Proposal

Solar Powered Smart Blind System

ECE4007 Senior Design Project

Section L04, DK-1

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Executive Summary

Solar Powered Smart Blind (SPSB) is an autonomous, self-sustaining window blind system. The SPBS system will automatically adjust the amount of the light that gets through depending on a user preference while operating solely on solar power. The reason for the construction of the SPSB system is to minimize the user interaction with blinds, therefore, increase living comforts. There is a profitable market for automated window blinds. Potential users for the Solar Powered Smart Blind system include senior citizens, the disabled, individuals who are willing to adopt environment-friendly smart devices, and home automation enthusiasts. The finalized SPSB prototype will consist of four photo sensors, stepper motor for controlling the blind, Arduino microcontroller, and a user interface device. The photo sensor will transmit information to the Arduino microcontroller, which will then interpret the incoming data and send necessary control signals to the stepper motor to adjust the blinds. The time, date, room temperature, and current user selected mode will be displayed on a Liquid-Crystal Display (LCD) that is integrated into the user interface device. The SPSB system will incorporate power-saving algorithms to guarantee low power consumption. The total cost of the Solar Powered Smart Blind system will be $72,020, with $320 spent on materials, $46,700 spent on design and labor, and $25,000 spent on marketing. The suggested retail price of the finished product will be at $300. The working Solar Powered Smart Blind system will be demoed on April 2009.

Solar Powered Smart Blind System

1. INTRODUCTION

1.1 Objective

The purpose of the Solar Powered Smart Blind (SPSB) system is to provide convenient, automated control of the amount of sunlight that is let through depending on the time of the day and the light intensity. Utilizing solar power to sustain its operation via batteries, the system will also incorporate digital displays of time and temperature. The SPSB system is the integration of modern electronic control circuitry with ordinary window blind sold in department stores and furniture outlets.

1.2 Motivation

Energy consumption is an enormous concern in the 21st century. The SPSB system can provide convenience while using energy that comes directly from the sun. It is particularly complimentary to people with limited mobility such as the disabled and senior citizens. Although the system will be more expensive than the currently available blinds, there will still be a profitable market for the product within the middle and upper class. If a device is within purchasing power, people are willing to incur a higher cost so that they may avoid performing trivial acts, in this case, turning the blinds every day. Examples of this tendency can be commonly seen in the household from dishwashers to automated vacuuming robot.

1.3 Background

Both electric and ordinary window blinds are available for purchase through the internet and retail stores. Manually-adjusted window blinds have prices as low as $20 while electric blinds range from $50 to $300. The most sophisticated version on the market incorporates stepper motors that are controlled remotely to turn the blinds [1]. Batteries are required to power the motors as well as the remote; therefore, battery replacement is necessary. There are also non-commercialized smart blinds constructed by individuals who are interested in the topic. One particular prototype relied on four photo-detectors to determine the sun light intensity and adjusts the angle of the blinds accordingly [2]. Other feasible approaches to implement a smart blind system include tracking the angle of the sun and voice-recognition. However, prototypes operating under either of these principles have not been constructed [3].

None of the blind systems mentioned above is fully automatic. Although the remote-controlled blinds are more convenient than the non-electric blinds, they still require the user to give an input. The light-sensitive blind may be able to regulate light passage during the day, but the users, nonetheless, need to manually close the blind at night time. In addition, all the electric blinds introduced thus far do not have self-sustaining capability, as they depend on external power or batteries to operate.

2. PROJECT DESCRIPTION AND GOALS

Window blinds in homes have to be manually adjusted throughout the day to account for changes from outside luminescence and temperature conditions. Solar Powered Smart Blind is a microcontroller-embedded system that automatically adjusts itself in real time to account for variations between indoor and outdoor luminescence conditions. The automation of the SPSB system is accomplished by making use of photo-sensors integrated into the blinds. The power supply for the system will be recharged with solar panels attached to the window to capture maximum sunlight.

