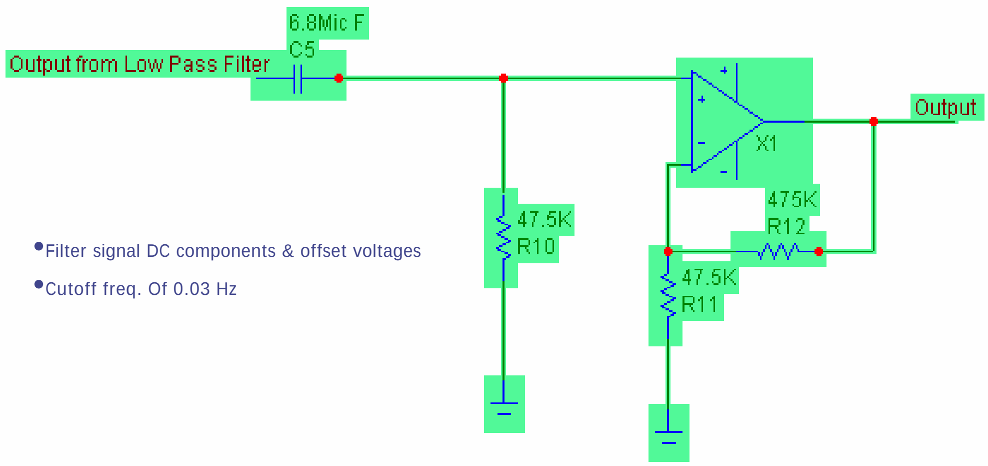
2. The Second-order Low-Pass Butterworth Filter

First Stage Second-Order Low-Pass Butterworth Filter (LM324)



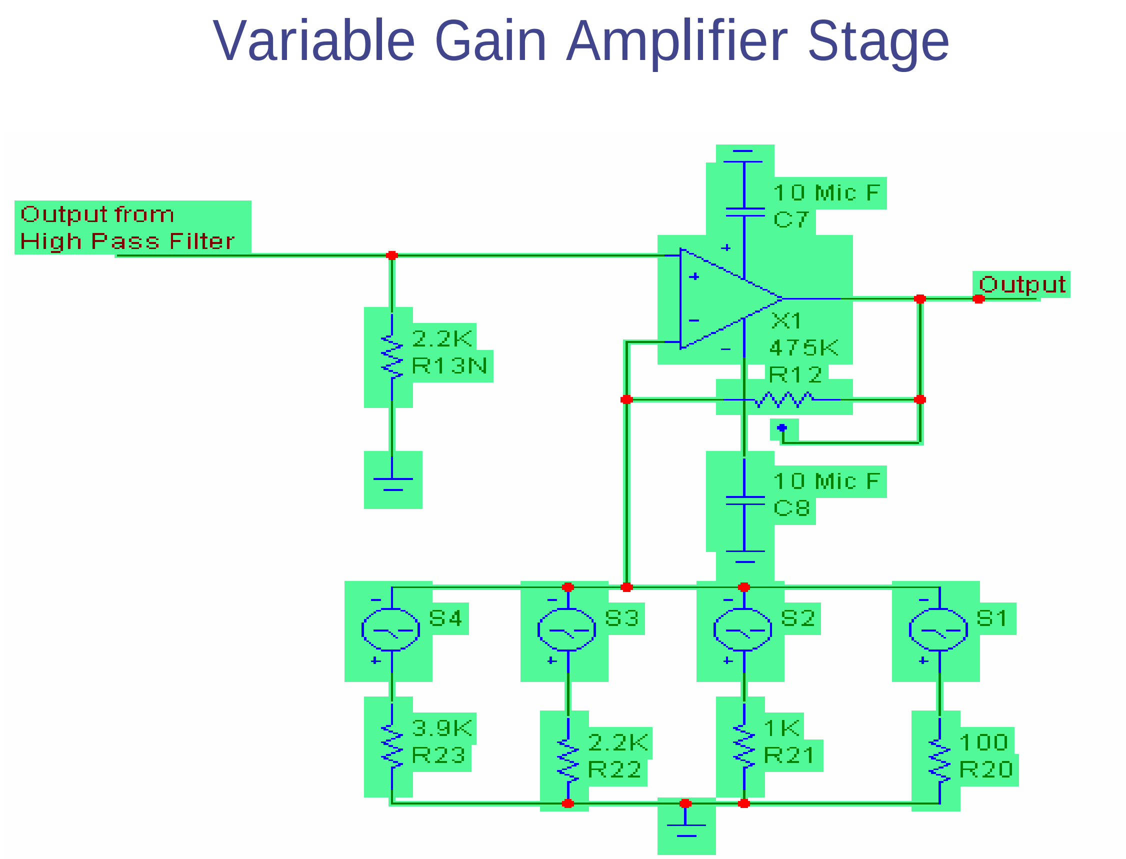
3. The Butterworth High-Pass Filter

Butterworth High-Pass Filter (LM324)



