THE SHOWER ZONE 350

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ABSTRACT

The Shower Zone 350 is explained in this paper. The Shower Zone 350 circuit consists of a Mini-Max/51C-2 microcontroller board manufactured by BiPOM Electronics. Its purpose is to make showers more fun and automated. Different users prefer different temperatures in their showers. The microcontroller is used to save the settings for a number of users and allow water of that particular temperature into the shower. The user needs to enter their username and password and the microcontroller adjusts the hot and cold valves automatically producing the required temperature. The Shower Zone 350 project was designed and prototyped by a senior design student team consisting of four members under the supervision of faculty and teaching assistants.

INTRODUCTION

The objective of this design project is to develop a unique, energy saving automatic shower system for residential or commercial use. The design will bring comfort and many more functionality to the modern shower system. The Shower Zone 350 is powered through the house electrical circuit and it is designed to operate successfully despite power outage, water or equipment failure. The system is equipped with LCD screen and Keypad for clear reading and user interface with the shower system. The Shower Zone 350 is environmentally safe and easy to operate; it eliminates the guess work that one goes through while trying to achieve the optimal shower temperature and guarantees to retrieve the previously stored user settings due to any unfortunate events. Each user may have his/her own settings that could be saved using the username and password feature. Settings may be saved for multiple users as it regards to water temperature, speed, etc., so that each user need not make changes each time he/she enters the shower.

HARDWARE

The Shower Zone 350 Microcontroller Assembly consists of a BiPOM MINI-MAX/51-C2 Microcontroller, the BiPOM TB-1 board, and the BiPOM MOTOR-1 board [1]. The 8051 microcontroller stores the software in the ROM and any user data in the RAM. The TB-1 peripheral board fits directly onto the microcontroller. The analog to digital converter (ADC) is the only chip being used on this board. The ADC chip interfaces with the temperature sensor. The MOTOR-1 board fits directly onto the TB-1 board. This board is the drive card for the stepper motor.

The keypad and LCD display shown in Figure 1 connects to the microcontroller. These components allow the user to interface with the system. The LCD displays system information such as current water temperature and allows the user know when the system is expecting a user entry. The keypad allows the user to communicate with the microcontroller. Through the keypad, the user will enter desired temperatures and stop the shower.

Figure 1. Keypad and LCD

The Airpax 6V DC 1.8 degree stepper motor in Figure 2 will generate the power to turn the shower valve. The stepper motor is driven by the MOTOR-1 card. The motor is connected to the shower water temperature valve through a spoke and chain system. The water control valve is a basic plumbing shower fixture. The valve turns left and right to adjust the hot and cold water inputs affecting the output temperature of the water.

Figure 2. Stepper Motor

The temperature sensor is a standard LM35 Fahrenheit temperature sensor [2] which has been water proofed using electrical wire heat shrink to avoid damage to the sensor as shown in Figure 3. Water proofing was done as per safety and regulations standards available online [3]. The temperature sensor will constantly monitor the output temperature of the water temperature valve. This information will then be sent to the microcontroller which will process any needed adjustments. The sensor is wired to the

Figure 3. LM35 Temperature Sensor

TB-1 ADC. The temperature sensor is placed in a drilled hole in the pipe in order to come into direct contact with the water. This is essential to protect the users from scalding due to high temperature water [4]. Figure 4 is a block diagram of the hardware interfaces in the Shower Zone 350.

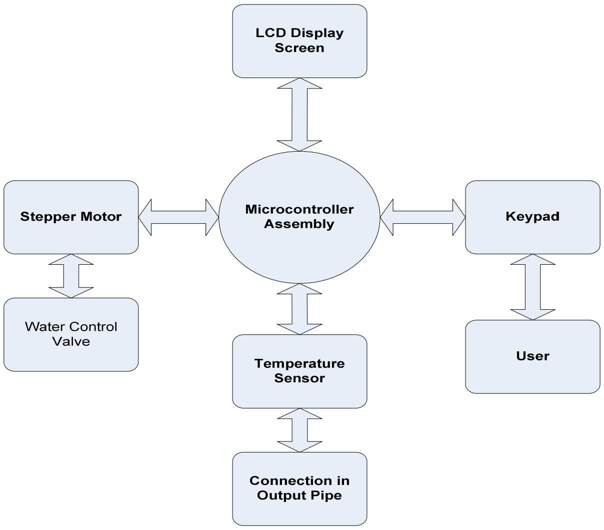

Figure 4. Hardware diagram

The Water Temperature Control valve is a brass plumbing fixture with a stem that rotates. In one stem position, the water flow is completely shut off. As the stem turns, the water turns on cold, and as the stem continues to turn the water becomes increasingly warmer. The temperature change is accomplished through the valves changing allowed entrance amounts of hot and cold water from the source piping [5]. The design of the stepper motor connected to the valve is shown in Figure 5, Figure 6 shows the actual stepper motor connection, and Figure 7 is the system drawing, and Figure 8 shows the completed prototype.

