Arduino Energy Monitoring

Jack's Phillies
Aaron Ayala, Zane Mosby, and Brian-Ismael Vargas

Humboldt State University
WetyLand
ENGR215 Fall 2013

Table of Contents

LIST OF FIGURES **3**

1 PROBLEM FORMULATION **4**

1.1 INTRODUCTION 4
1.2 OBJECTIVE 4
1.3 BLACK BOX MODEL 4

2 PROBLEM ANALYSIS AND LITERATURE REVIEW **4**

2.1 INTRODUCTION TO PROBLEM ANALYSIS 4
2.2 SPECIFICATIONS AND CONSIDERATIONS 4
2.2.1 Specifications *4*
2.2.2 Considerations *5*
2.2.3 Criteria *5*
2.2.4 Usage *5*
2.2.5 Production Volume *5*
2.3 INTRODUCTION TO LITERATURE REVIEW 5
2.3.1 Programmable Microchips/Boards *6*
2.4 OPEN ENERGY MONITORING SYSTEMS 16
2.5 HARDWARE 18
2.5.1 Sensors *18*
2.5.2 Switches *18*
2.5.3 Display Modules *18*
2.5.4 LEDs *20*
2.6 SOFTWARE 20
2.7 MICROCHIP POWER SUPPLY 21
2.7.1 AC/DC Current *21*
2.8 WETLAND POWER SUPPLY AND SYSTEMS 21
2.8.1 Solar Energy System *21*
2.8.2 Batteries *22*
2.8.3 Solar Panels *24*
2.9 FLOCK HOUSE HYPER VISIBLE POWER METER 24
2.10 LAUREL TREE SCHOOL ENERGY 26

3 ALTERNATIVE SOLUTIONS **27**

3.1 INTRODUCTION 27
3.2 BRAINSTORMING 27
3.3 ALTERNATIVE SOLUTIONS 27
3.3.1 The Energy Station *27*
3.3.2 Tweet-A-Watt *28*
3.3.3 Simple& Effective(S&E) *28*
3.3.4 Looper *28*
3.3.5 Holographic Displays *28*
3.3.6 EnerJar *29*
3.3.7 Sound Board Alarms *29*
3.3.8 Battery Alarm *29*
3.3.9 Interactive Units with TFTs *30*
3.3.10 OpenEnergyMonitor.org *30*

4 DECISION PHASE **30**

4.1 Introduction to Decision Phase 30
4.2 Criteria Definition 30
Safety- 30
Cost- 30
Power Usage- 30
Maintainability- 31
Accuracy- 31
Interpretability- 31
Durability- 31
Aesthetics- 31
4.3 Solutions 31
4.4 Decision Process 31
4.5 Final Decision & Justification 32

5 SPECIFICATION OF SOLUTION 32

5.1 Introduction 32
5.2 Solution Description 32
5.3 Cost Analysis 32
5.3.1 Design(hours) 32
5.3.2 Construction($) 32
5.4 Maintenance 32
5.5 Implementation Instructions 33
5.6 Prototype Performance 33

6 APPENDICES 33

List of Figures

Figure 1.1 Black Box Model: The Black Box Model demonstrates a simplified view of the whole design process.. 4

1 Problem Formulation

1.1 Introduction

In Phase 1 of the design documentation process the Jack's Phillies, Arduino Energy Monitoring System have made an Objective Statement as well as a Black Box Model diagram shown in Figure1.1. A clear description of the design process is shown in figure 1.1.

1.2 Objective

The Objective is to design an interactive energy monitoring system that is educational, Intuitive, weatherproof, and safe for the general public.

1.3 Black Box Model

The black Box Model shown in figure 1.1 shows the state of the world as it is now and the state of the world after our solution is implemented.

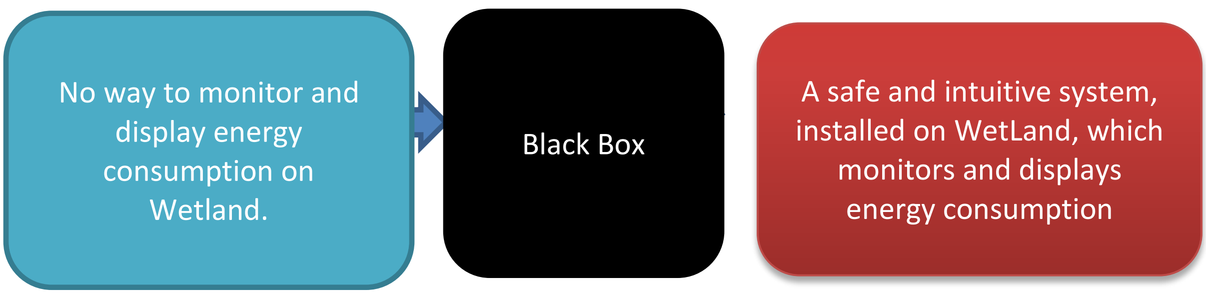


Figure 1.1 Black Box Model: The Black Box Model demonstrates a simplified view of the whole design process.

2 Problem Analysis and Literature Review

2.1 Introduction to problem Analysis

The Problem Analysis specifies the guidelines for making decisions and coming up with alternative solutions. The Document has the following specifications that will be considered during the design process: Specifications and considerations; Criteria, Usage, and Production Volume.

2.2 Specifications and Considerations

2.2.1 Specifications

Specifications are the minimum requirements for the energy monitoring system. The specifications for this project are as follows:

- WetLand is an off-grid solar energy system
- There will be four 12 volt batteries as energy storage
- The system will have a charge controller as well as a dc excess load and a watt invertor

- The system will contain an interpretive aspect
- It will be open to the public so the system is interpretable.

2.2.2 Considerations

Considerations are limits placed on the project based on aspects of wetland that are not under the control of jack's Phillies. Our considerations are as follows:

- It will be in Philadelphia, on the Delaware River
- The system must be weather proof.
- Will be used by artist.

2.2.3 Criteria

Table 1: Criteria Breakdown below is an analysis of the criteria jack's Phillies gave for the energy monitoring system. It is based on importance, each criteria was given a number, ranging from 1-10, 10 being important and 1 being unimportant.

Table 1: Criteria Listed in order of most important

Criterion	Constraints	Weights(1-10)
Cost	<$300	10
Safety		10
Maintainability		9
Aesthetics		6
Interpretability		8
Reproducibility		8
Accuracy		10

2.2.4 Usage

Jack's Phillies design is meant to run the whole time WetLand will be in operation. It will be used to ensure that the inhabitants have an accurate read-out of energy available and rates of usage. This is important in ensuring that the batteries on Wetland fulfill their potential lifespan.

2.2.5 Production Volume

Jack's Phillies designs and built one energy monitoring system to be sent to WetrLand and Installed by WetLand personnel. An easy-to=use instruction manual is provided. A web manual explaining how to reproduce our design written out for appropedia.org allows anyone with internet to access Jack's Phillies design.

2.3 Introduction to Literature Review

The purpose of the literature review is to provide appropriate background information which will provide a give a foundation for the design process jack's Phillies have accommodated. The following topics will be discussed: Programmable microchips/boards, pre-fabricated boards, Open energy monitoring systems, hardware involved, software, the microchips power supply, WetLand power supply, and other similar projects.

2.3.1 Programmable Microchips/Boards

A programmable microchip sometimes referred to as a microcontroller. The best way to explain microcontrollers is to start with your computer. Your desktop computer is comprised of multiple parts, a CPU (such as a Pentium or Celeron), some RAM, a hard disk, a keyboard and mouse and a monitor screen. Programs are stored on the hard disk and run on the CPU, with temporary data stored in RAM. You can run multiple programs at a time by having one 'master program' called an operating system (such as Linux, Windows or Mac OS X) and that master program keeps track of things for you.

The microchip has components, too. It has a CPU, some flash storage, some RAM and some EEPROM, all in one little chip. The CPU is just like the one in a computer, but it is much simpler and not nearly as fast. The flash storage is just like the flash storage in your mp3 player or digital camera card, except it is used to store programs. It is similar to the hard disk of the microcontroller, except you can only read from it. The RAM is just like computer RAM. The EEPROM is similar to flash except you cannot run a program from it, but it is used as long-term storage. The EEPROM doesn't get erased when the chip loses power.

Most computers have a 32-bit CPU running at 1GHz, with 1GB of RAM and 100 GB of storage. The kinds of microcontrollers discussed here run at 10MHz, have 1KB of RAM and 10KB of storage. (http://www.ladyada.net/learn/avr/whatisit.html 2012)

The term "board" refers to a ready to use microcontroller complete with various hardware enhancing the abilities of the microcontroller. These enhancements can range from a reset button (used to reset a process) to Wi-Fi or Bluetooth technology (enabling it to communicate using wireless communication).

2.3.1.1 Pre-Fabricated Boards

For the sake of time, our team will be focusing primarily on boards manufactured by Arduino and Raspberry Pi; these two companies have the most widely available information and ample amount of example projects of which, for the most part, the inventors of such projects have posted schematics and coding in an open-source spirit. Because of this, a wide array of information is at our fingertips.