The goal of the SPBS system is to fully automate the process of adjusting window blinds throughout the day based on a user provided input mode. SPSB adopters should be able to select a luminescence intensity level from a rotary dial that serves as a user input interface. Marketable consumers include senior citizens, disabled people, home automation enthusiasts, and individuals who are willing to adopt environment-friendly smart devices. The SPSB system will be designed with the following goals:

- Product price will be around $300
- Energy efficient
- Auto adjust based on user input parameters
- Environment-friendly
- Solar rechargeable
- Easy installation
- Manual override
- Fabricate a working prototype by early April 2009

3. TECHNICIAL SPECIFICATIONS

Sensor Data Processing System

The Arduino Duemilanove microcontroller, an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software, will be used to process incoming sensor data. The microcontroller contains a 16MHz crystal oscillator and an ATmega168 chip on board with 14 digital I/O pins, six of which can be used as PWM (Pulse Width Modulation) outputs [4]. The multichannel inputs and outputs on the Arduino will allow processing of several sensors simultaneously, which is an important part for cross-algorithm. A further hardware specification of the Arduino board is provided below in **Table 1**.

Table 1 – Arduino Duemilanove Microcontroller	
Model	
Brand	Arduino
Series	Duemilanove
Specifications	
Microcontroller	ATmega168
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 Pins
	6 pins provide PWM output
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	16 KB
	2 KB used by bootloader
SRAM	1 KB
EEPROM	512 Bytes
Clock Speed	16 MHz

User Interface (Input / Output)

The user controls for the SPSB system will include light intensity mode select, manual override, window blind open/close button, and a LCD display for data representation. The user interface device can be seen in **Figure 1**. The functionalities of button and rotary dial will be transmitted to the Arduino microcontroller for processing.

The user interface device for the SPSB system will comprise of brackets that allow mounting of the device in proximity of the window. The temperature reading for the room will be done with a DS1621 I^2C chip that will be mounted on the outside of the user control device for accurate temperature sensing of the room. **Table 2** describes the button functions of the interface device.

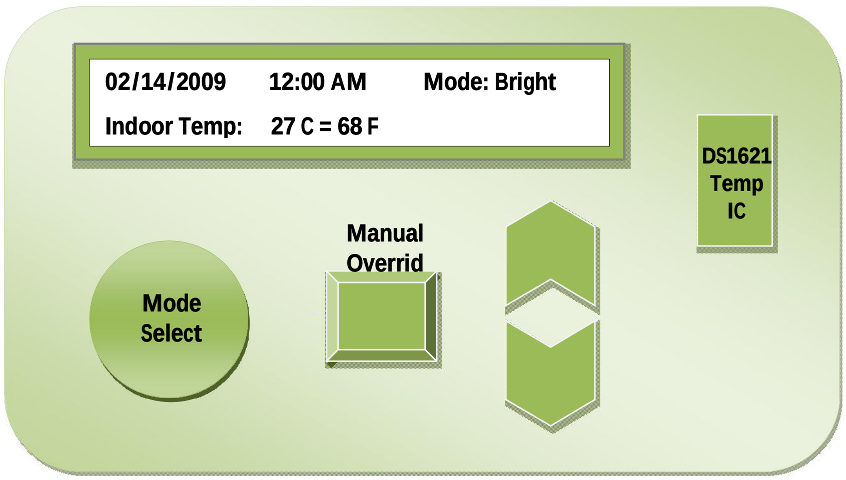

Figure 1. Solar rechargeable smart blind user interface.

Table 2 – User Interface Device	
Controls	**Function**
Mode Select	Selects brightness mode
Manual Override	Overrides the microcontroller's automatic mode for user adjustments
Arrow Keys	Tilts the blinds up and down for the user
DS1621 Temp IC	Mounted outside the box for sensing room temperature
LCD Display	Displays various information for the user to see

Physical Weight & Size

The four photo-resistors will be placed on the strings of the blind in a vertical line formation. The wiring required for connections of various sensors and components will be done with RJ-45 cable to achieve a clean installation of the SPSB system. Ideally, the solar smart blinds, consisting of stepper motor and a user interface device should be able to function on any house hold windows. However, due to the wide diversity of window arrangements, shapes, and sizes, the testing of the SPSB system will be confined to a small standard window size. A 23" X 64" bamboo blind will be utilized and the blind will weigh around 10 lbs. as shown in **Figure 2**.