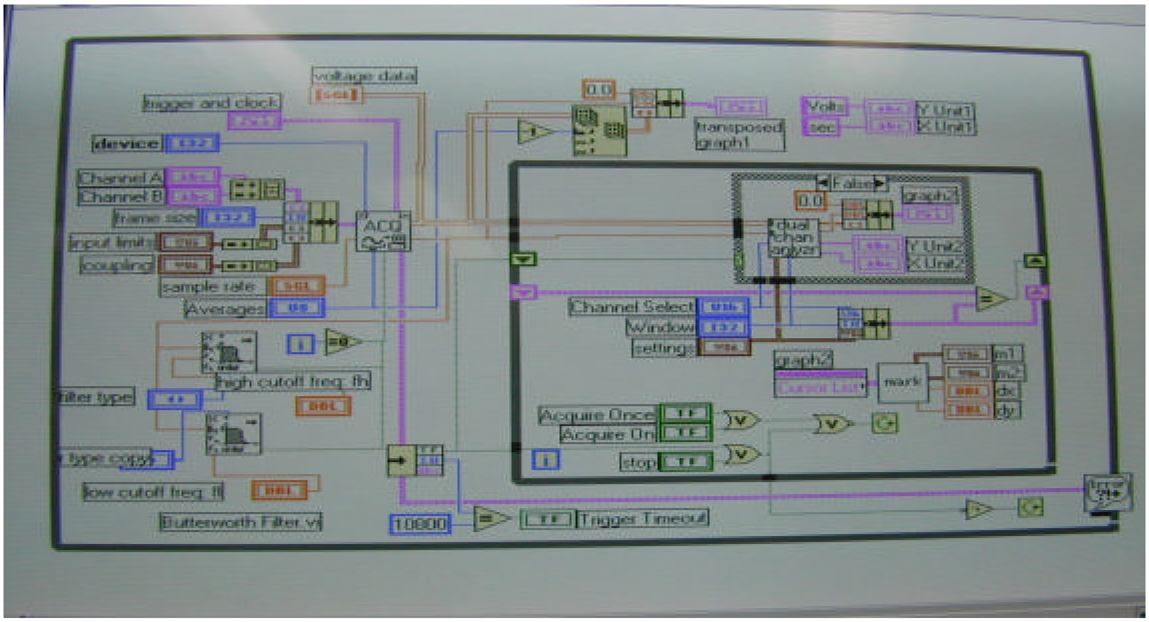
- Filter signal DC components & offset voltages
- Cutoff freq. Of 0.03 Hz