2.3.1.1.1 Arduino

Arduino is an open-source prototyping platform designed for anyone interested in electronics and much more. The software and assembly is accessible to most people with a general knowledge of electricity.

2.3.1.1.2 Arduino BT

The Arduino BT is a microcontroller board based on the ATmega328 and the Bluegiga WT11 Bluetooth module. Figure 2.1 is an image of the top of an Arduino BT. The Board Arduino BT supports wireless serial communication over Bluetooth, but is not compatible with Bluetooth headsets or other audio devices . It has 14 digital input/output pins of which 6 can be used as PWM outputs and one can be used to reset the WT11 module, 6 analog inputs, a 16 MHz crystal oscillator, screw terminals for power, an ICSP header, and a reset button. It contains everything needed to support the microcontroller and can be programmed wirelessly over the Bluetooth connection.

Figure 2.1 Arduino Bt

2.3.1.1.3 Arduino Due

The Arduino Due in figure 2.2 is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU. It has 54 digital input/output pins of which 12 can be used as PWM outputs, 12 analog inputs, 4 UARTs (hardware serial ports), a 84 MHz clock, an USB OTG capable connection, 2 DAC (digital to analog), 2 TWI, a power jack, an SPI header, a JTAG header, a reset button and an erase button. Unlike other Arduino boards, the Arduino Due board runs at 3.3V. The maximum voltage that the I/O pins can tolerate is 3.3V. Providing higher voltages, like 5V to an I/O pin could damage the board. (http://arduino.cc/en/Main/ArduinoBoardDue 2013)

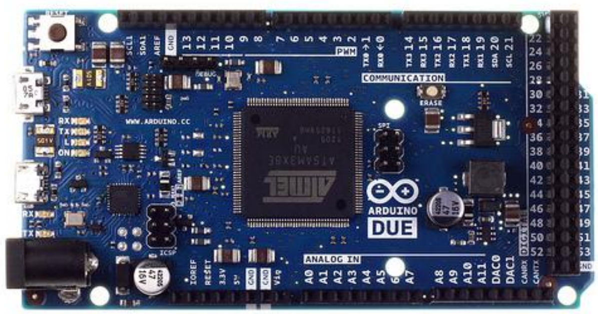


Figure 2.2

2.3.1.1.4 Arduino Leonardo

The Arduino Leonardo shown in figure 2.3 is a microcontroller board based on the ATmega32u4. It has 20 digital input/output pins of which 7 can be used as PWM outputs and 12 as analog inputs, a 16 MHz crystal oscillator, a micro USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer usb plug connection with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Leonardo differs from all preceding boards in that the ATmega32u4 has built-in USB communication, eliminating the need for a secondary processor. This allows the Leonardo to appear to a connected computer as a mouse and keyboard, in addition to a virtual (CDC) serial / COM port. (http://arduino.cc/en/Main/ArduinoBoardLeonardo 2013)

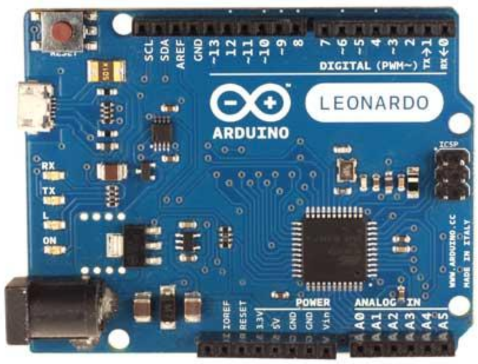


Figure 2.3 Arduino Leonardo

2.3.1.1.5 Arduino Esplora

The Arduino Esplora shown in figure 2.4 is a microcontroller board derived from the Arduino Leonardo. The Esplora differs from all preceding Arduino boards in that it provides a number of built-in, ready-to-use set of onboard sensors for interaction. It's designed for people who want to get up and running with Arduino without having to learn about the electronics first.
The Esplora has onboard sound and light outputs, and several input sensors, including a joystick, a slider, a temperature sensor, an accelerometer, a microphone, and a light sensor. It also has the potential to expand its capabilities with two Tinkerkit input and output connectors, and a socket for a color TFT LCD screen.
Like the Leonardo board, the Esplora uses an Atmega32U4 AVR microcontroller with 16 MHz crystal oscillator and a micro USB connection capable of acting as a USB client device, like a mouse or a keyboard. (http://arduino.cc/en/Main/ArduinoBoardEsplora 2013)

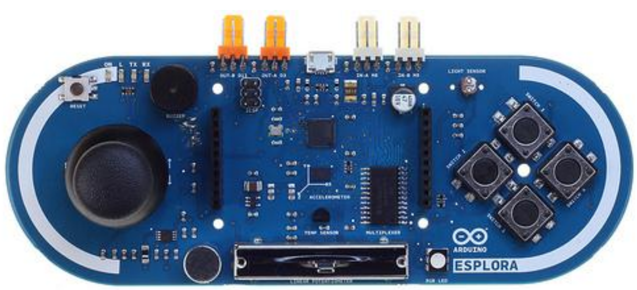
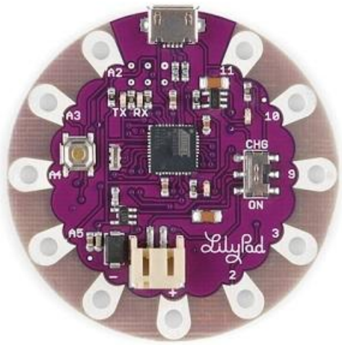


Figure 2.4: Arduino Esplora

(http://arduino.cc/en/Main/ArduinoBoardEsplora 2013)

2.3.1.1.6 LilyPad Arduino USB

The LilyPad Arduino shown in figure 2.5 USB is a microcontroller board based on the ATmega32u4. It has 9 digital input/output pins (of which 4 can be used as PWM outputs and 4 as analog inputs), an 8 MHz resonator, a micro USB connection, a JST connector for a 3.7V LiPo battery, and a reset button. It contains everything needed to support the microcontroller Arduino USB." (http://arduino.cc/en/Main/ArduinoBoardLilyPadUSB



2013)

Figure 2.5 : LilyPad Arduino USB

(http://arduino.cc/en/Main/ArduinoBoardLilyPadUSB 2013)

2.3.1.1.7 Arduino Yun

The Arduino Yún shown in figure 2.6 is a microcontroller board based on the ATmega32u4 and the Atheros AR9331. The Atheros processor supports a Linux distribution based on OpenWRT named Linino. The board has built-in Ethernet and Wi-Fi support, a USB-A port, micro-SD card slot, 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a 3 reset buttons. (http://arduino.cc/en/Main/ArduinoBoardYun 2013)
Because the Arduino Yún has two microcontrollers, two tables have been provided, one for each processor.

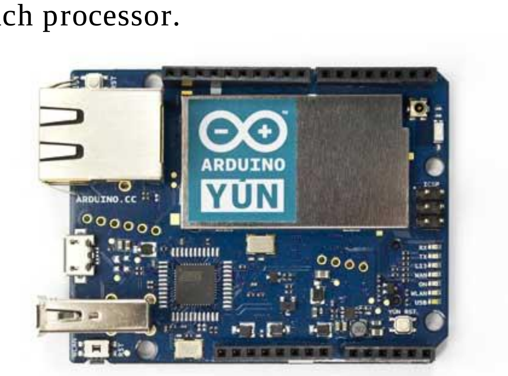


Figure 2.6 : Arduino Yún

(http://arduino.cc/en/Main/ArduinoBoardYun 2013)

2.3.1.1.8 Arduino Mini

The Arduino Pro Mini shown in figure 2.8 is a microcontroller board based on the ATmega168. It has 14 digital input/output pins of which 6 can be used as PWM outputs, 8 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six-pin header can be connected to an FTDI cable or Sparkfun breakout board to provide USB power and communication to the board.
The Arduino Pro Mini is intended for semi-permanent installation in objects or exhibitions. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. The pin layout is compatible with the Arduino Mini.

There are two version of the Pro Mini. One runs at 3.3V and 8 MHz, the other at 5V and 16 MHz.