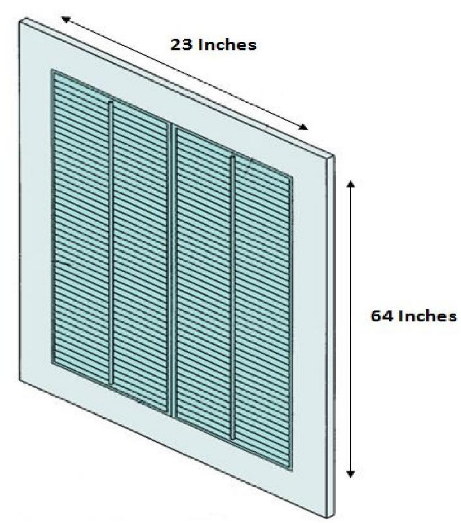

Figure 2. Bamboo Blind dimension (23" X 64") and weight (~10 lbs.).

Software & Power Supply

The software required for controlling the stepper motor, reading sensors, and communicating with I^2C chips will be written in C/C++ within the Arduino version 0012 integrated development environments (IDE). The open-source Arduino environment makes it easy to write code and upload it to the I/O board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing, AVR-GCC, and other open source software [4].

To minimize power consumption, various sleep modes will be utilized. The rechargeable batteries to be used in powering of the SPSB system will range from 9V to 12V as listed in **Table 3**. The recharging process will be achieved during the day time, but the system will also consume solar power when needed [5]. The SPSB system is operational during the day time and will remain in power down state during the night time to limit power consumption. The real-time clock (RTC) will be used to check the time to power off the SPSB system during night time.

Table 3 – Rechargeable Battery Specification	
Voltage Requirement	9 Volts – 12 Volts
Full Charging Time	3 Hours
mA Hour Rating	230mAh
Chargeable Quantity	~ 1000 times
Memory Effect	No memory effect

Motorized & Manual Adjustments

The software written for the solar blind system will be able to operate autonomously, and it will be able to take in user manual controls. Signals from the Arduino microcontroller will be sent to the stepper motor control driver to adjust the blinds. To achieve physical aesthetics, the stepper motor will be mounted inside the frame of the blind, as illustrated in **Figure 3**.

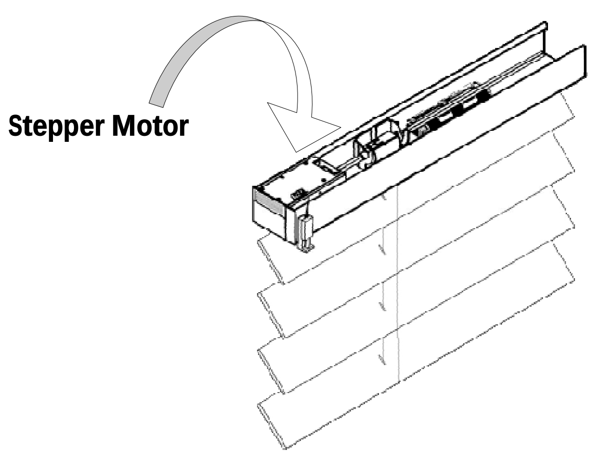

Figure 3. Stepper motor mounted inside the frame of the blind.

A 5V stepper motor will be used to control the physical movements of the SPSB system. The stepper motor is illustrated in **Figure 4**. Specifications for the stepper motor are described as follow:

- Manufactured by Symbol Technologies
- Operates on 5VDC

- 2 phase bi-polar / quadrature motor
- 20 steps per revolution
- Motor includes a printed copy of a simple driver circuit schematic
- Driver circuit schematic uses 1 - 74HC86, 1 - 74HC365 and 1 - 4013 integrated circuit and operates at 5 V
- Knurled shaft dimensions: .3" L x .06" Diameter
- Motor dimensions (not including shaft): .8" Dia. x .68" H
- 5 lead connection (2 leads connected together) terminated with a 4 pin female plug
- 2 3/4" long leads

Figure 4. 5 VDC Symbol Technologies stepper motor.