4. The variable-gain main Amplifier stage

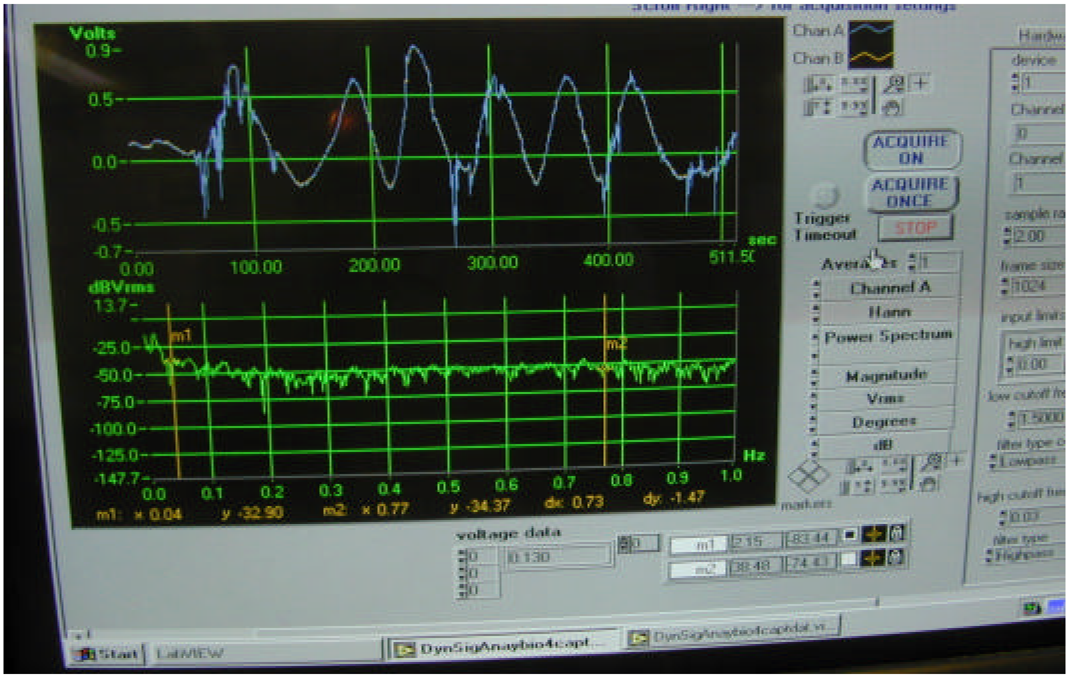


The above design was also configured and tested using the LabView Data Acquisition system:

Labview 4.1 – Schematic Diagram

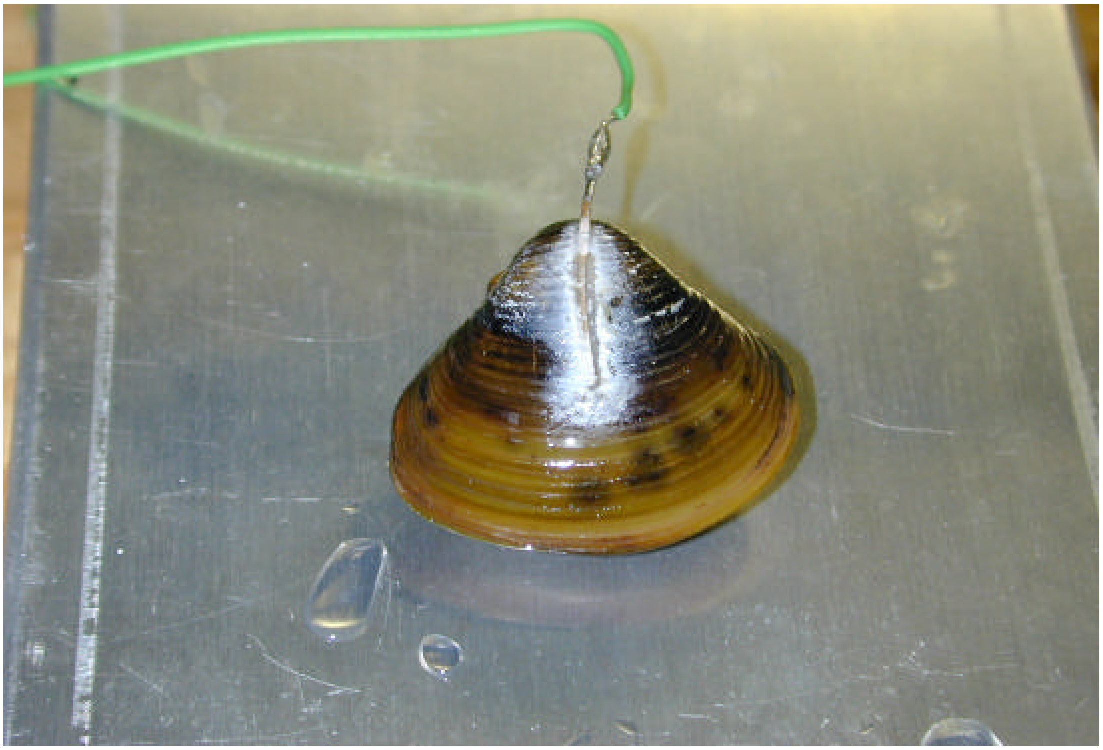


Front Panel data collection



What is Muscle-nerve (Myoneural) signatures—movement, respiratory, and cardiac activities of Bivalves