Figure 8: Arduino Mini

(http://arduino.cc/en/Main/ArduinoBoardProMini 2013)

2.3.1.1.9 Arduino Nano

The Arduino Nano shown in figure 2.9 is a board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove (Due), but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. (http://arduino.cc/en/Main/ArduinoBoardNano 2013)

Figure 2.9: Arduino Mini

(http://arduino.cc/en/Main/ArduinoBoardNano 2013)

2.3.1.1.10 Arduino Fio

The Arduino Fio shown in figure 2.10 is a microcontroller board based on the ATmega328P datasheet runs at 3.3V and 8 MHz. It has 14 digital input/output pins of which 6 can be used as PWM outputs, 8 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. It has connections for a Lithium Polymer battery and includes a charge circuit over USB. An XBee socket is available on the bottom of the board.
The Arduino Fio is intended for wireless applications. The user can upload sketches with an a FTDI cable or Sparkfun breakout board. Additionally, by using a modified USB-to-XBee adaptor such as XBee Explorer USB, the user can upload sketches wirelessly. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. (http://arduino.cc/en/Main/ArduinoBoardFio 2013)

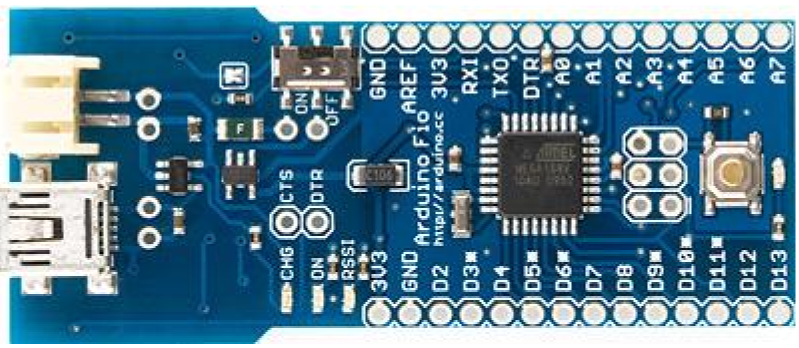


Figure 2.10: Arduino Fio

(http://arduino.cc/en/Main/ArduinoBoardFio 2013)

2.3.1.1.11 Arduino Uno

The Arduino Uno shown in figure 2.11 is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. (http://arduino.cc/en/Main/ArduinoBoardUno 2013)

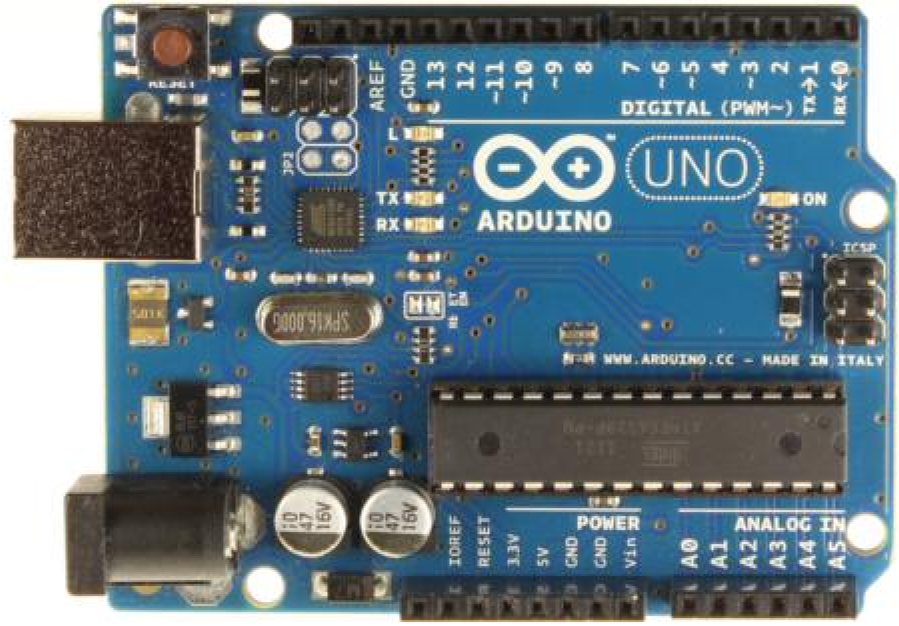


Figure 2. 11: Arduion Uno

(http://arduino.cc/en/Main/ArduinoBoardUno 2013)

2.3.1.1.12 LilyPad Simple

The LilyPad Arduino Simple shown in figure 2.12 is a microcontroller board designed for wearables and e-textiles. It can be sewn to fabric and similarly mounted power supplies, sensors and actuators with conductive thread. Unlike the LilyPad Arduino Main Board, the LilyPad Simple has only 9 pins for input/output. Additionally, it has a JST connector and a built in charging circuit for Lithium Polymer batteries. The board is based on the ATmega328. The LilyPad Arduino Simple can only take up to 5.5 v of power (http://arduino.cc/en/Main/ArduinoBoardLilyPadSimple 2013)

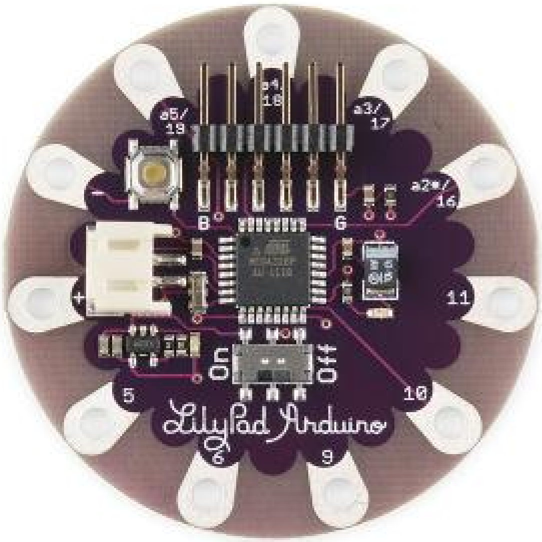


Figure 2. 12: LilyPad Arduino Simple

(http://arduino.cc/en/Main/ArduinoBoardLilyPadSimple 2013)

2.3.1.1.13 LilyPad Simple Snap

The LilyPad Arduino SimpleSnap shown in figure 2.13 is a microcontroller board designed for wearables and e-textiles. It is similar to the LilyPad Arduino Simple, except that it has a built in lithium polymer battery, and instead of through-holes, it has conductive snaps. By using matching snaps in your project, you can affix the LilyPad securely but remove it to wash your project or move it to another project. The LilyPad SimpleSnap has 9 pins for input/output. Additionally, it has a built in charging circuit for the battery. The board is based on the ATmega328. (http://arduino.cc/en/Main/ArduinoLilyPadSimpleSnap 2013)

Figure2. 13: LilyPad Arduino SimpleSnap

(http://arduino.cc/en/Main/ArduinoLilyPadSimpleSnap 2013)

2.3.1.1.14 Arduino Micro

Figure 2.14 below is an image of the Arduino Micro. The Arduino Micro is a microcontroller board based on the ATmega32u4, developed in conjunction with Adafruit. It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a micro USB cable to get started. It has a form factor that enables it to be easily placed on a breadboard. Table 2.13 (below) is a summary of the technical specifications of the Arduino Micro. (http://arduino.cc/en/Main/ArduinoBoardMicro 2013)

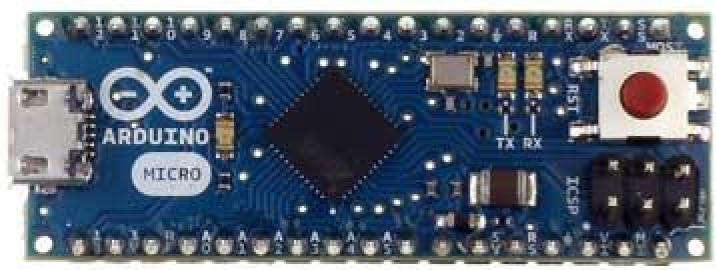


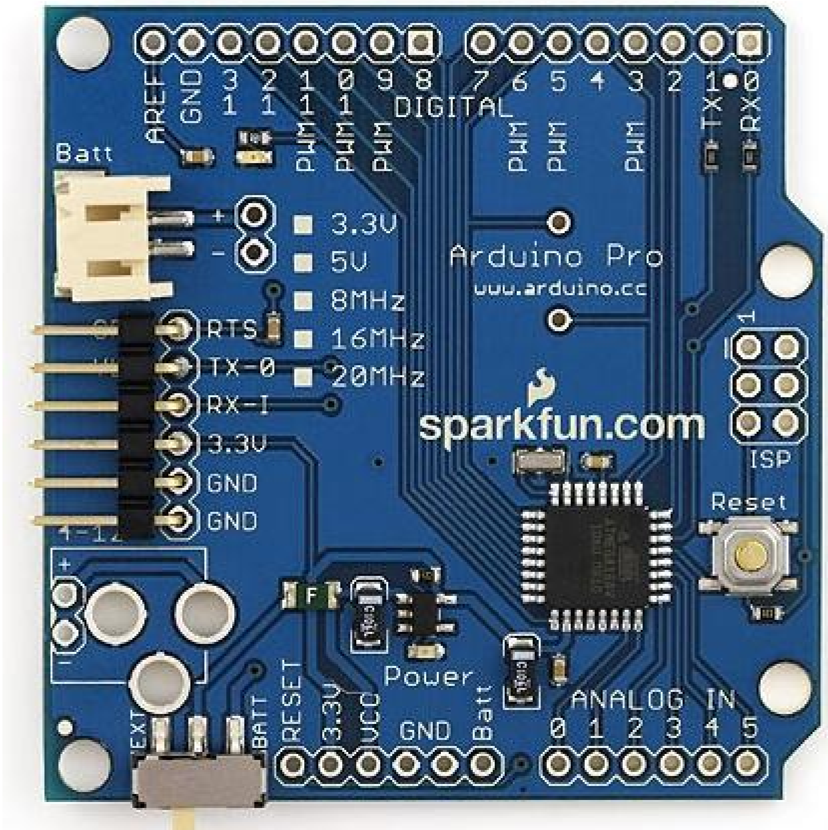
Figure 2.14: Arduino Micro

(http://arduino.cc/en/Main/ArduinoBoardMicro 2013)

2.3.1.1.15 Arduino pro

Figure 2.15 below is an image of the Arduino Pro. The Arduino Pro is a microcontroller board based on the ATmega168 or ATmega328. The Pro comes in both 3.3V / 8 MHz and 5V / 16 MHz versions. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a battery power jack, a power switch, a reset button, and holes for mounting a power jack, an ICSP header, and pin headers. A six-pin header can be connected to an FTDI cable or Sparkfun breakout board to provide USB power and communication to the board.