Performance & Operation

The performance and operation of the SPSB system prototype are the following:

- Recharge the on board batteries during the day with solar panels
- Blinds remain shut during night time
- Blinds automatically open in the morning
- Manual override can be performed by the user
- Blinds auto adjust based on user input mode

- LCD will display date, time, room temperature, and current user select mode
- The blinds, user interface device, wiring, sensors, and solar recharging components will be a package that is available to the consumers
- I^2C component integration

4. Design Approach and Details

The Brain – ATmega168 Microcontroller

The information processing of the SPSB system will be handled by a small, open-source Arduino Duemilanove microcontroller, as shown in **Figure 5**. This Arduino board will serve as the main controller for the SPSB system. The microcontroller is programmable in C/C++ and has the capability to import/export data to Matlab. The microcontroller will be enclosed in a transparent plastic enclosure that will be mounted near the window.

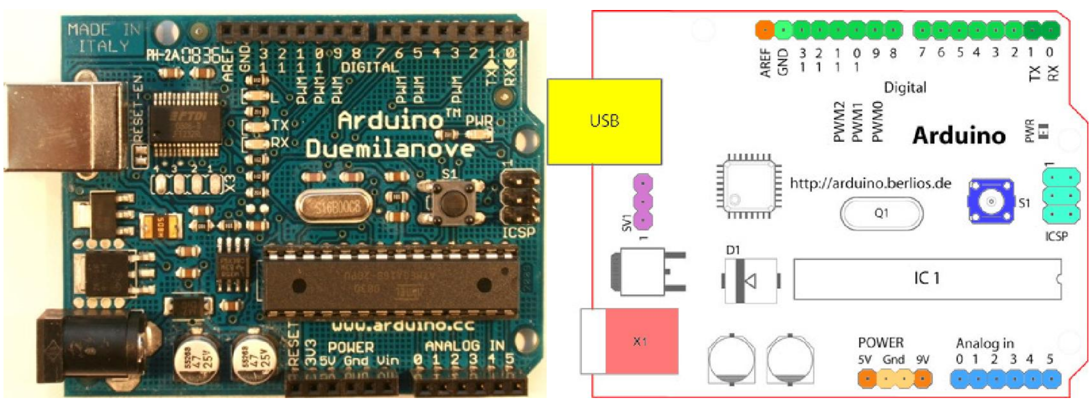

Figure 5. Arduino Duemilanove microcontroller and the board component layout.

The Automation – Blind Control Algorithm

The key feature of the SPSB system is to automatically adjust its orientation to maintain and control a room's light intensity base on user desired profile. Tentatively, there will be three modes: Dim, Moderate, and xBrite. Photo-sensors will generate voltage signals corresponding to the indoor and outdoor light intensities. The Arduino microcontroller will read in these voltage signals and compare them with pre-defined threshold voltage that is determined by the system mode. If the voltage differs by more than ±5% of the referenced level of the selected mode, the Arduino microcontroller will drive the stepper motor to turn the blind. The sensors will continuously take in data for recalculation until the light intensity inside the room match up with the reference point.

The Energy Source – Solar Recharging Circuit

There will be a 9V-12V DC input provided by a NiCad or Lithium-ion Polymers rechargeable battery. The battery will recharge via solar cell collectors, through a smart circuit that will protect it from over charge. The diodes will act as a switch that will open the charging circuit when the battery is full. The recharging of 9V batteries will be done during the daytime with a custom solar recharging circuit. 9V Lithium-ion Polymer batteries have approximately the same capacity as any alkaline 9V batteries and can outperform in high drain applications. Various solar recharging circuits will be examined and tested to implement in the final design part of the power source. Two possible solar recharging circuits are shown in **Figure 4**.