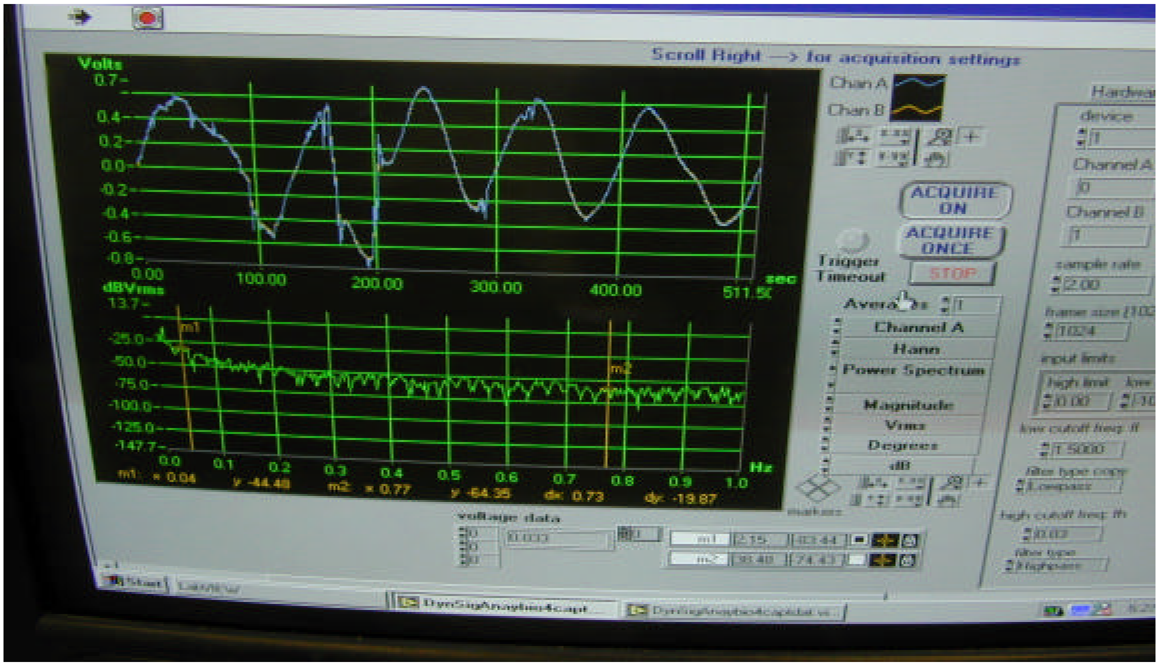
Probing of Clam



24 hrs acclimatization after electrode implantation

Sampling environment

Data Collection



Experiment Conditions

- 48 hr acclimatization in lab tank
- Water at 19+/- 0.5 degrees Celsius
- Water air equilibrated
- Solution of dog food mixture

Characteristics of Bivalves that Make Them Suitable Organisms For Bio-monitoring Application

- Very Abundant
- Relatively Inexpensive
- High sensitivity to environmental impacts
- High Filtration Rates
- Limited mobility

Behavior Under Stress

- Shell Closure
- Adductor Muscle Contraction (Gape Closing)
- Action Potential captured by electrode

Phase II of Research Project

- **Apply Toxins**
- **Compare results to determine toxins types**
- **Package the instrumentation circuit in a micro chip**

Conclusion:

- Bio-monitoring Applications can be used to determine toxicity in estuaries
- A data acquisition system was designed and implemented to continuously acquire and display the myoelectric data for multi-species aquatic animals.

Solar Lab Project

The Solar lab was developed to remotely power the Data Acquisition System when conducting field work at a river bank.

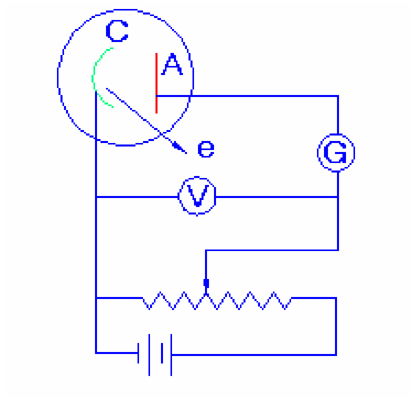
Objectives:
The primary intention of this project was to show how solar energy is a way of powering devices. In doing so, the following steps were executed:

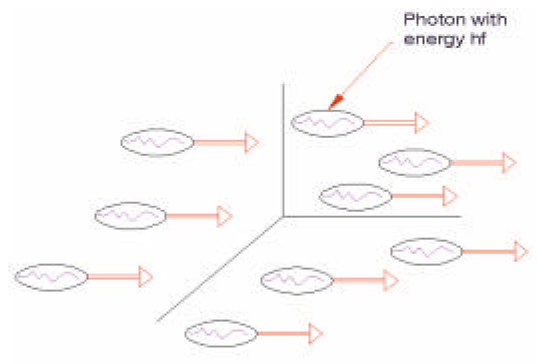
1) How electricity, solar cells and panels are created
2) How the solar kit was assembled
3) Data gathered, and obstacles encountered

Conversion Of Light

- Nature of Sun Light
  * Photons
- Semiconductors
  - Properties

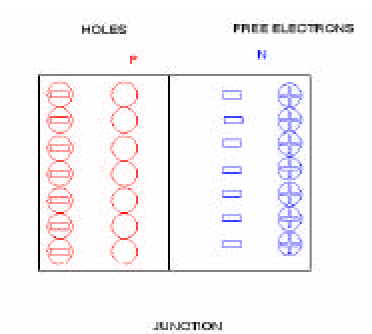
The Photoelectric Cell

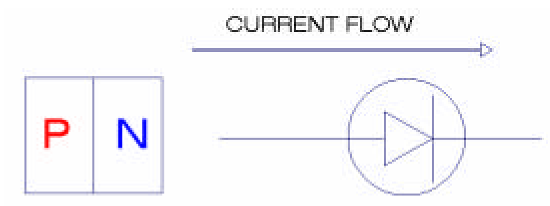




Einstein's photon picture of "a traveling light wave"

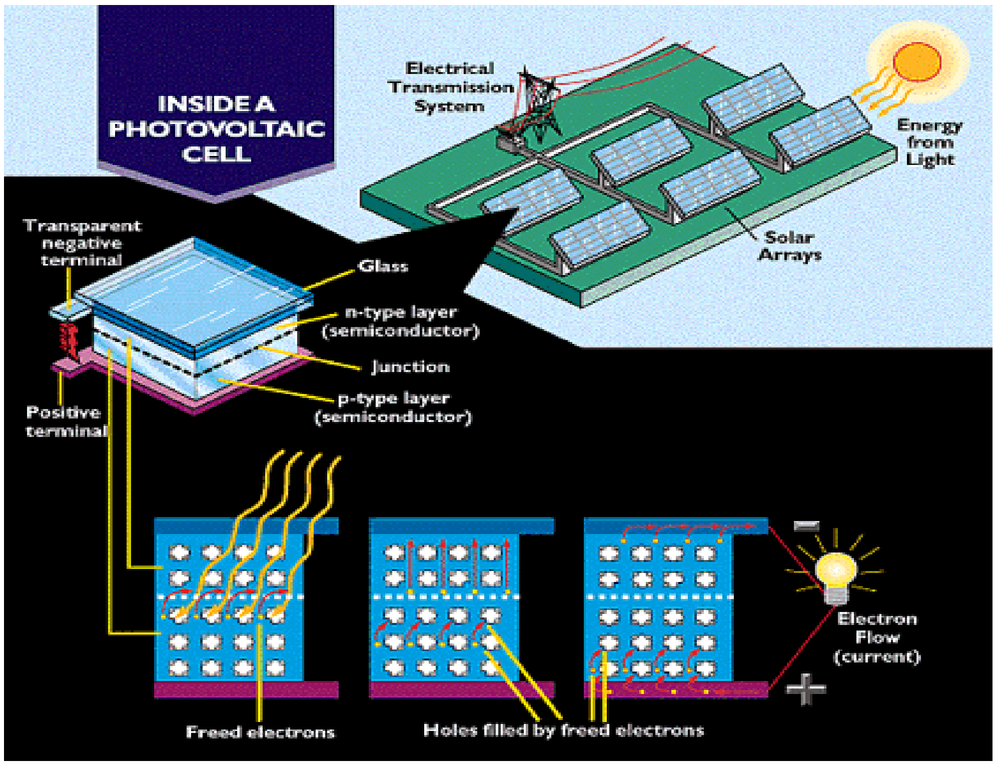
PN Junction, Diode



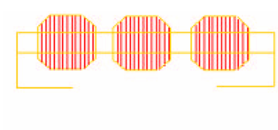


The Structure and Mounting of Solar Cells

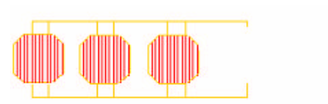
- Inside the Cell
  * Glass / protective layers
  * Semiconductor P and N type
- Parallel and Series Circuit


