January 13, 2004

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ***Post-Mortem for a Wireless Home Phone-operated Assistant***

Dear Dr. Rawicz,

The attached document, *Post-Mortem for a Wireless Home Phone-operated Assistant (HomePA)*, outlines the design and implementation of our final product, and emphasizes the deviations between the original and the final design for our ENSC 340 project.

Our project is to design a phone-operated system that can control multiple home appliances via wireless communication. This system consists of, a central control unit (CCU) acting as the base transmitter, and multiple client appliance units (CAUs), depending on the amount of electric devices to be controlled. The CCU is connected to the household phone line, receiving and processing a touch-tone command sent by an individual's phone call. The phone command determines the device to be controlled; the CCU will then communicate with the corresponding CAU to operate the device.

This post-mortem describes the various technical issues we encountered and improvements we made during the development of the HomePA, as well as discusses several possible future improvements or expansions of the HomePA. In addition, this document compares the projected costs with the actual incurred costs, and the proposed project schedule with the actual timeline. Finally, the contribution from each team member is acknowledged in the later section of this document.

Trax Technologies Inc. is comprised of five enthusiastic and industrious engineering students. Group members are Sean Hou (CEO), Jack Lin (CFO), Fred Yu (CTO), David Chen (COO), and Howard Chang (CIO). Each student brings their diverse knowledge and talents to the team. Should you have any question, please feel free contact us at traxtech-ensc340@sfu.ca, or visit our website at www.sfu.ca/~howardc/traxtech.

Yours sincerely,

Howard Chang

Howard Chang
Chief Information Officer
Trax Technologies Inc.

Enclosure: ***Post-Mortem for a Wireless Home Phone-operated Assistant***

Technologies Inc.

Post-Mortem for a Wireless Home Phone-operated Assistant

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Issued Date: January 13, 2005

Executive Summary

Many people are unable to independently operate and monitor standard home appliances and equipment without the assistance. Some of these people are physically disabled suffering from paralysis, leg amputation, arthritis, and other such debilitating conditions. Although the conventional home control systems are a solution, most people are unable to enjoy the comfort and efficiency that these systems provide. Most individuals cannot afford a versatile remote control system because of the excessive cost involved, along with the extensive and sophisticated installation required. Seniors and younger children may also be challenged by the complexity of familiarizing themselves with conventional system controllers.

Trax Technologies is committed to developing a Wireless Home Phone-operated Assistant (HomePA), which will allow individuals to remotely control and monitor the current operating status of home appliances or facilities via a phone call. This device will provide paraplegics, seniors, and even the general public the convenience of home remote controls.

The post-mortem describes the various technical issues we encountered and improvements we made during the development of the HomePA. It also outlines the design of our final product, and emphasizes the differences between the original and the final design. In addition, possible future improvements or expansions of the HomePA are discussed in this post-mortem.

This report also compares the projected costs with the actual incurred costs, and the proposed project schedule with the actual timeline. Finally, the contribution from each team member is acknowledged in the later section of this document.

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Glossary

CAU: Client Appliance Unit

CCU: Central Control Unit

D/A: Digital/Analog

DAA: Data Access Arrangement

DTMF: Dual Tone Multi-Frequency

HomePA: Home Phone-operated Assistant

IC: Integrated Circuit

IR: Infrared

PCB: Printed Circuit Board

PSTN: Public Switch Telephone Network

SPI Serial Peripheral Interface

1. Introduction

In the past fifteen weeks, Trax Technologies Inc. has been dedicated in developing the prototype of the proposed Wireless Home Phone-operated Assistant (HomePA). The HomePA allows individuals to remotely control and monitor home appliances via a phone call. The final design consists of two classes of modules: a central control station (CCU) acting as a base transmitter and multiple client appliance units (CAU) attaching to each home appliance that an individual would like to control. The CCU is connected to a household phone line, receiving and processing a touch-tone command sent by the user's phone call. The phone command determines the home appliance to be controlled and monitored; the CCU will then inform the corresponding CAU to operate the home appliance via wireless communication.

After thorough investigations, we have discovered a great demand and market potential for the HomePA. Our product is a cheaper alternative for general individuals who cannot afford the existing remote control systems. The HomePA is a user-friendly product for seniors or children who may be challenged by the complexity of familiarizing themselves with the controller. In addition, the HomePA is a perfect solution for disabled people who need to rely on their family members, friends or caretakers at home to assist them in controlling or monitoring home appliances. With the wireless implementation proposed by Trax Technologies Inc., the idea of controlling home appliances remotely and independently has become a reality.

1.1. Scope

The post-mortem describes the various technical issues we encountered in the development of our HomePA, and details the improvements we carried out to resolve these problems. This document outlines the design of our final product, and emphasizes the differences between the original and the final design. In the *Design Specification for a Wireless Home Phone-operated Assistant*, we proposed a theoretical design of the HomePA based on our pre-project research on several different components and our best understanding at that period of time. However, in the process of developing our product, we made modifications to accommodate some technical problems. As well, our knowledge regarding the different aspects of the product has expanded.

This post-mortem also compares our projected costs as stated in the *Project Proposal for a Wireless Home Phone-operated Assistant* with the actual incurred costs, and the proposed project schedule with the actual timeline. As for the reflection on the team dynamics, the contribution from each team member is acknowledged in the later section of this document. Possible future improvements or expansions of the HomePA are also discussed.

1.2. Intended Audience

This post-mortem is intended for project managers to evaluate the progress of the development team of the HomePA. This document provides a way to determine the success of the project team, as well as make decisions regarding the future expansions of the project.

2. Present State of the System

2.1. Overall System

The HomePA consists of several functional components as outlined in Figure 1. Our latest design includes one central control unit (CCU), and four client appliance units (CAU), i.e. door, window, light switch, and heater.