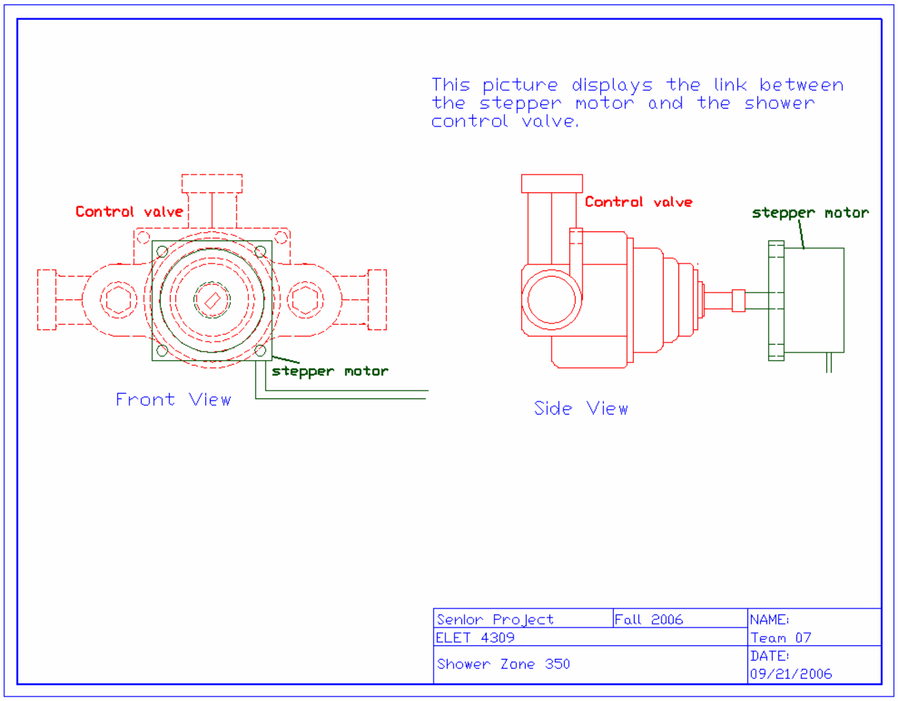

Figure 5. Design for stepper motor

Figure 6. Stepper motor connections

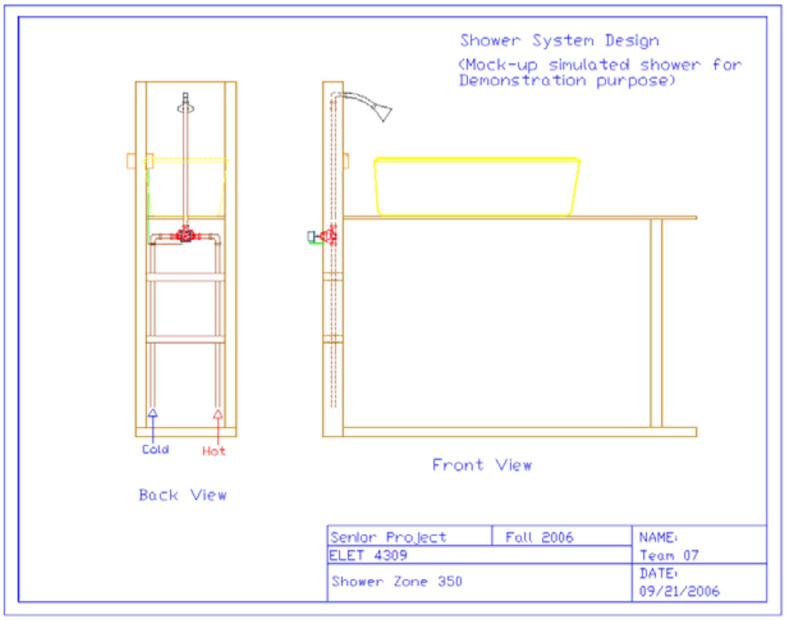

Figure 7. System Design

Figure 8. Final prototype of Shower Zone 350

POWER

The Shower Zone 350 is powered through the standard 120V AC found in the homes across the United States. A 6V DC converter and a 5V DC converter are used to convert the 120V AC into a useable form for the Microcontroller Assembly. The 5V DC voltage is wired into the 8051 microcontroller. This voltage provides power to the microcontroller which will in turn feed the voltages to the TB-1 board, the MOTOR-1 board, the keypad, and the LCD display screen. The 6V DC voltage is used to power the stepper motor. The 6V DC voltage is wired into the MOTOR-1 board and finally to the stepper motor. Figure 9 illustrates the simplified power distribution configuration of the Shower Zone 350.

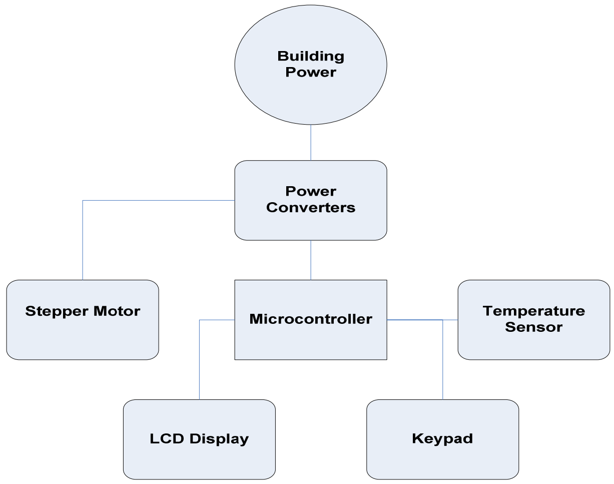

Figure 9. Power distribution configuration

SOFTWARE

The software for the Shower Zone 350 is stored in the ROM of the microcontroller. The software drives the entire system through simple user interface. Upon initial power up, the user accounts will have no information available. Upon start-up, the user will be asked if they would like to create an account or log into an existing account. If