INSIDE A PHOTOVOLTAIC CELL
Electrical Transmission System
Energy from Light
Solar Arrays
Transparent negative terminal
Glass
n-type layer (semiconductor)
Junction
p-type layer (semiconductor)
Positive terminal
Electron Flow (current)
Freed electrons
Holes filled by freed electrons

- Solar Cell Parallel and Series Circuit



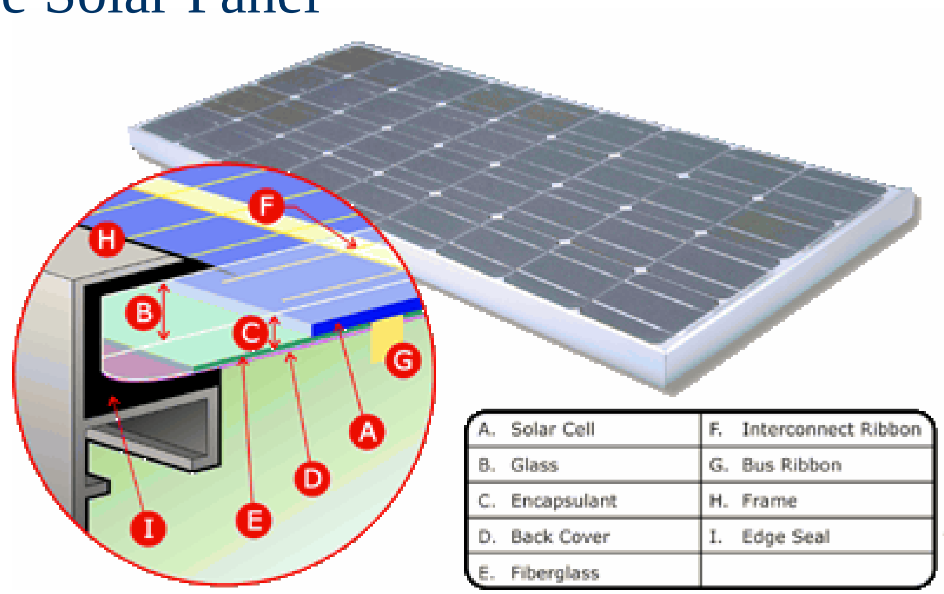
Current = I (Cell)
Voltage = 3 V (Cell)



Current = 3 I (Cell)
Voltage = V (Cell)

Solar Lab

The Solar Panel



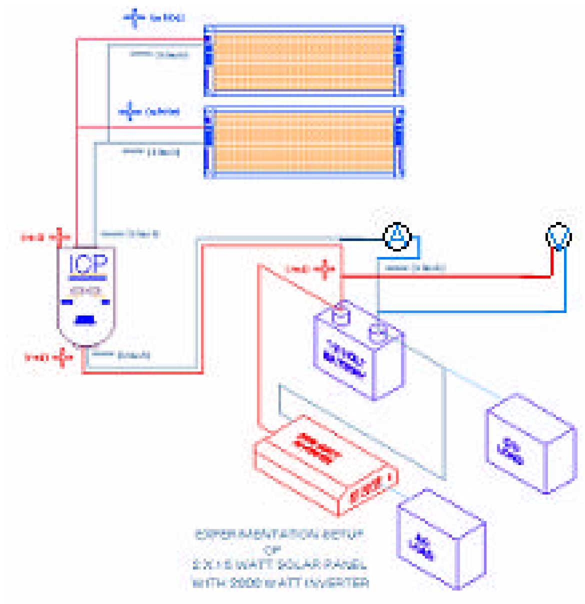
Solar Lab

Building Solar Lab

- Circuit Diagram
  - * Wiring the Equipment
- Building the Tower
  - * Measuring, Cutting, Welding, Painting … the structure
- Mounting the Equipment
  - *Wiring, soldering, testing … the components