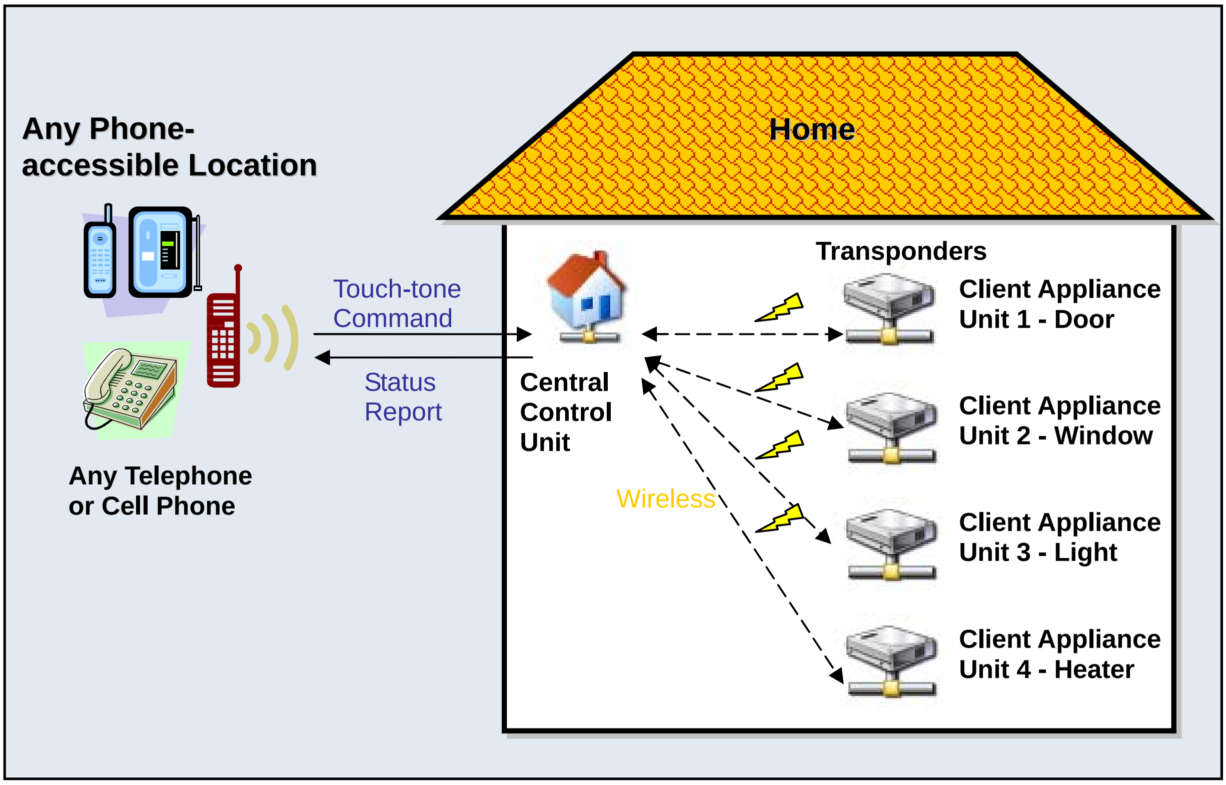

Figure 1: Collaboration Diagram of the HomePA

2.2. Central Control Unit (CCU)

The CCU is plugged into a household phone jack. It receives and processes an incoming touch-tone command sent by a user's phone call. The phone command determines the home facility or appliance to be controlled. The control station will then call the corresponding transponder to operate the device via wireless communication. In the situation that an abrupt change in appliance status occurs, the CCU can inform the user by dialing out to a user preset phone number.

2.3. Client Appliance Unit (CAU)

The CAU is connected to the home facility or appliance that a user would like to control. Once it receives a command from the CCU via wireless communication, it performs the assigned operation on the appliance – switch on/off, open/close, lock/unlock, etc. The CAU can also report back to the CCU the status of the appliance currently connected to it. Multiple CAUs co-exist; they are controlled by the same CCU through the wireless network.

3. CCU Design Specifications

The architectural overview of the central control unit, as shown in Figure 2, consists of five major components, including the PIC16F877A microprocessor, the Dual Tone Multi-Frequency (DTMF) transceiver, the Data Access Arrangement (DAA) line interface, the voice playback device, and the wireless transceiver. Each component is controlled by the same PIC microcontroller, which has sufficient input/output (IO) pins and suitable clock frequency for our design.

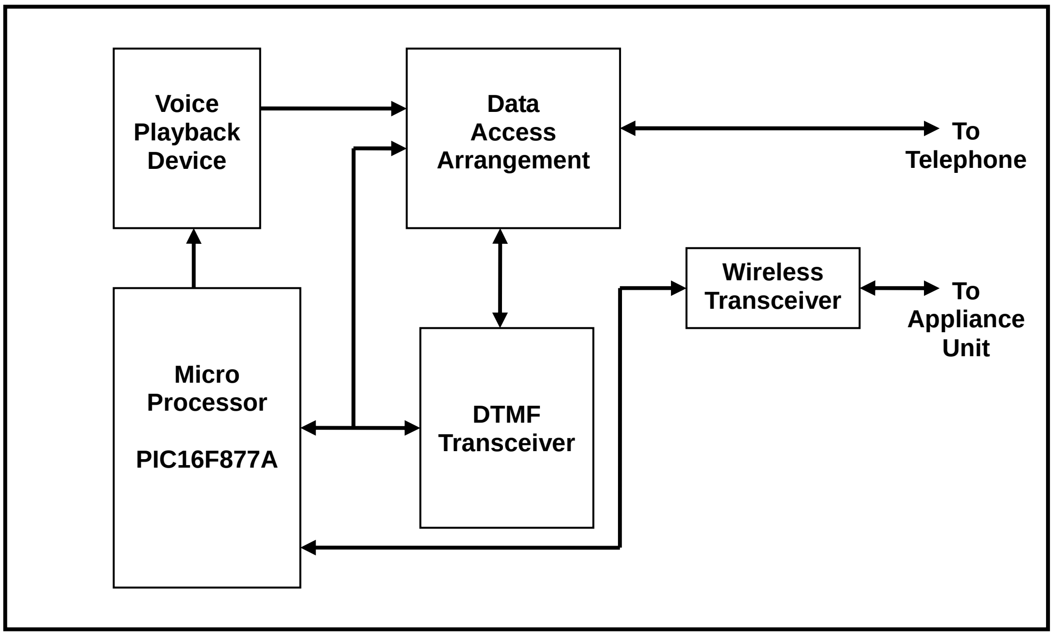

Figure 2: Architectural Overview of the Central Control Unit

In order to connect our CCU to the Public Switched Telephone Network (PSTN), we use the MH88435 from Zarlink Inc., a DAA device, to provide an interface between analog transmission equipment and the telephone line. Moreover, the DAA chip has the necessary optical isolation and surge protection for the rest of the circuit components in the CCU from any ultra-high voltage that may exist in the telephone line.