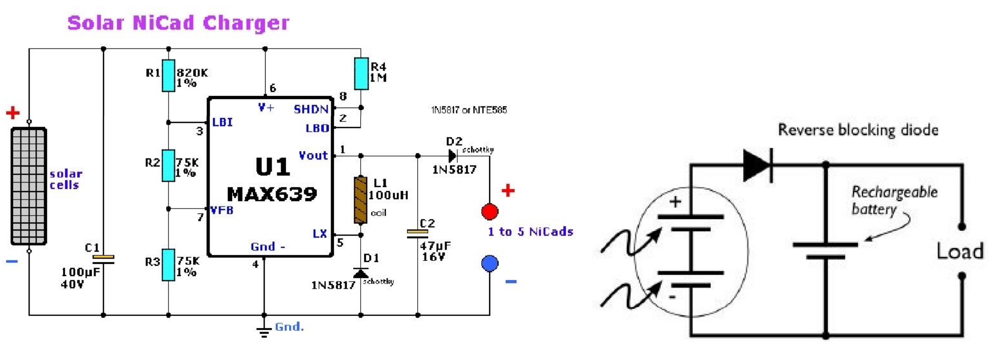

Figure 4. Solar recharging implementation circuits.

The Integration – The I^2C LCD Display

The SPSB system will have a text based LCD control module that allows the users to select various modes. LCD screen will be able to display and accept user input such as time, alarm clock, temperature, and light intensity mode. There will be a UI programmed into the LCD controller or the Arduino board. Outside and indoor temperature sensors, Real-Time Clock (RTC), and text based LCD display will all be communicated on multi-master serial computer bus, I^2C invented by Philips. The I^2C components will receive and transmit data with the Arduino microcontroller using only two bi-directional open-drain lines, Serial Data (SDA) and Serial Clock (SCL). With the two bi-directional clock and data lines, multiple number integrated circuit devices can be connected and utilized with I^2C communication protocol. (See **Figure 5**)

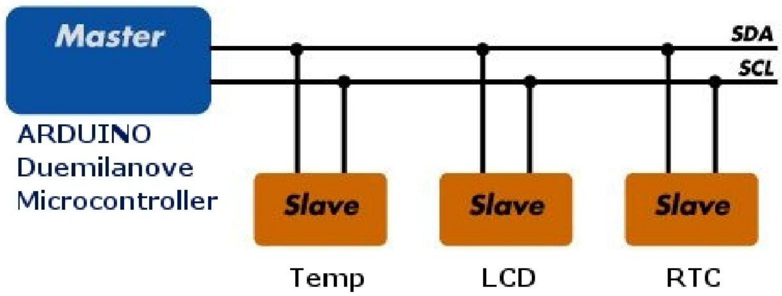

Figure 5. Solar recharging circuits.

4.2 Codes and Standards

The Arduino microcontroller for this project is based on the Atmel ATmega168, which contains a 16KB programmable flash memory, 1KB SRAM, 512 Bytes EEPROM, 8 Channel 10-bit A/D-converter (TQFP/MLF), and wire on-chip debug system. This AVR chip is certified by the American National Standards Institute (ANSI). The Arduino programming language C/C++ also satisfied ANSI standards [6].

. The SPSB system is integrated with multitude of electronics: stepping motor, photovoltaic charging circuitry, lithium ions/polymers battery. An extensive code and standards is available on the IEEE domain [7]. The stepper motor for the SPSB system will be implemented using the IEEE Standard 1349. The standard indicates general-purpose enclosure for the motor and precautions against excessive surface temperatures. The SPSB system will so have to be constructed to minimize sparking of rotor bars and enclosure joints [8].

To be able to sell the SPSB system on the U.S. consumer market, the SPSB system must comply with the IEEE Standard 1375. The standard specifically states that DC power systems must minimize the risk of equipment damage during electrically faulted conditions, limit the number and duration of the battery system service interruptions as a result of electrically faulted conditions [8].

4.3 Constraints, Alternatives, and Tradeoffs

The SPSB prototype does not contain hazardous materials to the environment. The system will help the user save energy by utilizing a solar power energy source. According to the Go Green Initiative, the SPSB system will reduce energy consumption (See **Appendix A**). By utilizing solar powered energy source, a trade off will be an inconsistent energy supply when there is no sunlight; during stormy days, cloudy days, nights etc. However the system is design to address that with rechargeable battery powered circuitry with DC input from regular outlet AC power source. Care must be taken whenever operating equipment that requires electrical power.