The Arduino Pro is intended for semi-permanent installation in objects or exhibitions. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. The pin layout is compatible with Arduino shields. The 3.3V versions of the Pro can be powered with a battery. Table 2.14 (below) is a summary of the technical specifications for the Arduino Pro. (http://arduino.cc/en/Main/ArduinoBoardPro



2013)
Figure 2.15: Arduino Pro

(http://arduino.cc/en/Main/ArduinoBoardPro 2013)

2.3.1.2 Raspberry Pi Boards

"The Raspberry Pi shown in figure 2.16 is a credit-card sized computer that plugs into your TV and a keyboard. It's a capable little PC which can be used for many of the things that your desktop PC does, like spreadsheets, word-processing and games. It also plays high-definition video." (http://www.raspberrypi.org/faqs 2013)

Figure 2.16 Raspberry Pi

(http://www.raspberrypi.org/faqs 2013)

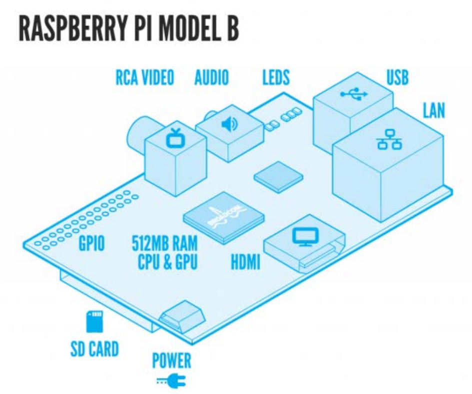


Figure 2.17 Raspberry Pi Components

(http://www.raspberrypi.org/faqs 2013)

2.4 Open Energy Monitoring Systems

Open Energy Monitoring System an end-to-end open-source energy monitoring system that is Arduino IDE compatible is a project to develop an open-source energy monitoring too help the general public relate to their energy consumption, Jacks Phillies energy system, and the challenge of sustainable energy.

The Open Energy Monitor system comprises of wireless sensor nodes that send data at periodic intervals to a web-connected base-station. Currently it is possible to sense: AC Electricity (apparent power, current, voltage, real power, power factor), Temperature, Humidity Pulses (from pulse output utility meters) and Elster IrDA (direct utility meter interface).

The recommended base-station is either a Raspberry Pi with an RFM12Pi wireless adapter board or NanodeRF (Arduino + Ethernet clone). At the moment using the pi requires some knowledge of Linux terminal. The Raspberry Pi can both log the data locally to its SD card and display the data locally (accessing it as you access your home router) or it can be configured to forward the data to a remote server such as emoncms.org. Other base-station options such as the NanodeRF post the data directly to an external remote sever as soon as the data is received from a sensor node.

The Raspberry Pi you will need a small adapter board that enables the PI to receive RF data from the wireless sensor nodes, this board is called the RFM12Pi. Using a small multi-purpose open hardware board called the emonTx it is possible to measure:

- AC currents with clip on CT sensors.
- 1 × AC Voltage with an AC-AC Voltage adapter for isolation.
- Multiple temperatures with one-wire DS18B20 based sensors.
- 1 × Pulse counting input for pulse output meters.

A system could comprise of one emonTx doing everything or, depending on the proximity of meters, the locations you wish to measure temperature, how much cable you want to run etc., you may prefer to install multiple emonTx's around a building with each emonTx carrying out a different function. Each emonTx will need to be given a different wireless node ID. If you already own an Arduino you many want to consider using an emonTx Shield.

There are a series of standard emonTx configurations with associated hardware build notes and Arduino firmware to make the process of setting up the emonTx as easy as possible. Figure 2.18 belo is an image of the emonTx shield with parts labeled. Figure 18 is a slightly older version of the build and some of the minor parts have changed but is a good reference for the main components. is an up-to-date quasi-schematic showing where the individual components are placed on the board.
(http://openenergymonitor.org/emon/guide 2013)

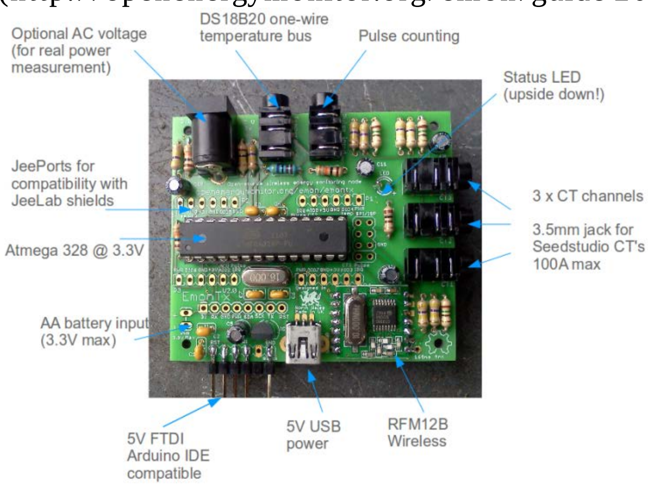


Figure 2.18: emonTx Shield
(http://openenergymonitor.org/emon/emontx/make/assemble/buildguide22 2013)

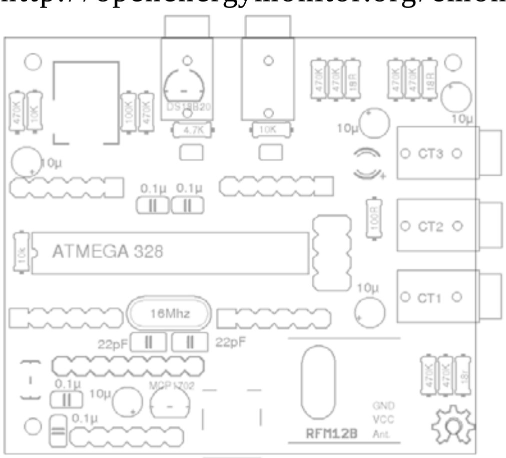


Figure 2.19 emonTx Shield Parts

(http://openenergymonitor.org/emon/emontx/make/assemble/buildguide22 2013)

The step-by-step instructions for assembling the emonTx shield are found at http://openenergymonitor.org/emon/emontx/make/assemble/buildguide22.

2.5 Hardware

2.5.1 Sensors

Some of the sensors that could be used in the device would be for temperature, humidity, energy (replenish or depleting), amount of devices plugged in, daily tasks, etc. A sensor can be make-shifted to sense just about anything desired. (http://www.ladyada.net/learn/sensors/ 2012)

2.5.1.1 CT Sensors

A Ct Censor is a device that is used to interface with an Arduino plugged into the direct voltage to divert the I pulses of the electrons in order for the Arduino to better interpret the information instead of having it overflow with voltage hurt someone. Figure 22 (below) is an image of CT sensors. (http://openenergymonitor.org/emon/buildingblocks/ct-sensors-

interface 2013)

Figure 2.20: CT Sensor

(http://openenergymonitor.org/emon/buildingblocks/ct-sensors-interface 2013)

2.5.2 Switches

Switches are multi-purposed components that help accomplish simple tasks such as a simple off or on switch, alarms, flashing lights, pop-up alerts, etc. A possible switch that could be on the device would stop the use of any further energy usage if the energy level of the device is at critical low. This will keep whoever is using the device to be more aware of energy used. (http://www.ladyada.net/learn/arduino/ 2012)

2.5.3 Display Modules

There are a few main ways users interact with the many devices that are user friendly:

- User Interface (UI)
- Interface Device (IDF)
- Human-Computer Interface (HCI)
- Graphical User Interface (GUI)

By interacting with a computer, the user is allowed to access documents, search on different browsers, create documents, search the web, watch videos, etc. Interacting with devices are more broad now for users because hand-held devices like most cellular phones today have built in CPUs enabling the users to access the web from any place that they want. Interacting with a computer or phone isn't just accessing the web but

simply dragging the mouse, pressing keys on a keyboard, etc.
(http://whatis.techtarget.com/definition/interface-device-IDF 2013)

2.5.3.1 Liquid Crystal Display (LCD)

Many devices laptops and phones enable the user to interact through keyboard or touch screen. The size of these screens have inspired many to create portable multi-purposed devices that allow users to use the many possible functions that these devices contain such as programing, creating and composing works of art, researching, exploring the web, and so much more. Figure 2. 21, below shows a few examples of flat panel displays that use LCDs allowing the user to contact other devices (phones or a type of messenger), play PC games, watch videos, or see what the web has to offer on the device.
(http://www.webopedia.com/TERM/F/flat_panel_display.html 2013)

Figure 2.21 Various LCDs

(http://www.advenira.com/applications-flat-panel-displays.html 2013)

Liquid crystal displays shown in figure 2.22 have a variety of interactions that can supply the user with the desired information ranging from a simple clock to reading the temperature. The liquid crystal display is energy efficient and surpasses other models. The screen itself has a built in backlit allowing the user to still carry on with their daily tasks in the bright of day. The LCD screen has a built in backlit allowing the user to still carry on with their tasks in the bright of day. These screens are made thin and compact which allows much more room for the other components of the device to fit and all the components together help to preserve energy, which is an important factor for this project to contribute to the WetLand Project on the Delaware River.