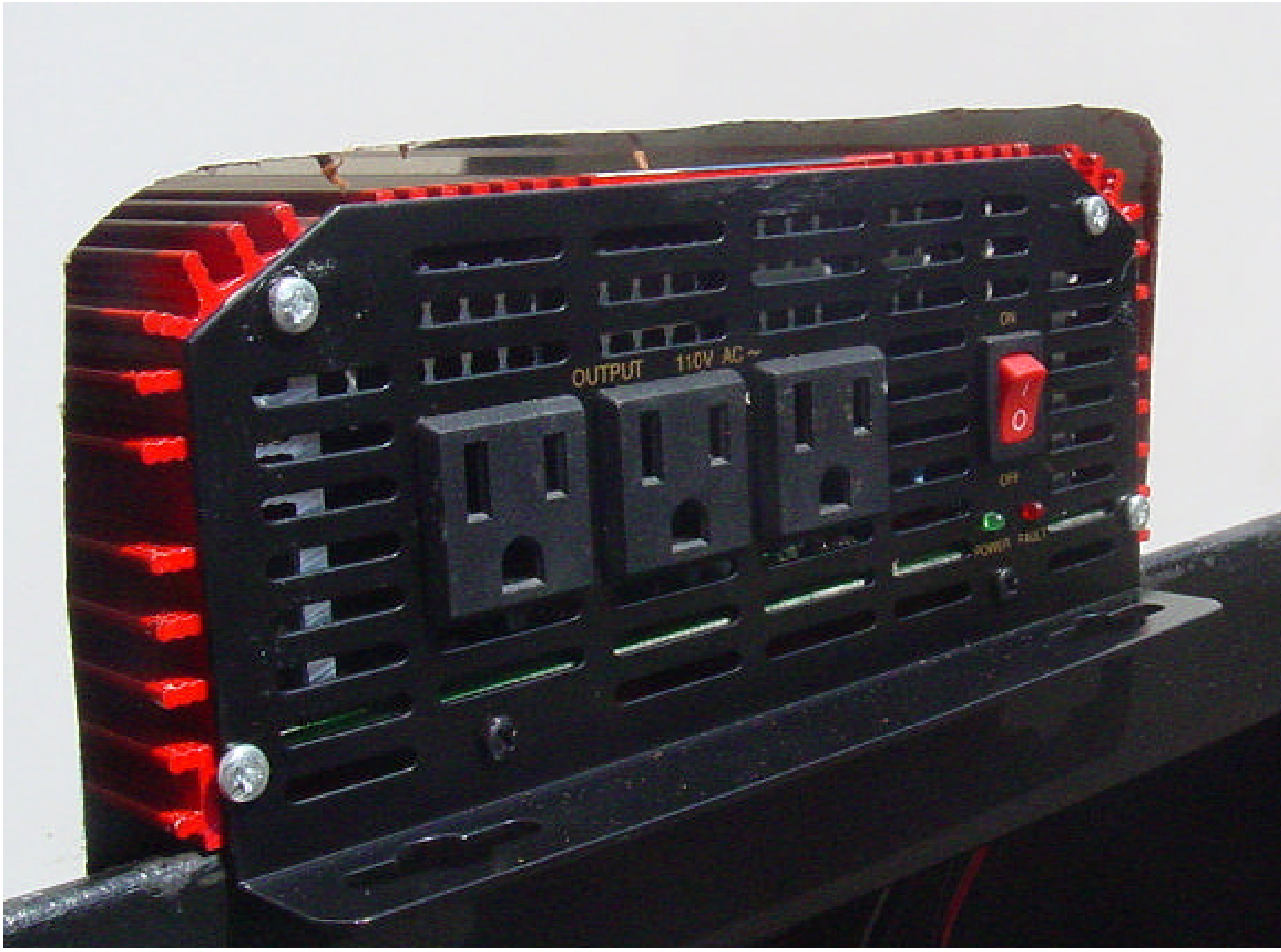
Solar Lab

Measurements



A: Solar Panel
B: Inverter
C: Controller
D: Battery
E: DC Out

E



Solar Lab

Analysis

- Data:

Time (min)	Voltage (V)	Current (A)	Weather Condition
0	11.74	0.78	S
5	11.43	0.33	PC
10	11.28	0.17	C
15	11.23	0.13	C
20	11.17	0.15	C
25	11.14	0.53	S
30	11.11	0.59	S
35	11.05	0.33	C
40	11.02	0.37	C
45	10.96	0.22	VC
50	10.89	0.09	VC
55	10.8	0.03	VVC
60	10.83	0.01	VVC
65	10.78	0	VVC
70	10.74	0	VVC
75	10.59	0	VVC
80	10.5	0	VVC
S: Sunny, PC: Partially Cloudy, S: Sunny, C: Cloudy, VC: Very Cloudy, VVC: Very Very Cloudy			

Analysis

- Graphs