creating a new account, the user will then enter the desire temperature of the water. If using an existing account the user will verify that they wish to use the previously stored temperature. If they do not then they will be asked to set the temperature. After setting or verifying the temperature, the software instructs the MOTOR-1 board to turn the stepper motor to an estimated set starting position for the entered temperature. The microcontroller then compares the temperature sent from the sensor to the desired temperature. If adjustments are needed, the program once again instructs the MOTOR-1 board to turn the stepper motor.

This process continues throughout the duration of the shower. From the shower start up, through the end of the shower, the software keeps track of how many steps the motor has made in each direction. This will allow the system to properly shut off when instructed. The program constantly polls the keypad for the "D" character to be pushed by the user. The "D" character starts the shutdown process, and the MOTOR-1 board is once again instructed to turn the motor the needed amount of turns to completely shut off the water valve.

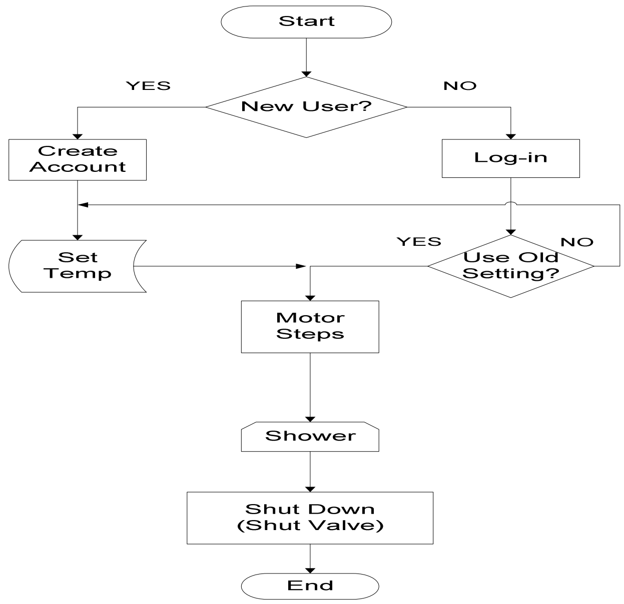

Figure 10. System software diagram

Figure 10 shows a very basic breakdown of the program hierarchy. A more complete flowchart is shown in Figure 11.