Constraints

- Complexity of wireless communication
- Better user interface requires more energy expenditure

Alternatives

- AC power source adds carbon waste
- Remote controlled blinds requires wireless communication & user inputs

Tradeoffs

- Reliable power source from an AC outlet
- Reduced cost of manufacturing
- Engineering simplicity

5. Schedule, Tasks, and Milestones

The project has been divided into eight specific tasks shown in **Table 4**. Every task will be collectively completed by at least two group members. Each group member will be given four tasks, except the team leader who will be fully involved in every process of the entire design tasks. The entire process of project completion has been scheduled into five milestones. The corresponding tasks and the allotted time associated with each milestone are shown in the Gantt chart in **Figure 6**.

Table 4. Individual Group Member Tasks

Tasks	Solar Charging Circuit	Photo-detector Implementation	Motor Control	Micro-controller Programming	Website and Documentation	I^2C Components	Prototype Construction	Testing
Kevin Vo	X	X					X	X
Lai Li	X		X	X				X
Marco Herrera		X		X		X	X	X
Naing Oo	X	X	X	X	X	X	X	X

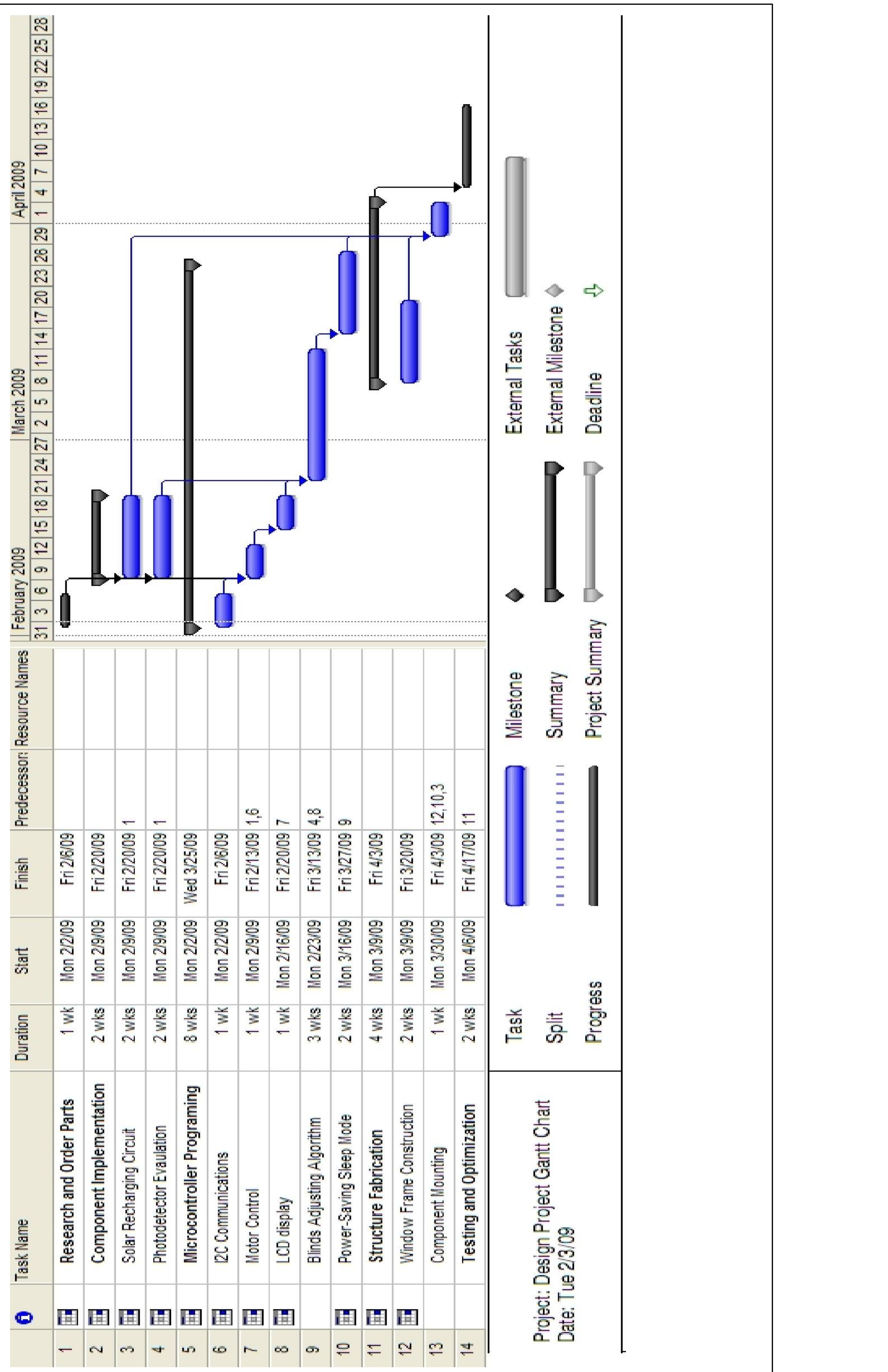

Figure 6. Gantt chart for project schedule.

6. PROJECT DEMONSTRATION

The final project demonstration will take place in an open area at noon, when the sunlight has maximum intensity. The demonstration will include two parts: a live demonstration and a recorded video demonstration. The SPSB system will be mounted on the window fixture as shown in **Figure 7**. To simulate a lighted room, the blind side of the window will be surrounded by three small walls and corresponding ceiling. There will be an AC light bulb acting as the inside light source.

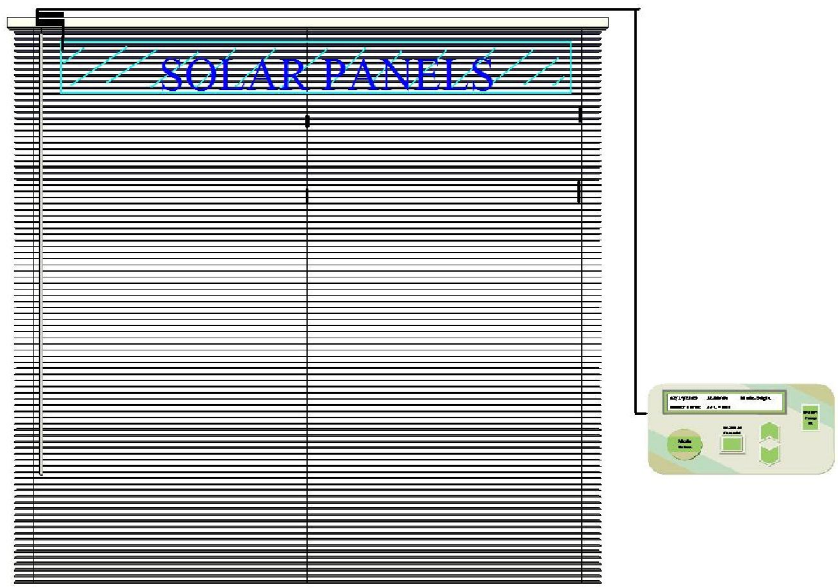