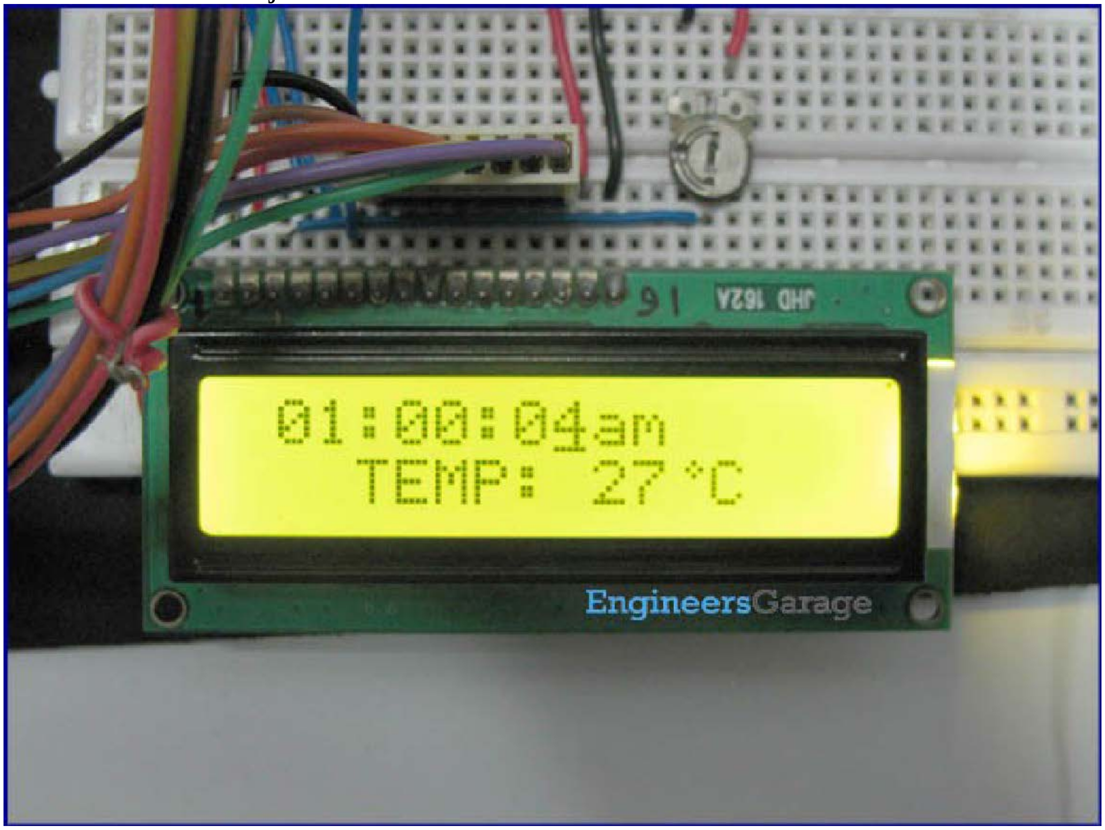


Figure 2.22: Simple LCD Based Alarm Clock

(www.engineersgarage.com/microcontroller/8051projects/digital-clock-with-digital-thermometer-AT89C51-circuit 2013)

2.5.4 LEDs

LED lighting would be the best route in preserving energy in our device. Light emitting diodes take in less energy than any incandescent or CFL, and put out a great deal of lighting. Most LEDs will have their own heat sinks because they produce a large amount of heat, relatively, and properly assembling them to the device will keep it from overheating. Apart from assembling the LEDs to work to the user's advantage, they can be programmed to sense or switch a component in the device. (http://www.energystar.gov/index.cfm?c=lighting.pr_what_are 2013)

2.6 Software

There are many types of software that can help the programing aspect of the project move much smoother. There will be a plethora of time consuming code that has to be programmed into the device we're making, but what if there is a way to make it all much simpler and faster to accomplish. Searching for an application programming interface (API) will cut down the workload for us and contribute significantly. An API is the process of putting information in and getting information out of your system without having to type it yourself. (www.headshift.com/our-blog/2009/06/03/whats-an-api-and-why-do-i-want/ 2013) Finding the right API and letting the group access the software would be something to look into.

2.7 Microchip Power Supply

The programmable microchip can be power from an external source or from a USB lead. The user must decide how much amps (power) is necessary to run the board since the USB provides a maximum amount of power at 500 milliamps (mA). Some USB leads only provide up to 100mA. The standard Arduino (brand of programmable microchip) has two sockets for connecting power, USB and external (AC powered supply or battery pack). (Margolis 2012) For specific power requirements see table () in appendix c.

2.7.1 AC/DC Current

Batteries, fuel cells and solar cells all produce something called **direct current** (**DC**). The positive and negative terminals of a battery are always, respectively, positive and negative. Current always flows in the same direction between those two terminals.
The power that comes from a power plant, on the other hand, is called alternating current (AC). The direction of the current reverses, or alternates, 60 times per second (in the U.S.) or 50 times per second (in Europe). The power that is available at a wall socket in the United States is 120-volt, 60-cycle AC power. (Brian et al. 1998)

2.8 Wetland Power Supply and Systems

WetLand will be powered with electricity produced by the solar panels connected to four 12 colt batteries. The amount of sunlight and arrangement of batteries will affect the amount energy the system can produce. The inhabitants of WetLand will be able to plug-in their laptops and cell phone while living on WetLand. Also, depending on the type of inverter being used, the system will have a certain amount of sockets to connect devices to the system. (Mary Mattingly 2013)

2.8.1 Solar Energy System

A solar, or photovoltaic (PV), off-grid energy system is composed of, at minimum, two components. A set of solar panels that produce a DC current that travels to a DC load (light bulb etc.). One can also add batteries to store the energy produced. Also, a charge controller is sometimes added to prevent the batteries from overcharging.WetLand inhabitants will be charging cell phones and laptops, the system is going to require an off-grid inverter; this piece of technology, converts what would normally be DC current, into the AC current found in homes and required for devices like laptops and computers. Below, Figure 2.19 is a simple drawing of an off-grid solar energy system.
(http://www.appropedia.org/Photovoltaics 2013)

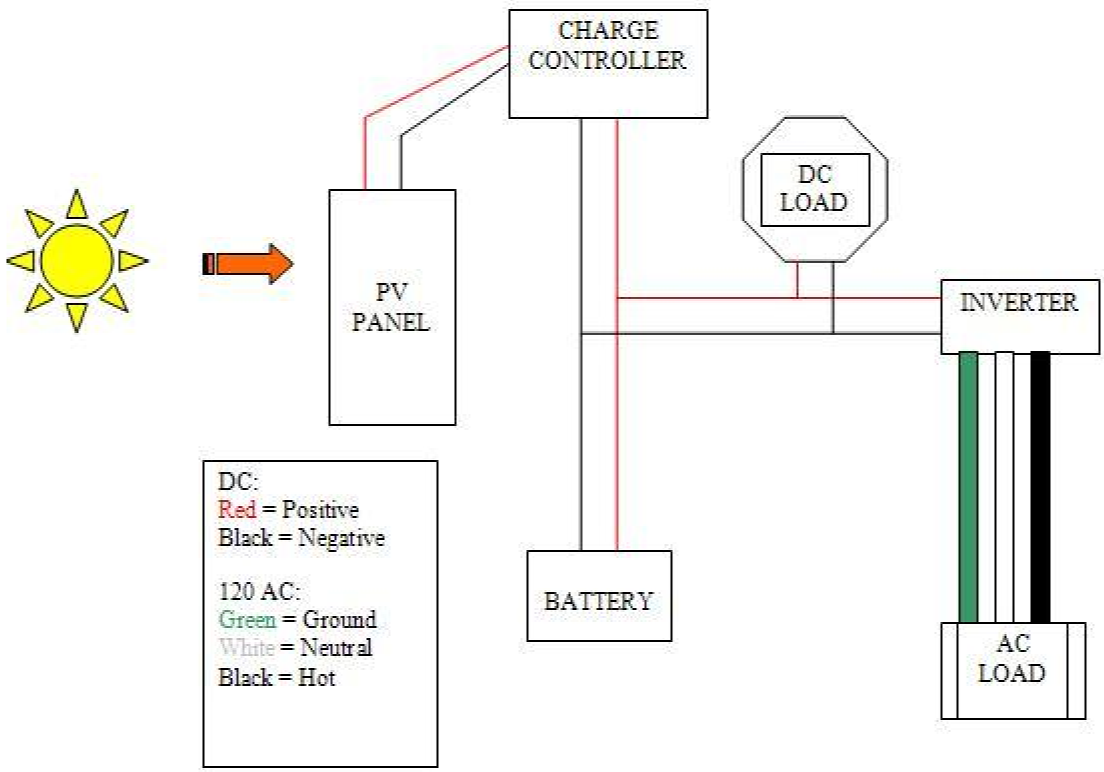


Figure 2.23: Solar Powered Off-Grid System (http://www.appropedia.org/Photovoltaics 2013)

2.8.2 Batteries

There are four batteries being used on WetLand, all four are the Concorde Sun Xtender PVX-560T. These are 12volt(v) batteries with 56-ampere hours (Ah). The storage of the battery is important and plays an essential role in determining the efficiency of the system. The manufacture recommends that the batteries should be preferably not exceeding 20°C (68°F). The higher the temperature, the faster the battery will self-discharge and require boost charging. (Concorde Battery Corporation 2011)
Figure 21, Figure 22 and Figure 23 show various arrangements of the batteries and the effects of each.