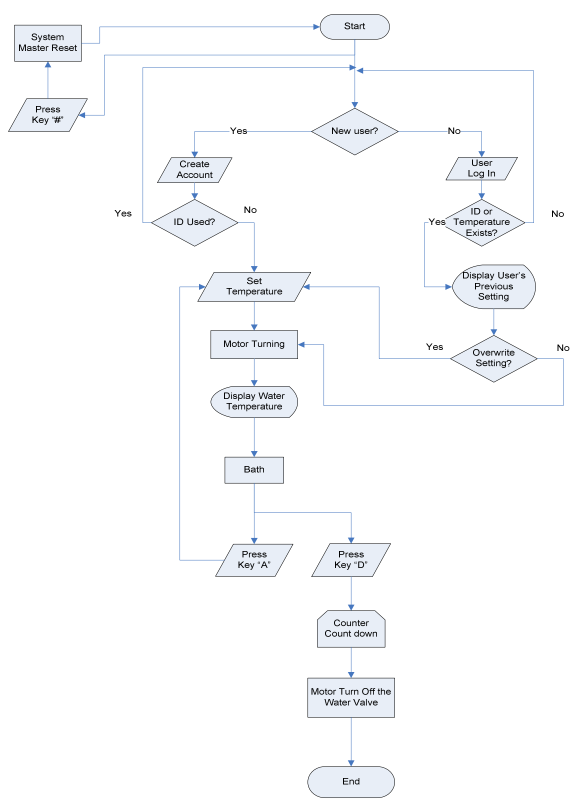

Figure 11. Shower Zone 350 software flowchart

DESIGN DESCRIPTION

Power

The Shower Zone 350 requires two separate voltages. The BiPOM MINI-MAX/51-C2 microcontroller requires a 5V DC power source, while the stepper motor requires a 6V DC power source. A 120 V AC to DC converters are used for both of these voltages. In the prototype, the converters were plugged into a common 120V AC wall outlet. This allowed for easy transportation and demonstration. In reality the wall plugs would be cut off of the end of the cables to the converters, and the wires would be hardwired into the home electrical circuit.

After conversion from 120V AC to 5V DC, the 5V source is fed into the power connector of the BiPOM MINI-MAX/51-C2 Microcontroller. The BiPOM MINI-MAX/51-C2 Microcontroller is available with the proper 5V DC converter with the proper connection fitting. The 5V fed into the microcontroller will in turn power the TB-1 and the MOTOR-1 boards.

The 6V DC will be fed into the positive and negative terminals of the X1 terminal on the MOTOR-1 board. The 6V source is then fed into the common terminals on the X1 terminal board for use by the 6-wire stepper motor.

Microcontroller Assembly

The microcontroller assembly consists of five components. These components are the BiPOM MINI-MAX/51-C2 Microcontroller, the BiPOM TB-1 board, the BiPOM MOTOR-1 board, the LCD display screen, and the keypad. The three BiPOM boards are stacked consecutively on top of each other through the expansion ports of the boards. The keypad is attached via cable to pins 1-8 on the J1 terminal of the microcontroller. The LCD display attaches to terminal J3 of the microcontroller through a 4 bit parallel interface ribbon cable.

The entire system relies on the functionality of the BiPOM MINI-MAX/51-C2 Microcontroller. The microcontroller stores and processes the software algorithm, stores the user temperature data, and reacts to any user changes through the keypad.

The BiPOM TB-1 board is a training board designed by BiPOM as a prototyping tool. The board is used in the Shower Zone 350 because it has an ADC0834 analog to digital converter chip. BiPOM makes other boards which will also make this conversion, but the TB-1 board is the most economical choice since only one conversion is needed. The ADC is used to interface the temperature sensor with the microcontroller.

The BiPOM MOTOR-1 board is a stepper motor drive assembly. Through the software, the driver sends voltages to given ports on the X1 terminal of the board. The positive and negative terminals of X1 also serves as the entrance wiring point for the incoming 6 volts needed to operate the stepper motor. The common terminal of X1 feeds the voltage to the commons of the stepper motor coils is shown in Figure 12. Terminals A and B of X1 are wired to one coil of the stepper motor, while C and D of X1 are wired to the other coil. When the microcontroller needs to move the stepper motor, the MOTOR-1 card sends the incoming 6 volts to the common terminal to power the stepper motor. The card then activates switches which complete the circuit between the wires of connected coils. The card activates one coil then the other, causing the motor to turn [6].