The DTMF transceiver chosen in our design is CM8880-PI, from California Micro Device Inc., which is responsible for decoding and generating DTMF tones that are received and transmitted through the DAA line interface chip. Upon receiving a DTMF tone, the DTMF transceiver will decode and output a four bit binary code that represents the corresponding tone to the PIC microcontroller. Similarly, to generate a DTMF tone, the PIC microcontroller outputs a four bit binary code to the DTMF transceiver, and the corresponding analog tone will be generated and output onto the telephone line via the DAA device.

All the voice messages for the user menu are recorded and stored in the voice playback device, APR6016 from Aplus Integrated Circuits Inc., which features a good quality audio playback of pre-stored messages in the on-chip memory. In addition, the device uses a proprietary analog multi-level storage technology implemented in an advance non-volatile Flash memory, thus no additional back-up power source is required for reproducing undistorted audio signals. The APR6016 utilizes an industry standard Serial Peripheral Interface (SPI), which allows us to easily program and control the device using our PIC microcontroller.

After successfully receiving and decoding a user input DTMF tone from the telephone, the PIC microcontroller transmits the command to the corresponding CAU through the wireless transceiver, RTF-Data-Saw 4800 bps AM Transceiver Module. The wireless module utilizes Manchester encoding for transmission; therefore, the PIC microcontrollers in both the CCU and CAU are programmed in a way such that they are able to encode and decode Manchester-encoded instructions. Moreover, with the additional antenna installed, the transmission range of the wireless transceiver is sufficient for most common households.

Finally, the CCU uses a voltage regulator, LM7805, to prevent overload current or shock voltage from the power supply that may cause non-replaceable damage to the circuit. Currently, the CCU is powered by a standard 9-volt battery cell.

4. CAU Final Design Specifications

The four CAU modules, to a large extent, concur with our previous function and design specifications. Section 4.1 highlights the function and the design aspects for each CAU module. And, Section 4.2 discusses, in detail, any deviation from our design specifications.

4.1. Final Design

Each client appliance unit consists of a sensor, an actuator and a microprocessor. The architecture of each type of client appliance resembles the block diagram as in Figure 3. Note that the appliance can be either controlled electronically by the microprocessor or physically by the user. The CAU communicates with the CCU via the RTF-Data-Saw wireless transceiver.

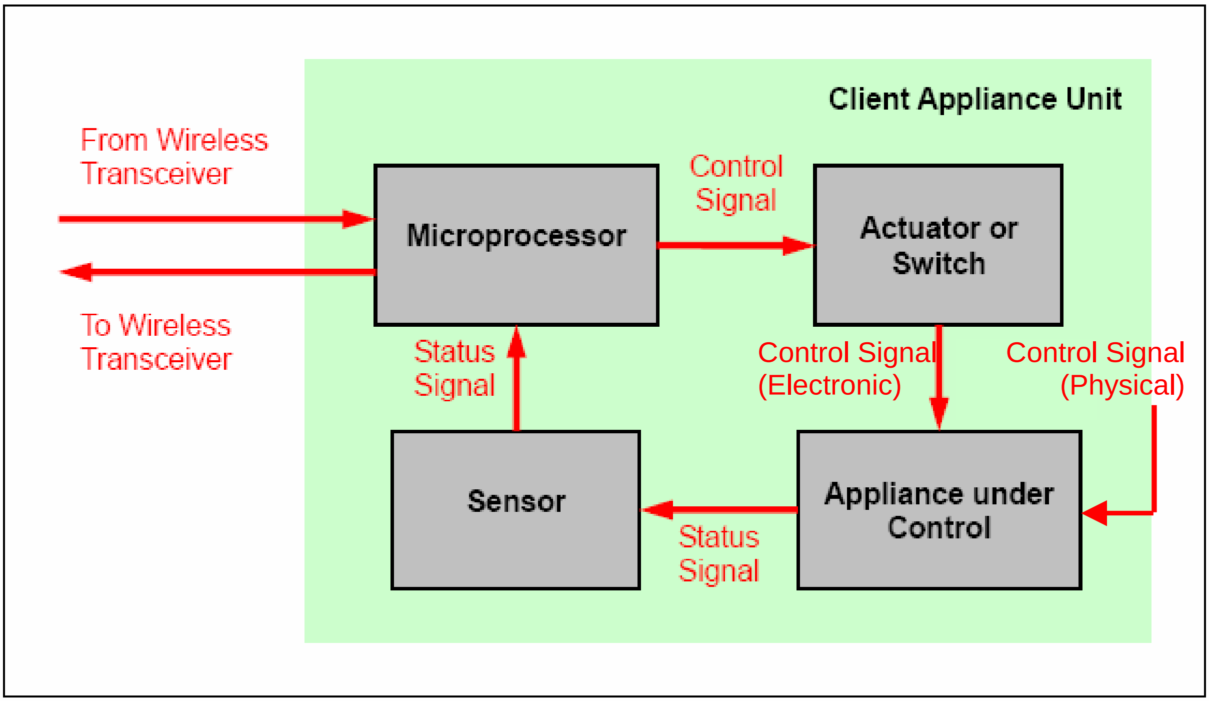

Figure 3: Block Diagram for the Client Appliance Unit

4.1.1. Door Module

The door module is implemented with the function of locking and unlocking. In addition, the door module can monitor the current status by two different metal contact points on the prototype. A picture of the final product is shown in Figure 4.