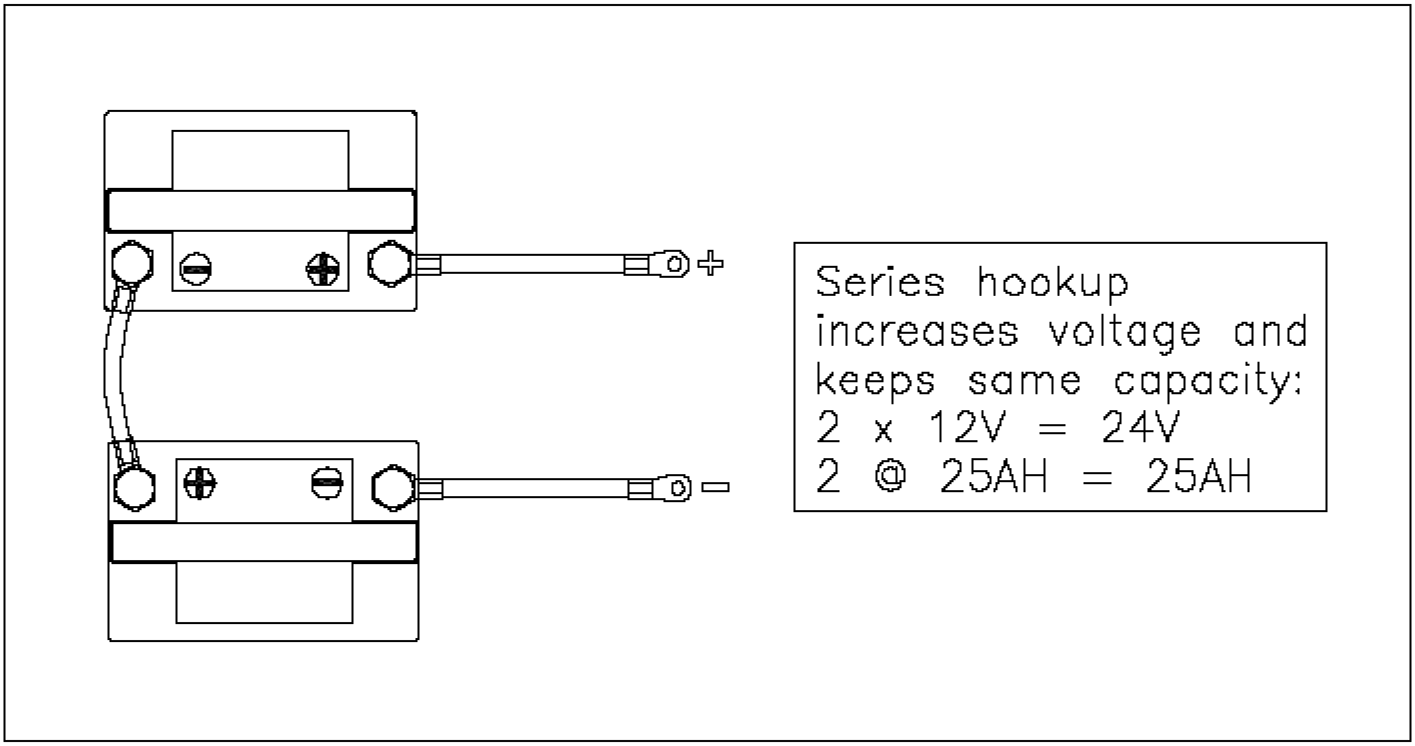


Figure 2.24: Battery Arrangement 1

(Concorde Battery Corporation 2011)

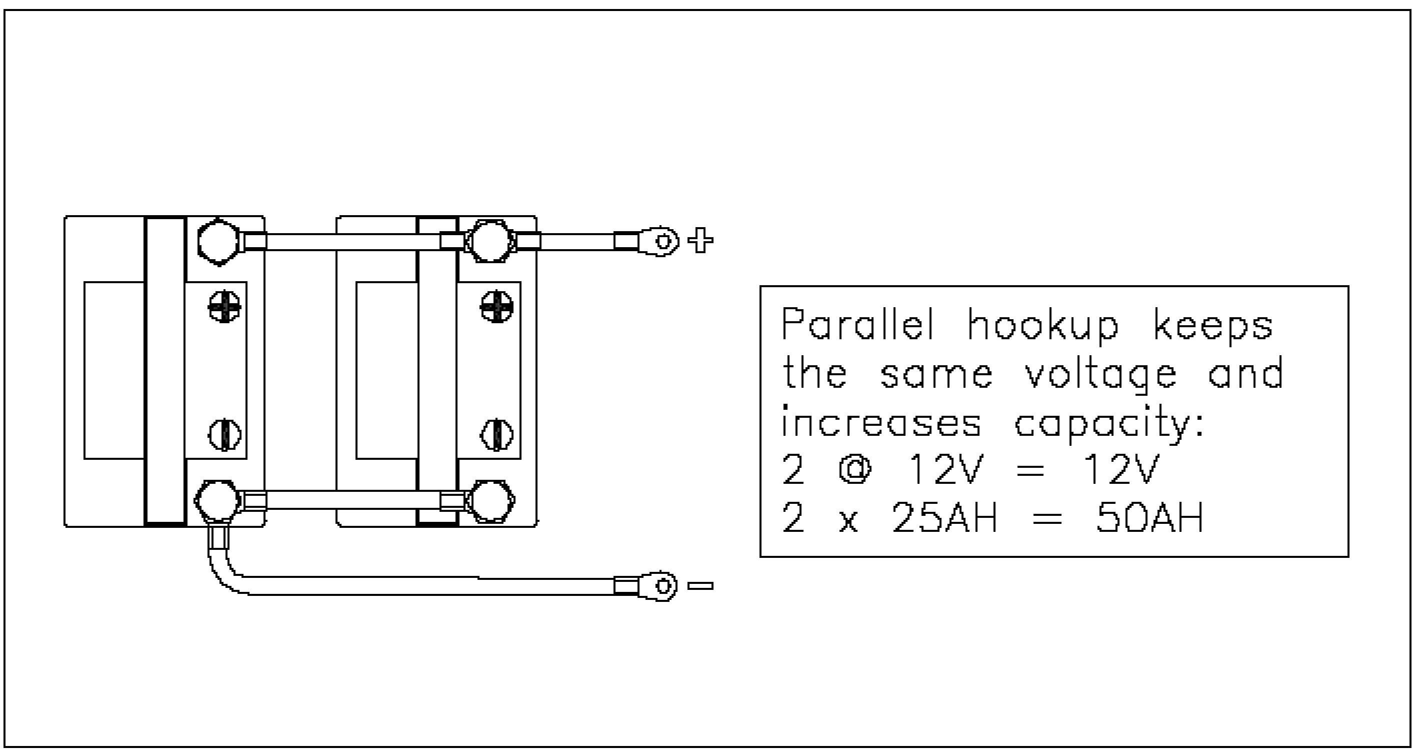


Figure 2.25: Battery Arrangement 2

(Concorde Battery Corporation 2011)