Figure 7. The SPSB system installed and ready for operation.

Live Demonstration

The window fixture will be position so that the window plane surface is approximately perpendicular to the sun's light beam. The mode will be set to xBrite, which will allow the maximum light into the room. The blinds will solely adjust to an angle where the sun light enters the room at the greatest intensity and will signify a successful demonstration.

Recorded Video Demonstration

The window fixture will be position where a vast amount sun light is directed to the window. The simulated inside light will be lit and the mode will be set to Dim. From 9 A.M. to

8 P.M. for a day, a camcorder will be used to record the blinds reacting to sun light. The successful recorded video demonstration will show the SPSB system limiting the amount of sunlight entering a simulated room.

Design Prototyping

Interfacing components with the microcontroller will be done by wiring the components and running code to input and output data. For three consecutive days, the charging system will be examined carefully with the microcontroller and components constantly running. The battery should remain fully charged during the testing period. Installing the system on the fixture and testing the full product will conclude prototyping.

7. MARKETING AND COST ANALYSIS

7.1 Marketing Analysis

The SPSB product will be available to every person, but the main goal is primarily aimed at two distinct groups: handicapped/elderly and home automation enthusiasts. The self maintained product comes with built in modes that will continuously adjust the blinds autonomously. The handicapped and elderly may benefit from these smart blinds, since a great majority of these individuals are unable to manually adjust the blinds. The home automation enthusiasts will enjoy this additional device to their home.