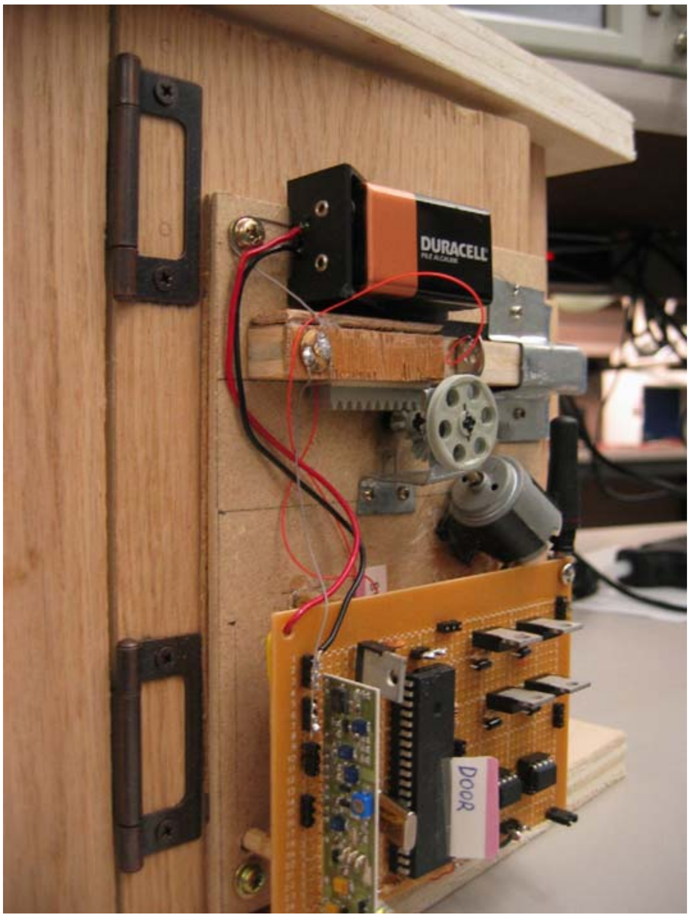

Figure 4: Door Lock Module

The movement of the door locking is achieved with a DC motor and a series of LEGO gears. When the door is locked, the locking rod is pushed to the right and therefore the door can not be opened. However, when the door is unlocked, the locking rod is pushed to the left, and the door can open/close freely. For the prototype, the microcontroller and wireless unit are mounted underneath the door lock. PIC16F877A microcontroller is used for setting the direction of motor movement, reading the current status, as well as communicating with the CCU via the wireless module.

4.1.2. Window Module

For the window module, we implement the basic function of opening and closing the prototype window. As well, the module allows detection of any obstacle that might be present while the window is in the processing of closing. In addition, the status of the window module is constantly monitored by the central control unit (CCU). When the window is open in the case of a break-in, the CCU informs the user through an outgoing telephone call. The following figure shows the window module that has been built.

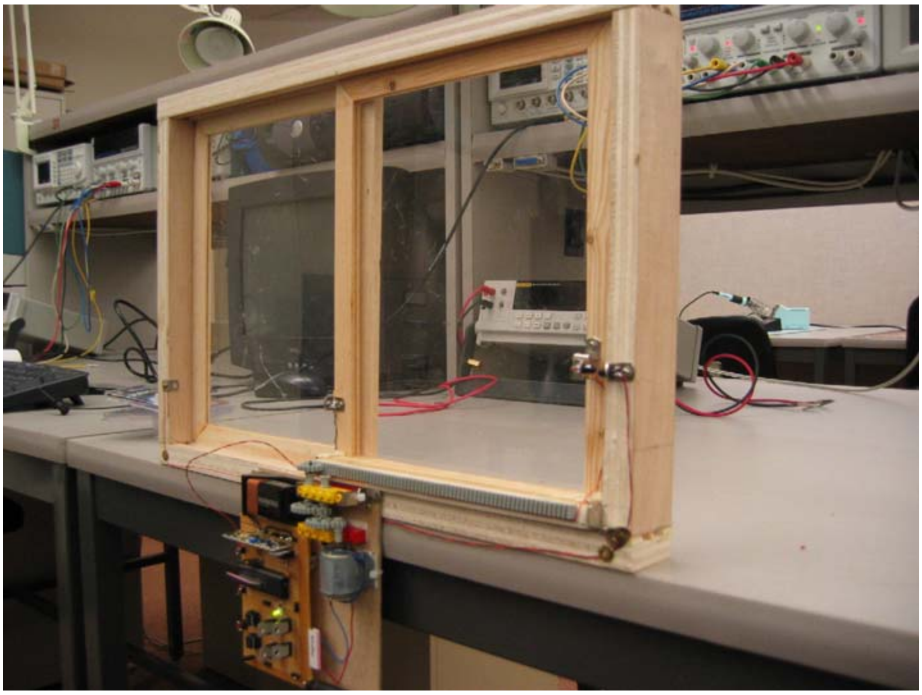

Figure 5: Window Module

As shown above, two transparent plastic boards are used to represent the sliding windows. Also, the RE-280RA-2865 Mabuchi motor works with a series of standard, rack and bevel gears in order to slide the window left and right. Two sets of metal contacts are placed on opposite ends of the window to indicate the open and the close status of the window. As well, the SFH4502 infrared emitter and the QSD122 infrared receiver are implemented for obstacle detection.

The circuit for the infrared sensors is shown in Figure 6. The output of the circuit becomes high (5V) if an obstacle is present in the closing path of the window and thus blocks the infrared signal coming out of the emitter from reaching the receiver. Otherwise, the output of the circuit remains low (0V).

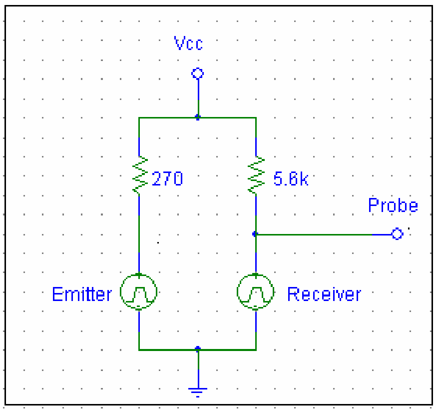

Figure 6: Schematic for the Infrared Emitter and Receiver

Finally, a PIC16F877A microprocessor is used for setting the direction of the motors, reading the status of the metal contact and infrared sensors and performing wireless communication with the CCU.

4.1.3. Light Module

The light module is designed to have the capability of controlling all kinds of household light bulbs. However, the light module is powered by a single 9V battery for driving the motor. A picture of the final product is shown in Figure 7.