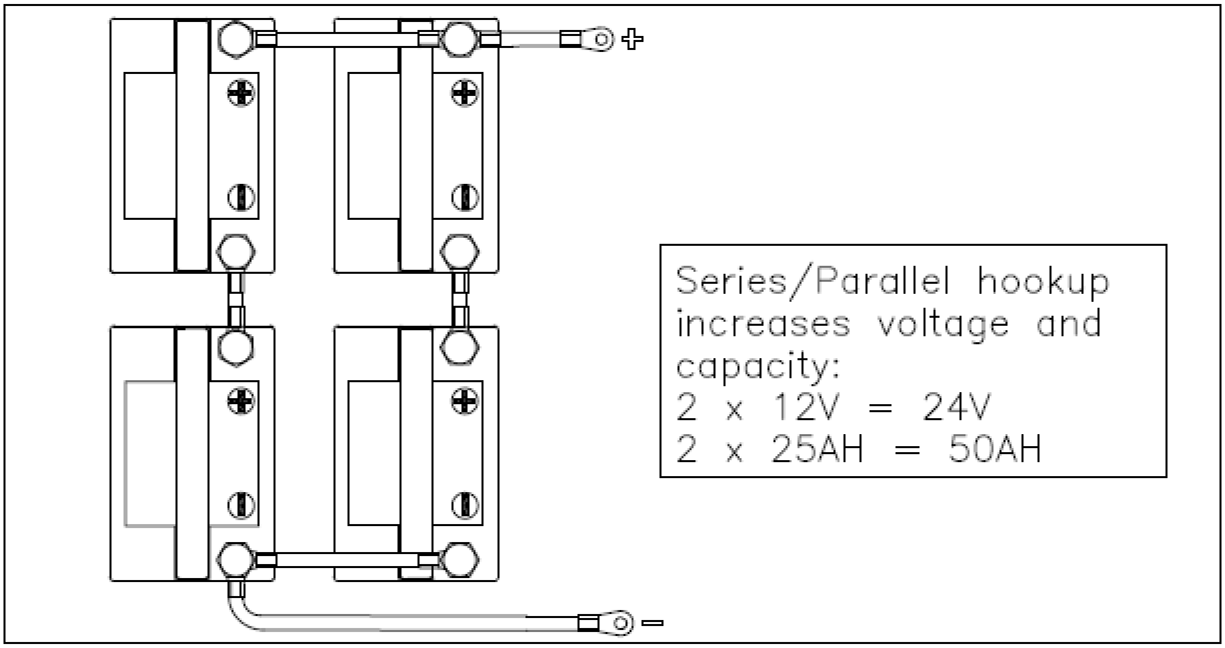


Figure 2.26: Battery Arrangement 3

(Concorde Battery Corporation 2011)

2.8.3 Solar Panels

WetLand is employing two Sharp ND-30QCJ 290w 29v polycrystalline solar panels. (Mary Mattingly 2013) Table 1 (below) is a summary of the technical specifications of a single Sharp ND-30QCJ 290w 29v solar panel.

Table 12 Solar Panel Specs

Maximum power (Pmax)	230 W
Open-circuit voltage (Voc)	36.9 V
Maximum Power Voltage (Vpm)	29.3 V
Short-circuit current (Isc)	8.45 A
Maximum Power Current (Ipm)	7.85 A
Module efficiency	14.1 %

(http://www.ecodirect.com/Sharp-ND-230QCJ-230W-29V-Solar-Panel-p/sharp-nd-230qcj.htm 2013)

2.9 Flock House Hyper Visible Power Meter

This power meter was an ENGR 215 project from fall 2011. Team Stark Industries were responsible for designing a power meter that displays two types of data: the status of the battery and the power generated. (below) is an image of the final design of the Hyper Visible Power Meter. The display had to be clearly visible from at least 20 feet away and

aesthetically pleasing. This monitor was designed to track energy produced by a bike powered generator and the status of charge on batteries. Team Stark Industries employed an Arduino LilyPad as the brain of the Hyper Visible Power Meter; the display is a ring of LEDs placed between two mirrors, creating the illusion of infinity. Table 3 (below) is a list costs and materials used. Step-by-step instructions for building the Hyper Visible Power Meter can be found at:
http://www.appropedia.org/Hyper_visible_power_meter_instructions.

Figure 2.27: Hyper Visible Power Meter

(http://www.appropedia.org/Flock_House_Hyper_Visible_Power_Meter 2011)

Table 3 Hyper Visible Power Meter Materials Costs

Materials	**Use**	**Quantity**	**Estimated Total Price**	**Actual Price**
Aluminum plates	Frame to support meter	15	$150.00	$0.00
Arduino Lily pad micro-controller	Electronics to measure power	3	$39.99	$39.99
Wheels	Transportability	4	$25.00	$0.00
Aluminum tubing	Supports meter	4	$20.00	$0.00
LED lights	Visibility	100	$6.99	$6.99
Circuit board	Electronics to measure battery	1	$42.00	$42.00
Electronic wires	Electronics	5	$1.00	$0.00
Electrical conduit	Protects wires	1	$24.00	$24.00
Silicon caulking	Seal housing against elements	1	$6.00	$6.00
Total Cost	**$314.98**	**$118.98**		

(http://www.appropedia.org/Flock_House_Hyper_Visible_Power_Meter 2011)

2.10 Laurel Tree School Energy

The Laurel Tree Energy Use Visualization was an ENGR 215 project in fall 2012. The Lonely Protons was the team in charge of designing this monitoring technique. Figure 25 (below) is an image of the final design. The Lonely Protons' objective was to design an energy monitor with the ability to display energy use in a way that anyone could understand. Energy usage was obtained from the breaker box of Laurel Tree Charter School, sent to a micro-controller; that, depending on usage data, used a changing color light source to illuminate a quartz crystal green, yellow or red, based on current energy use. The Lonely Protons employed an emonTx shield to collect energy data, and a Nanode 5v as the micro-controller. Table 3 (below) is a list of all parts used and associated costs. (http://www.appropedia.org/Laurel_Tree_Charter_School_energy_use_visualization 2012)

Figure 2.28: Laurel Tree Charter School Energy Use Visualization

(http://www.appropedia.org/Laurel_Tree_Charter_School_energy_use_visualization 2012)

Table 4: Laurel Tree Charter School Energy Visualization Costs

Material	Cost
Nanode v5 Kit	$39.99
emonTx 433Mhz kit	$47.00
CT Sensor	$23.15
JeeLabs RFM12B Board	$21.95

Fiber Optic Line	$26.00
BB400T Breadboard	$5.50
Electrical Wall Housing	$3.99
Miscellaneous Hardware	$2.00
Super Glue	$6.29
Lamp Housing	$8.99
Fishing Wire 8lb Test	$2.69
Engraved Plaque	Donated
Surge Protector	Donated
2 USB Cables	Donated
Quartz Crystal	Donated
Wood	Donated
Lexan	Donated
Total	**$185.69**

(http://www.appropedia.org/Laurel_Tree_Charter_School_energy_use_visualization 2012)

3 Alternative Solutions

3.1 Introduction

During brainstorming sessions alternative solutions of design were discusses and researched. Each of these designs satisfies the objective statement and the criteria. A total of 11 alternative solution designs were developed during our brainstorm sessions.

3.2 Brainstorming

The brainstorming methods used was a cloud/bubble technique. That technique involved selecting major components of the energy monitoring such as display, microcontroller, lighting, etc. Images and list of jack's Phillies brainstorm sessions can be found in Appendix B.

3.3 Alternative Solutions

3.3.1 The Energy Station

The Energy Station is a power meter light post. The microcontroller sits inside an outdoor switch box attached to a post. An umbrella shaped weather durable material is attached to the top of the post protecting the different components. Above the switch box is the display, and above the display is an interpretive sign that explains the enrgy monitor, and whatever else the client wants it to say. The figure below is a sketch of the Energy station. The lights can serve as a release of excess energy if the batteries begin to get over charged, as well as an alert system if energy is being depleted too fast.

3.3.2 Tweet-A-Watt

The tweet-A-Watt is an open source energy monitor developed by www.ladyada.net. The tweet-A-watt is Lady Ada's design, optimized for the inverter being used on wetland. Sio instead of one plug in and one LCD, Tweet-A-watt has two of each. This system sends data wirelessly and stores it as cloud data, making it accessible to multiple parties all at once, on or off wetland. The Tweet-A-watt also has an interpretive sign explaining the energy monitor as well as a battery and PV monitor sending data wirelessly. The figure below is a sketch of the tweet-A-watt. The addition to the invertor serves as a monitor for individual devices used. The application to the battery and PV wire serves as a monitor for the energy being produced and the energy stored in the batteries. This data is sent wirelessly through a hotspot provided by the client. After programmed calculations the data represents familiar and pertinent units of energy. This could then be used as an alert system via text message or e-mail.

3.3.3 Simple& Effective(S&E)

Simple& Effective shown in a sketch in figure()is a design inspired by the Humboldt State University installation on the Music Building. S&E consist of a basic microcontroller to process data and convert it into familiar units, an LCD displaying energy produced current day, energy used current day, the date and time, and finally an interpretive sign explaining the system.

3.3.4 Looper

An LED array term used for LEDs placed closed together going on and off at programmed times, creating words, images, or even animations. The Looper consist of a circular LED array mounted around the upper portion of a 6-7 foot post with a microcontroller sending a self-updating loop of information at timed intervals for the LEDs to display. The information displayed will be similar to the information displayed in S&E solution; however, with a LEd array it is possible to create some-eye-catching displays. The array also serves as an alert system for energy consumption. The microcontroller is of the basic variety.

3.3.5 Holographic Displays

Holographic displays shown in figure 2.13 gives the viewer a 3-D view of an object or description of choice that is suspended in mid-air. This device will be used to display helpful and easy to understand energy monitoring information. The holographic display system has an already programmed unit converter that makes the whole process of knowing how much energy is being consumed by devices or not much simpler. Simply type in desired information about any device on the barge connected to an outlet, and the energy monitor shows the amount of energy being consumed by the device and how it affects the overall energy consumption. The cost for a holographic display is low. The only thing bought was the glass with the right dimensions, an LCD screen. The software to make the objects or description appear in 3D is free.