There are no available products in the market that are identical to the SPSB system. The closest competitive product is not autonomous. The Hunter Douglas PowerRise Honeycomb Cellular Shades is one of the competitive blinds. These blinds require the user to adjust the blinds with a remote control. The competitive blinds system is battery powered and priced at $100 or more [9]. Other competitive products work similarly, requiring the user to adjust the blinds with various user interfaces (control box, remote control). The SPSB system will contain manual operation in addition to automatic operation. Solar panels will charge batteries, which is the power source for the system. These features are not integrated into any competitive product.

7.2 Cost Analysis

The development, design, and a five-year marketing plan of the SPSB system is estimated to cost $72,020. **Table 5** shows the material, design, labor, and marketing costs.

Table 5 – Total Project Cost	
Material Cost	$320
Design/Labor Cost	$46,700
Marketing (5 Years)	$25,000
Total Project Cost	$72,020

The product will be mass produced and is expected to be sold at major home hardware stores. Material cost is expected to be reduced from $320 to $250 per SPSB system if parts and components are purchased in quantities of thousands. The labor cost to assemble and test the product by a third party is expected to be $25 per SPSB system. The projected profit per system is $25. The resulting retail price is $300. Over a period of five years, it is expected to sell 40,000 units, yielding a profit of a million dollars. The profit will cover the total project design cost with over $900,000 left for design improvements. Individual detailed costs are located in **Appendix B.**

8. SUMMARY

The design group has ordered and obtained the majority of the essential components for the SPSB system. The temperature sensor has been successfully interfaced with the microcontroller via I^2C communication protocol. The group is researching on an efficient battery recharging circuit to integrate the solar panels to the prototype. Several experiments have been performed on how the photo-resistors work with respect to sunlight and artificial light sources. One group member is attending soldering classes while the remaining members are reviewing C/C++ programming language syntax. The group is working on acquiring the remaining components (LCD display, stepper motor, and RTC) to start assembling the SPSB system.

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APPENDIX A – DETAILED COST ANALYSIS

Component Cost

Parts	*Unit Price*	*Quantity*	*Cost*	*Shipping*
Arduino Microcontroller [10]	$30	1	$30	**$2**
Blinds [11]	$35	1	$35	**$0**
DS1621 Temperature Sensor [12]	$3	1	$3	**$2**
DS1307 Real Time Clock [13]	$3	1	$3	**$2**
Photo-resistor, Pack of 5 [14]	$4	1	$4	**$0**
Stepper Motor w/ Driver	$25	1	$25	**$7**
Solar Panels	$5	4	$20	**$5**
Recharging Circuit PCB	$25	1	$25	**$4**
Rechargeable 9V Battery	$5	3	$15	**$0**
16x2 Character LCD - Serial I2C/SPI/RS232-TTL [15]	$24	1	$24	**$6**
Plexiglas Enclosure	$20	1	$20	**$0**
Cat5e Ethernet Wire 100 ft w/Connectors	$50	1	$50	**$5**
Wires, Various Sizes and Lengths	$20	1	$20	**$0**
Buttons	$2	4	$8	**$3**
TOTAL PARTS COST			**$282**	**$38**

Design & Labor Cost

Design	*Rate*	*Hours*	*Persons Involved*	*Cost*
Lectures and Meetings	$50/hr	136	All 4	**$27,200**
Research/Design/Reports/Presentations	$50/hr	50	All 4	**$10,000**
Programming	$75/hr	20	Naing, Marco	**$3,000**
Assembling Prototype	$75/hr	30	Lai, Kevin	**$4,500**
Testing/Troubleshooting	$50/hr	20	Naing, Marco	**$2,000**
Total Design Cost				**$46,700**

Marketing Cost

Advertisement Medium	Cost
Television Commercials [16]	$3,000
Newspaper Adds	$1,000
Internet	$500
Special Event	$500
Total Marketing Cost Per Year	$5,000