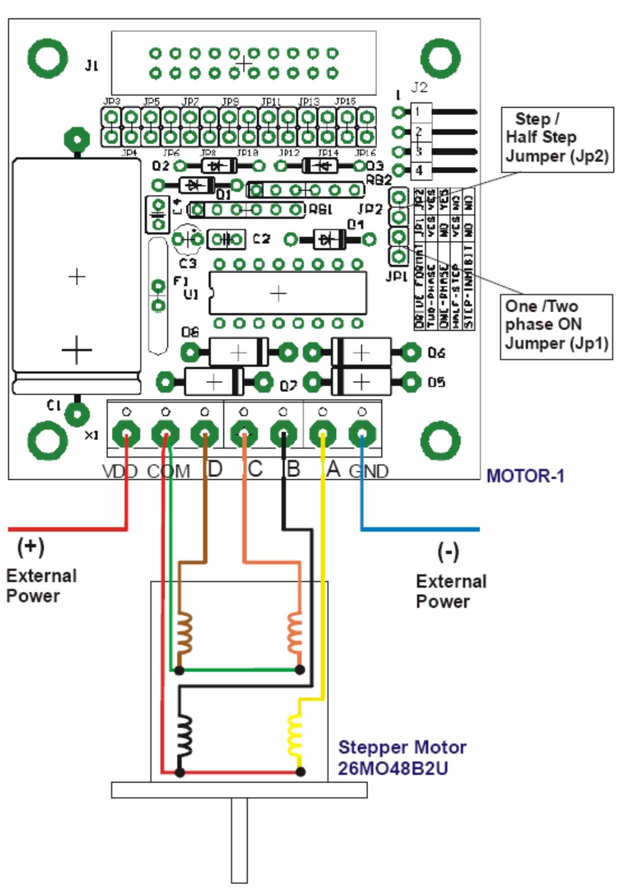

Figure 12. Motor-1 board and stepper motor connections

The LCD allows the displaying of 2 rows of up to 24 characters. The Shower Zone 350 uses the display to communicate with the user. Through the display the microcontroller can ask the user for information, display menu options, and show the current water temperature.

The keypad works hand in hand with the LCD display. Through the keypad the user can interact with the microcontroller. This allows the user to react to questions being asked by the microcontroller through the LCD display. The user will enter login numbers, temperature, interrupt shower to change the current temperature, and shut the shower off through keypad.

The wiring diagram in Figure 13 illustrates all of the connections associated with the Microcontroller Assembly.

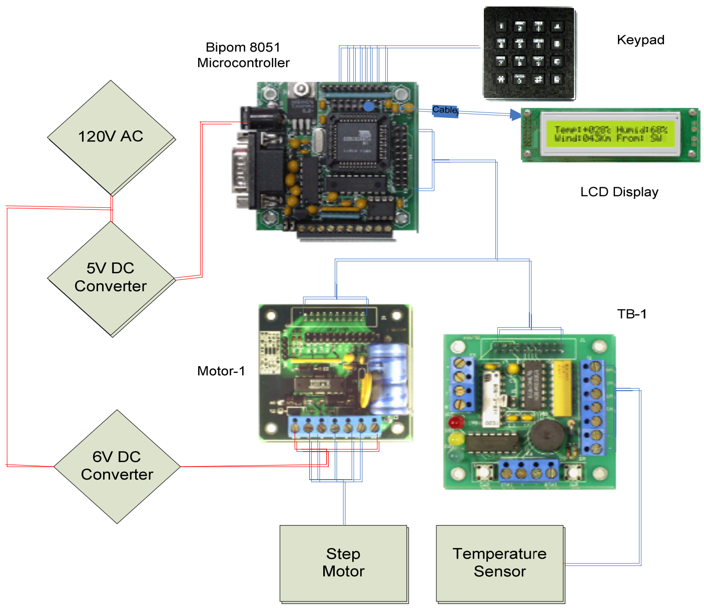

Figure 13. Wiring diagram

Stepper Motor

The Shower Zone 350 uses an Airpax 6 wire, 1.8 degree, 6V DC driven stepper motor. The coils of the step motor are activated when the MOTOR-1 drive card completes the circuit between the coils and a 6V DC voltage is present on the coils common leads. The card completes the circuit to one coil, the coil fires, and then the card shorts out the circuit. The next coil then goes through the same process. Each time a coil is energized the motor valve stem turns 1.8 degrees. This rotation can easily be modified by altering the energized time of the coils in the code. The direction in which the stem turns depends on the energizing order. This is also selected by the program depending on whether the system is turning on or off, or needs hot or cold water.