Figure 3.4 Holographic Display

3.3.6 EnerJar

The EnerJar2.0 is an upgraded version from the previously manufactured device. This device reads an amount of energy being consumed from any device such as refrigerators, toasters, laptops, phone chargers, etc. The Enerjar 20 gives the view multiple unit conversion calculation just by pressing the desired unit such as watts, volts, amps. All of this information is displayed on a simple LCD within a jar structure. The structure itself for the display and all of its components are being placed in a 3D printed plastic jar. This made the device much safer from the previous model, because of the "problem stem from a lack of isolation between the AC line and the low-voltage circuitry.'; the cost for printing the jar model was done through HSU, but the price was reasonable for the plastic, the simple LCD, power outlet connectors, and the low-voltage circuitry.

3.3.7 Sound Board Alarms

The device being used will alert the user if the usable energy on the barge is reaching a critical low. This device gives the user a list of alerts and sounds to choose from. These alerts range from alarms, sounds, music, or humorous quotes from movies. To project the urgency in the alerts the designer made a, make-shifted from old speakers to be placed around the compound as surround sound alarming the inhabitants when the energy level us at critical low. This alarm system will be hooked up to the energy monitor system we created. The costs for the speakers were affordable since the designer found them at shops. There was no cost for the sounds, alarms, and other noises.

3.3.8 Battery Alarm

The device being used will alert the user if the usable energy on the barge is reaching a critical low. This device gives the user a list of alerts and sounds to choose from. These alerts range from alarms, sounds, music, or humorous quotes from movies. To project the urgency in the alerts we make-shifted from old speakers to be placed around the compound as surround alarming the inhabitant when the energy level is at a critical low level. This alarm system will be hooked up to the energy monitor Jack's Phillies have constructed. The cost for the speaker were affordabkle since jack's Phillies found donators.

3.3.9 Interactive Units with TFTs

Interactive Units with TFTs use a smart phone to be interactive with the load of monitoring the energy consumption. The architecture of this system is based on three independent elements. The smart meter monitors and logs the energy consumption by the sensors. The second element consists of a small parser, a database, and a tiny web server. To acquire the logged data from the Landis+Gyr m=smart meter E750[3] on a continuous basis in real time, the Smart message language(sml) parser automatically pols the meters data and stores it in a SQL database. In order to enable interoperability with other applications, the web server offers access to the gateway's functionality and the smart meters sensor values using URLs.

3.3.10 OpenEnergyMonitor.org

Open-Source Energy Monitor shares much of the same principles and approaches. Free and open-sourced software and code are available to the public to mix and match to make their own energy monitoring systems. There are two types of ways the WetLand personnel can go about implementing these systems, wireless or wired, but first the personnel will need to establish the type of electrical current you are being able to be access to. This limits the hardware, because there is only so much you can do with wireless systems if our energy supply is dc or ac.

4 Decision Phase

4.1 Introduction to Decision Phase

Section Four describes jack's Phillies decision process and finals decision justification. In this section you can find a list of criteria and constraints , the Delphi Matrix, a list of alternative solutions, and a final justification.

4.2 Criteria Definition

Safety-

Preventing the battery from exploding and keeping Wetland personnel from electrical shock is our priority.

Cost-

The cost of all material for the Energy monitor must be 400 dollars or below.

Power Usage-

The energy monitor will draw no more than 5% of overall PV's power capacity.

Maintainability-

This design will require up to one hour of maintenance per week. With our wireless design maintenance can be done for some components off the barge.

Accuracy-

The accuracy of data collected and calculated by our energy monitor will be within 55 of the actual power supply and production.

Interpretability-

The data displayed will be icon and symbol heavy, with multiple languages for the visitors and inhabitants of the barge

Durability-

The energy monitor will be stationary, but must withstand the elements

Aesthetics-

The aesthetics of the energy monitor will have a minimalistic design, yet somewhat futuristic.

4.3 Solutions

The following is a list of the alternative Solutions

- Looper
- S&E
- Tweet-a-watt
- Energy Station
- Holograph
- Battery Alarm
- Sound Board Alarm'
- EnerJar 2.0
- Led+Sign
- TFT
- Tablet

Criteria Calculations for each alternative solution can be found in Section 3.

4.4 Decision Process

The Delphi Matrix was brought in to help determine the solution Jack's Phillies implemention. This technique starts with determining criteria for the overall project and assignment a weight to each. A scale from 1-10 is used for each criteria, 10 being very-important and one being of low importance. After determining criteria and weights for each alternative solution it is time to choose. Some totals were very similar, so table 5 below shows The Delphui Matrix for the alternative solutions that Jack's Phillies came up with.

4.5 Final Decision & Justification

The Final result of the Delphi Matrix and client feedback resulted in choosing the Simple and Effective style solution. This energy monitoring is a wired version, making the data easy to be interpreted using an LCD display. Some components of the system can be maintained from outside the barge. The LCD makes it easy for the personnel to relate to their energy consumed, produced, and stired by portraying it in the screen. This makes the inhabitants a one-stop update on WetLand's system.

5 Specification of Solution

5.1 Introduction

The Specification of solution section describes the technical aspects of our design solution. Beginning with a description of the design and breakdown of cost associated. This section then provided implementation instructions as well as a summary of the prototype's performance.

5.2 Solution Description

5.3 Cost Analysis

5.3.1 Design(hours)

The design cost are the cost that where obtained by the Energy Monitoring System. The cost are measured in hours for each of these phases, as seen in figure . The total hours spent where
.

5.3.2 Construction($)

Jack's Phillies Contraction cost are broken down into price, tax, and shipping. Table shows the final cost of our finished product. Some pieces were generously donated by Colin and Marty in the machine shop. Their time and experience could very-well be considered a consultant type of cost.

5.4 Maintenance

The device is water-proofed making it safe and easy to maintain. The Plexiglas shell would need to be cleaned off once in a while. The system will undergo a restart at a given time to keep it running efficiently.

5.5 Implementation Instructions

5.6 Prototype Performance

6 Appendices

6.1 Refrences

O'Donoghue, Niall. "Interface Device (IDF)." What Is ? N.p., Dec. 2010. Web. 04 Oct. 2013.
QuinStreet Inc. "Flat-panel Display." Webopedia. N.p., 2013. Web. 04 Oct. 2013.
(http://www.appropedia.org/Laurel_Tree_Charter_School_energy_use_visualization 2012)
(http://www.appropedia.org/Laurel_Tree_Charter_School_energy_use_visualization 2012)
(http://www.appropedia.org/Flock_House_Hyper_Visible_Power_Meter 2011)
(http://www.ecodirect.com/Sharp-ND-230QCJ-230W-29V-Solar-Panel-p/sharp-nd-230qcj.htm 2013)
(Concorde Battery Corporation 2011)
(Bielman et al. 2011)
(http://www.appropedia.org/Photovoltaics 2013)
(Mary Mattingly 2013)
(Margolis 2012)
(www.headshift.com/our-blog/2009/06/03/whats-an-api-and-why-do-i-want/)
(http://www.ladyada.net/learn/arduino/ 2012)
(http://www.ladyada.net/learn/sensors/ 2012)
(http://www.energystar.gov/index.cfm?c=lighting.pr_what_are 2013)
(www.engineersgarage.com/microcontroller/8051projects/digital-clock-with-digital-thermometer-AT89C51-circuit 2013)
(http://www.advenira.com/applications-flat-panel-displays.html 2013)
(http://www.webopedia.com/TERM/F/flat_panel_display.html 2013)
(http://whatis.techtarget.com/definition/interface-device-IDF 2013)
(http://openenergymonitor.org/emon/emontx/make/assemble/buildguide22 2013)
(http://openenergymonitor.org/emon/guide 2013)
(http://openenergymonitor.org/emon/ 2013)
(http://www.raspberrypi.org/faqs 2013)
(http://arduino.cc/en/Main/ArduinoBoardPro 2013)
(http://arduino.cc/en/Main/ArduinoBoardMicro 2013)
(http://arduino.cc/en/Main/ArduinoLilyPadSimpleSnap 2013)
(http://arduino.cc/en/Main/ArduinoBoardLilyPadSimple 2013)
(http://arduino.cc/en/Main/ArduinoBoardUno 2013)
(http://arduino.cc/en/Main/ArduinoBoardFio 2013)
(http://arduino.cc/en/Main/ArduinoBoardNano 2013)

(http://arduino.cc/en/Main/ArduinoBoardProMini 2013)
(http://arduino.cc/en/Main/ArduinoBoardYun 2013)
33
33
Jack's Phillies Energy Monitoring System
(http://arduino.cc/en/Main/ArduinoBoardLilyPadUSB 2013)
(http://arduino.cc/en/Main/ArduinoBoardEsplora 2013)
(http://arduino.cc/en/Main/ArduinoBoardLeonardo 2013)
(http://arduino.cc/en/Main/ArduinoBoardDue 2013)
(http://arduino.cc/en/Main/ArduinoBoardBT?
from=Main.ArduinoBoardBluetooth 2013)
(http://www.ladyada.net/learn/avr/whatisit.html 2012)

6.2