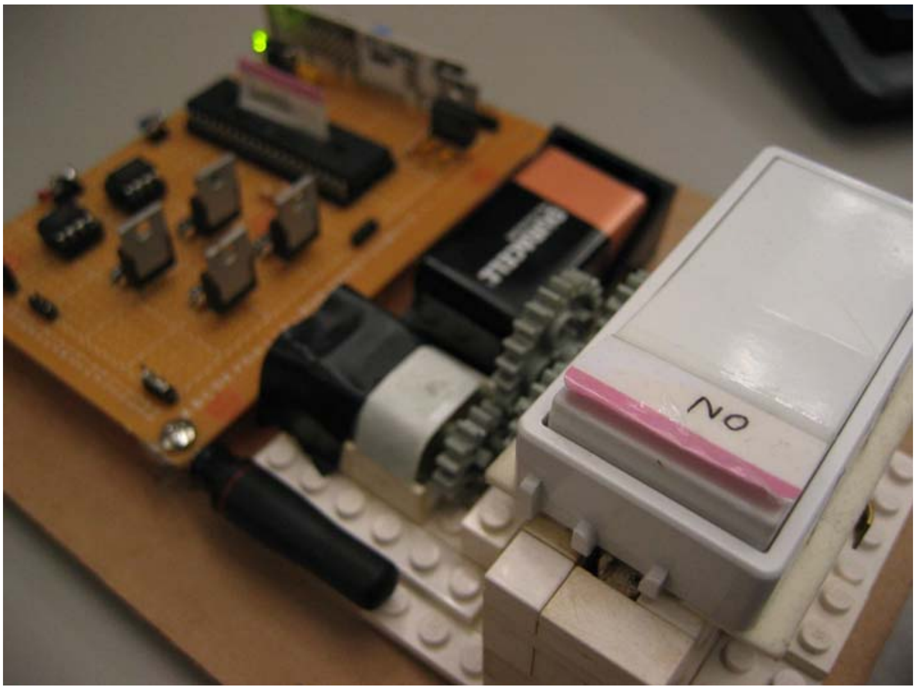

Figure 7: Light Switch Module

In order for the microcontroller to switch the light bulb on and off, a motor and a series of gears are implemented to actuate the movement. During the “switch on” state, the microcontroller will send out the corresponding output to the H-bridge circuit, and therefore turn the motor in a predefined direction. As a result, the light bulb attached to the light module will conduct current and turn on. On the other hand, during the “switch off” state, the microcontroller will turn the motor in the opposite direction from the “switch on” operation, and the light bulb will be turned off. Two metal contacts are placed inside the light module to indicate the ON/OFF state of the device. Finally, the dimension of the light module is approximately 10 cm by 8 cm in base, and 8 cm in height.

4.1.4. Heater Module

For the heater module, we implement the functions of changing and checking the room temperatures. The range of controllable temperatures is selected to be 18 °C to 25 °C. The figure below shows the heater module.

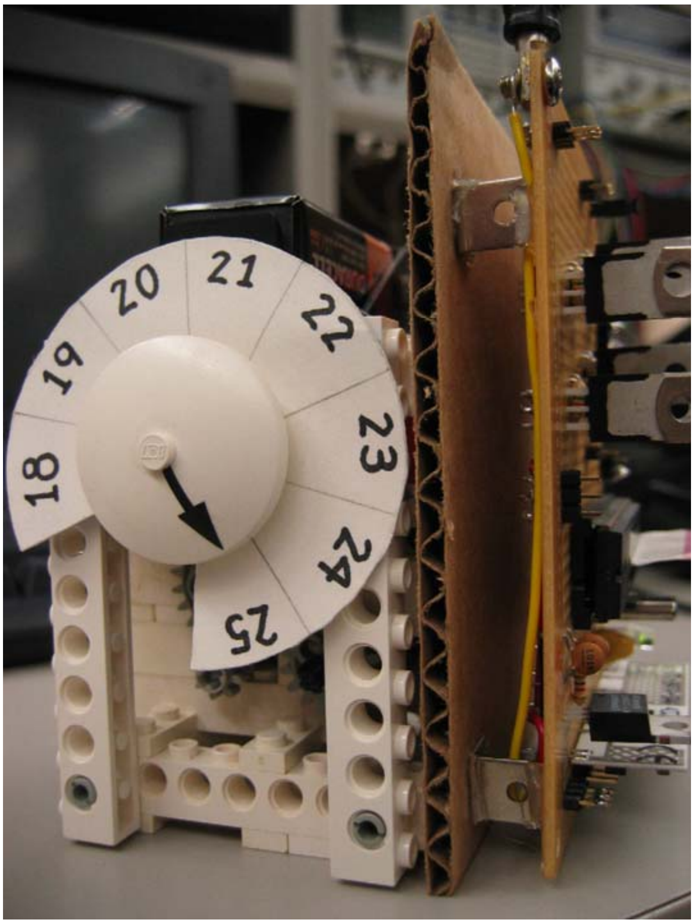

Figure 8: Heater Module

First of all, the RE-260RA-18130 Mabuchi brush motor is connected to several levels of gear trains in order to achieve precise control of temperature knob. Also, the embedded 3310Y-001-103 potentiometer measures the angle of the temperature knob (see Section 4.2.4 for detail) to determine the exact temperature reading. Finally, a PIC16F877A microprocessor is used for setting the direction of the motor, performing A/D conversion on the potentiometer reading and performing wireless communication with the CCU.

4.2. Technical Problems and Solutions

Throughout the development of the HomePA, we have made several modifications to original proposed designs of the central control unit and the client appliances units to accommodate the various technical problems encountered. The following subsections discuss the technical issues during while developing our product, as well as some details about design deviations.

4.2.1. Motor Driver

In *Design Specification for a Wireless Home Phone-operated Assistant*, we anticipated the problem that the output of the PIC16F877A microcontroller output would not provide sufficient current levels to drive the motors used by the four client appliance units. We proposed the adaptation of two NPN BJT common-collector amplifiers in the Darlington configuration, aiming to achieve the optimal performance of the motors. However, the motors did not turn with this design since only the transistors for sourcing the current exist; no transistors for sinking the current are present. Such a situation implies that no current from the load component, i.e. the motor, can be pulled away when the output voltage of the microcontroller, V_{OUT}, goes low although the current is effectively pushed into the load when V_{OUT} goes high. As a result, we introduce a pair of PNP transistors so the motor driver circuit is now a Class B output stage that operates in a push-pull fashion.

Nevertheless, the mismatch between the bipolar NPN and PNP transistors can affect the performance of the motor spinning significantly. Based on our research, we then decided to use an H-bridge as the motor driver since this electronic component basically replicates the exact circuit configuration of a Class B output stage. A typical H-bridge is shown in Figure 9 with each switch signifying a transistor. To power the motor, the two switches that are diagonally opposed are turned on, i.e. in an A-D or B-C fashion. The direction that the motor turns depends on which of the two switches are active and cut-off.