The stepper motor's shaft is attached to a bicycle spoke. This was the alternate design implemented since coupling the motor directly to the valve did not produce the needed torque of the valve. When the coils energize, the valve stem turns the bicycle spoke. The spoke rotates a bicycle chain, which in turn rotates a bicycle spoke attached to the water temperature control valve stem of the plumbing.

Water Temperature Control Valve

The Water Temperature Control valve is a brass plumbing fixture with a stem that rotates. In one stem position, the water flow is completely shut off. As the stem turns, the water turns on cold, and as the stem continues to turn the water becomes increasingly warmer. The temperature change is accomplished through the valves changing allowed entrance amounts of hot and cold water from the source piping.

The project implementation posed few challenges when working with the water temperature control valve stem. The torque needed to turn the valve constantly changed dependent on how often the valve was in use. Attempts to grease the valve only complicated matters when the chemical used combined with the lubricant already inside. This created a compound which made the valve more difficult to turn. The ideal situation would be to have the motor directly attached to the water valve stem. The required starting torque would not allow this. An attempt was made to use a gear and pulley system in addition to the chain link. Time and budget was another challenge to overcome. More time to investigate gear motors and shaft encoders would have helped. Another challenge with this system, other than time and budget concerns, would be to determine how this type of motor would interface with the microcontroller and required changes of the software algorithm. A higher torque stepper motor is another option. The MOTOR-1 drive card can interface with motors up to 35V DC.

Temperature Sensor

The temperature sensor is a standard LM 35 Fahrenheit temperature sensor. The sensor has been water-proofed using electrical wire heat shrink. The temperature sensor is connected to the Analog to Digital Converter of TB-1. The three leads are connected to the positive, ground, and the A_0 input of the X1 terminal board. The sensor sends a voltage to the converter. This voltage represents the temperature of the water. The ADC converts the information into a digital value which can be interpreted by the software of the microcontroller.

The temperature sensor is continually monitoring the temperature. The software decides when the microcontroller will actually process the information or not. During the shower, the temperature sensor is continually being processed in order to determine whether an adjustment in needed.

CONCLUSIONS

This paper described a circuit that was developed to interface an ATMEL 89C51 microcontroller with various sensors and switches in order to control the operation of the shower in order to create a quick and convenient showering experience. The only problem faced was that the stepper motor could not produce enough torque to turn the valve and produce the desired effect. However this problem could be overcome in future designs by using a motor with higher torque. For the project prototype however, the only valve available suffered from insufficient torque. A possible solution would be to find a motor with higher torque to enable operation of the stepper motor. The project was completed under the given budget of $350, $332 to be exact. Any upgrades would only replace the already existing parts thus stay within the project budget.

Potential follow up projects or additions to the product could include a motion sensor which turns on the shower when the individual steps inside. This addition would help conserve water, but the difficulty would be in getting the water to first come out of the shower nozzle at the desired temperature. No one would want to be hit with a burst of cold water. A possible second addition is the expansion of the system to the bath. The addition would be rather simple. The shower temperature valves are manufactured with the bath plumbing. In this project, the bath outlet is simply closed off. The system would simply have to be expanded to support another type of shut off valve to turn the bath on and off. Another temperature sensor would also be needed to monitor the bath outlet water temperature.

REFERENCES

[1] "BiPOM 8051 Mini-Max/51 Series Microcontroller," BiPOM Electronic Inc
http://www.BiPOM.com/minimax51-set.shtm

[2] Temperature Sensor, November 2000
http://www.ece.osu.edu/~passino/LM35.pdf

[3] "IPX Waterproof Specifications," E-Headlamps, 8 Sept. 2006
http://www.e-headlamps.com/ipx_waterproof_standard.asp.

[4] "Scald Protection," Plumbing Supply, 8 Sept. 2006
http://www.plumbingsupply.com/scald.html.

[5] "MultiChoice™ Universal Rough-in Body," Delta, 10 Sept. 2006
http://www.deltafaucet.com/media/Product_Tech_Docs/Spec_Sheets/DSP-B-R10000_RevB_9c0f.pdf.

[6] Motor1 board specifications sheet, 12 May 2004
http://www.bipom.com/documents/peripherals/motor-1.pdf