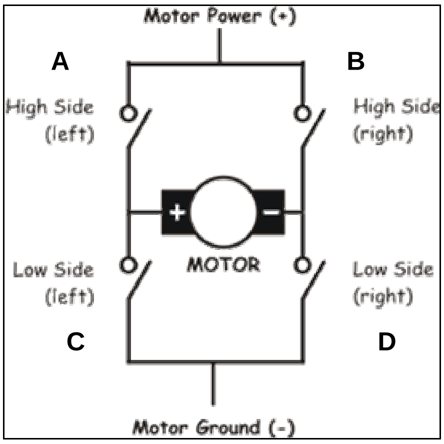

Figure 9: A Basic H-bridge

We implemented the ZHB6718 SM-8 bipolar transistor H-bridge manufactured by Zetex. The internal circuitry is shown in the diagram in the upper-left corner in Figure 10. The following is the schematic diagram of the motor driver circuit using the ZHB6718 H-bridge. The following table summarizes the various behaviours of the motor when each switch is turned on or off.

Table 1: Truth Table of an H-Bridge Motor Driver

High Side Left	High Side Right	Lower Left	Lower Right	Quadrant Description
On	Off	Off	On	Motor goes Clockwise
Off	On	On	Off	Motor goes Counter-clockwise
On	On	Off	Off	Motor stops
Off	Off	On	On	Motor stops

The last two rows of Table 1 describe a maneuver where the motor is short-circuited. The turning motor generates a voltage which tries to force the motor to turn the opposite direction, which causes the motor to rapidly stop spinning.

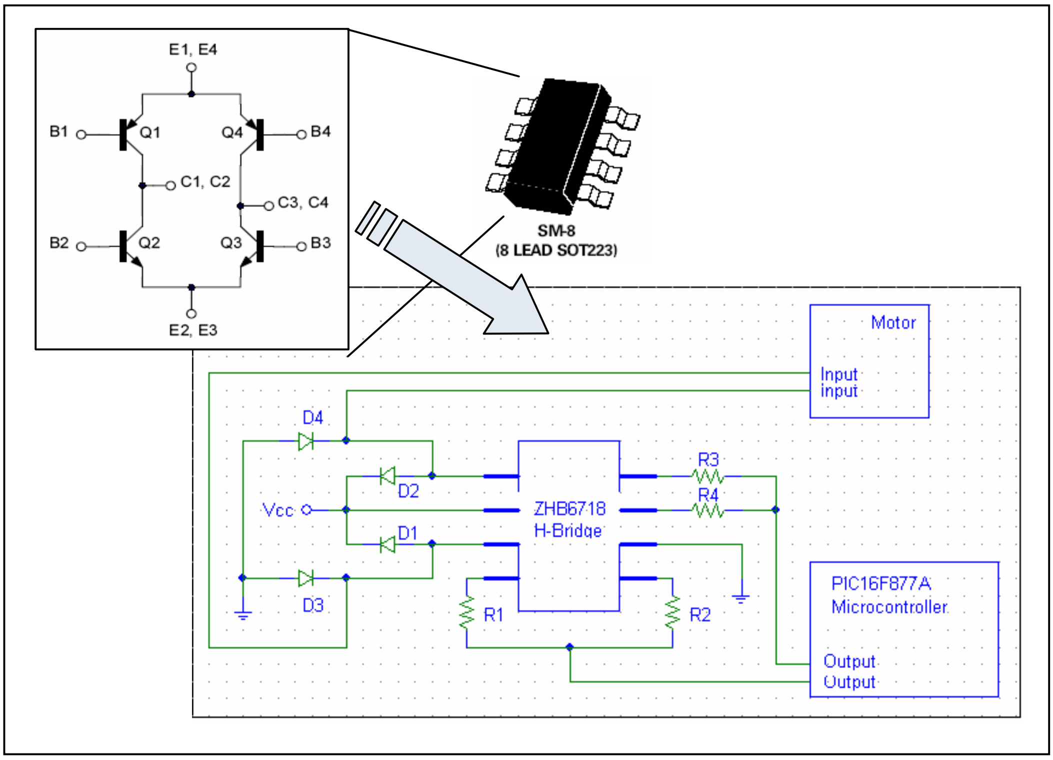

Figure 10: Schematic of the Motor Driver Using the ZHB6718 H-Bridge

Although the motor driver using the ZHB6718 H-bridge had successfully provided the necessary current to turn the motor without fail, its manufactured package failed to withstand the intense heat generated by the flow of high current as a result of driving resistive mechanical loads. During the process of testing this motor driver, we burned several H-bridges involuntarily, even with a heat sink attached and thermal greased applied onto its surface.

In order to be able to conduct currents in the ampere range and withstand power dissipation in the watts range, we decide to build an h-bridge using four power transistors such as the BUZ73

MOSFET along with the TC4427 MOSFET driver as shown in Figure 11.

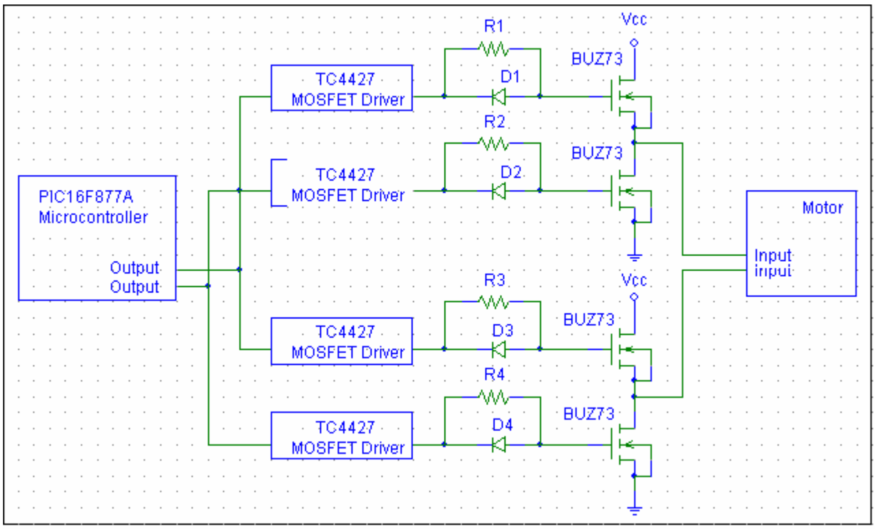

Figure 11: Schematic of the Motor Driver using the Power H-Bridge

The purpose of the MOSFET driver here is to have matched rise and fall times when charging and discharging the gate of a MOSFET. These devices are also highly latch-up resistant under any conditions since their high power and voltage ratings allow them to handle more heavy-duty tasks. Nevertheless, the motor driver using the power H-bridge requires more power to operate. While the design with the ZHB6718 H-Bridge is supplied with 6V DC, the MOSFET-based H-bridge requires 9V DC to achieve its optimal performance.

4.2.2. Gear Train vs. Electromagnet

For the light switch module in the client appliance unit(s), our original design was to have an electromagnet placing under both side of the switch. The contact area between the electromagnet and the switch is attached with a permanent magnet. When one of the electromagnet conducts, it will ideally attract the permanent magnet attached to the switch, lowering the position of one side of the switch. However, we did not anticipate that in order to ensure strong magnet attraction, two objects must be placed at very close proximity to each other; otherwise, the weak attraction is not powerful enough to pull one side of the switch down. However, we could not further reduce the contact distance since it would diminish the bi-stable property of the switch, i.e. impossible to tilt each side. Instead, we design an alternative solution, shown in Figure 12 using purely mechanical components such as a motor and gear train.

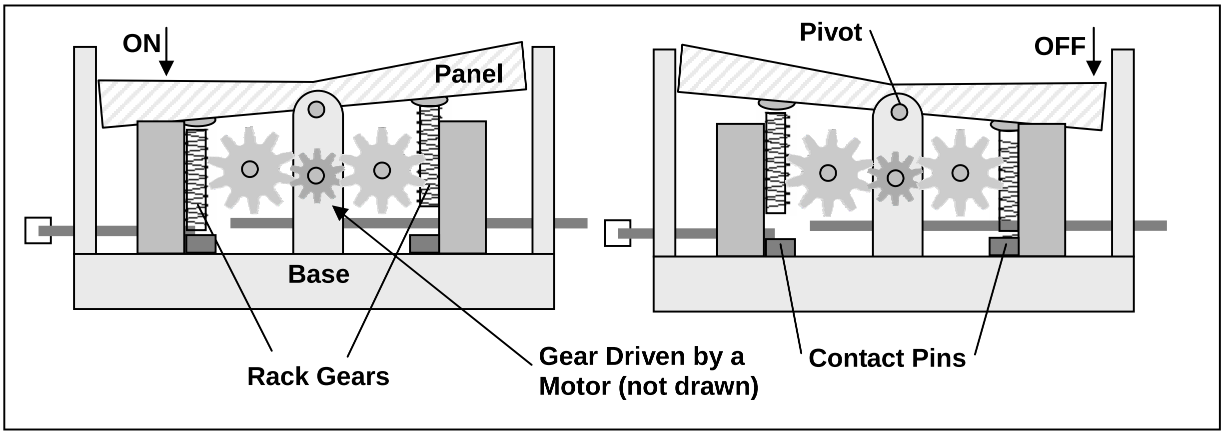

Figure 12: Schematic of the Alternative Homemade Switch using Motor and Gear Train

From the above figure, the middle small gear is driven by the motor; as the motor turns, this gear simultaneously turns the two larger gears right beside it. Notice that the directions that the two larger gears turn are opposite. Due to their respective gear ratios, the speed that the larger gears spin is slower than that of the middle gear; however, a larger resulting torque is generated with such a mechanical implementation, lessening the mechanical effort that the motor needs to generate. As soon as the two larger gears move, the two rack gears displace vertically in the opposite direction since the source rotational motion has been transformed to a translational movement. As one side of the switch is lowered, the bottom of its corresponding rack gear will hit the metal contact pin (pulled high if no contact) underneath. The microcontroller responsible for the light switch can then stop the motor once it detects a low from one of the contact pins.

With the alternative design of the light switch module, we can guarantee a more stable up-and-down movement of the switch panel. Unlike the power-inefficient electromagnet, using the motor in combination with the effort-saving gear train eliminates the amount of current required to supply the mechanical energy when moving the switch.

4.2.3. Gear Train vs. Pulley

The purposed design for setting the temperature controller knob to a desired position in our previous design specification involves a pulley system driven by a motor. In reality, when we performed several test runs for the heater module in the client appliance unit, the pulley belt always had a tendency to slip. Two reasons for this failure situation are: the resistive load to be driven by the pulley belt exceeded the maximum capability that the motor can sustain; the surface of the pulley wheel did not provide sufficient grips for the belt. As a result, to totally eliminate the frustration of slippage while also providing sufficient amount of torque when turning the knob, we decided to cascade several effort-saving gear trains as illustrated in Figure 13.

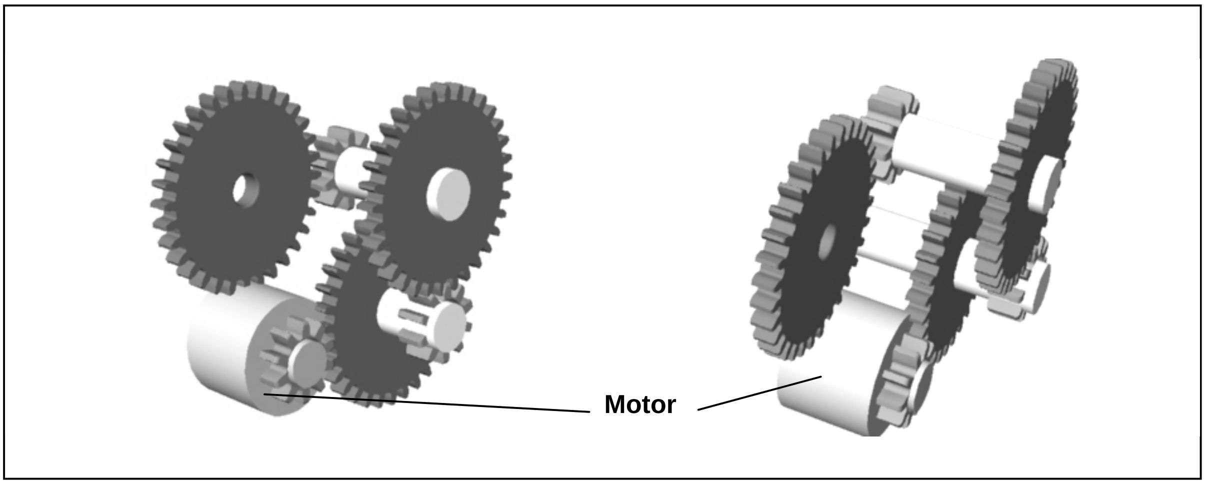

Figure 13: The Gear Train and Motor Used in the Heater Controller Module

4.2.4. Potentiometer

In the previous design specifications, we propose the use of temperature sensor to monitor the current room temperature. When a change in room temperature is requested by the user, the microprocessor samples the current room temperature by reading the temperature sensor, adjusts the temperature knob toward the new temperature (increase or decrease), and checks the new room temperature to determine whether further changes are necessary. This process iterates until the desired temperature is reached.

The major concern with this approach is reaction time. When the temperature knob is adjusted, the heater starts to change toward the new temperature. However, even with the smallest room size, the room temperature will not fully reach the new temperature until some time later. This means that the reading on the temperature sensor will not be finalized for quite a while. As a result, each iteration in temperature adjustment will experience a certain amount of waiting period that is required for the new room temperature to settle. Therefore, the process of temperature adjustment will take a while. This set-back is undesirable to the user who is waiting at the other end of the phone call.

The second concern with the temperature sensor approach is testing. If room temperature is adjusted based on the reading from the temperature sensor, we expect to perform and observe real changes in the room temperature. This means, the integration of our module with an actual heater is necessary when we reach the testing phase of our product. However, since the proof of concept is the emphasis at this point of our development, building the module that is independent of the actual heater is more ideal for the testing purpose.

As a result of the two concerns mentioned, we abandon the use of temperature sensor and adapt the potentiometer scheme for monitoring the room temperature.

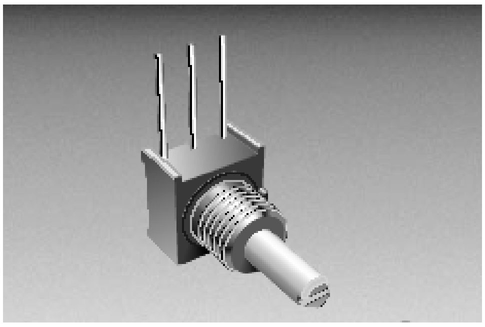

Figure 14: Potentiometer

As shown in Figure 14, the potentiometer we select is 3310Y-001-103 Square Sealed Panel Control from Bourn Inc. The total resistance of the potentiometer is 10 kΩ, and it has a 0.25 W power rating. The three pins coming out the potentiometer are V_{CC}, V_{EE} and output. V_{CC} is connected to the 5 V power of the heater module and V_{EE} is connected to the common ground. We then connect the potentiometer output to the A/D input of the PIC16F877A microprocessor which is used to control the heater module. The potentiometer, itself, is attached onto the same rotating axis as the temperature control knob. As the knob turns, the resistance from the potentiometer varies linearly with the knob angle, and the voltage reading by the A/D input of the microprocessor also varies linearly. Therefore, the A/D input accurately indicates the angle of the motor and the temperature reading associated with the motor angle.

The following table summarizes the mapping of 10-bit A/D reading from the microprocessor to the room temperature.

Table 2: A/D Reading vs. Temperature Reading

A/D Reading (Binary)	Temperature Reading (°C)
0000000000 to 0001111111	18
0010000000 to 0011111111	19
0100000000 to 0101111111	20
0110000000 to 0111111111	21
1000000000 to 1001111111	22
1010000000 to 1011111111	23
1100000000 to 1101111111	24
1110000000 to 1111111111	25

The potentiometer resistance varies according to the current room temperature setting. As a result, checking temperature becomes merely reading the A/D input. The potentiometer scheme is an improvement over the use of temperature sensor because we can obtain the current temperature reading on the heater module almost instantly, and the testing of the heater module can be done without integration with an actual heater.

4.2.5. Power Source and Regulator

For the CAU, the power source has been modified to a 9V DC battery from the initial 6V battery design. The main reason for such modification is because the H-Bridge circuit requires 9V in order to supply the current needed to drive the DC motor. However, an additional 5V voltage regulator is included in the final design because PIC16F877A microcontroller requires a 5V power source. The voltage regulator not only supplies the 5V needed, but it also acts as a protection for the microcontroller in case of excessive current damaging controlling circuit.

5. Budget and Funding

5.1. Budget

Table 3 outlines the comparison between the estimated budget and the actual costs incurred upon the completion of HomePA. The costs are rounded to the nearest dollar, and the contingency expenses stated in the proposal are eliminated.

Table 3: Comparison between Estimated and Actual Costs

Equipments	Estimated Cost	Actual Cost
DTMF Decoder/Generator IC	$10	$42
Microcontrollers	$100	$130
Power Supplies	$30	$26
Electronic Components and Sensors	$80	$33
Motors and Controlling Devices	$300	$349
Wireless Transceivers and Antennas	$200	$170
Total	**$720**	**$750**

The large deviation between the estimated and the actual cost for the DTMF decoder comes from the unexpected high shipping and handling expense. Also, the change of design in the motor drivers has added an extra cost by almost $50. Fortunately, due to an overestimation for the price of sensors, the actual cost dropped by more than 50%.

5.2. Sources of Funding

We have been granted the ESSEF Funds, valued at $400, towards the purchase of the wireless and DAA modules. On the other hand, we are currently in the process of applying for Wighton Development Funds. In addition, each team member has contributed $60 from his personal capital.

6. Time Constraints

Figure 15 and Figure 16 are the Gantt charts that show the estimated and the actual dates of which the corresponding tasks have been completed.

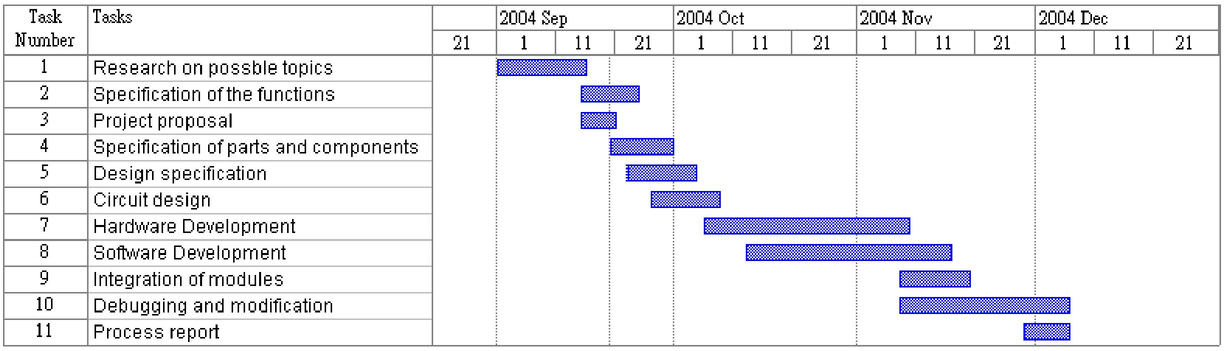

Figure 15: Proposed Timeline

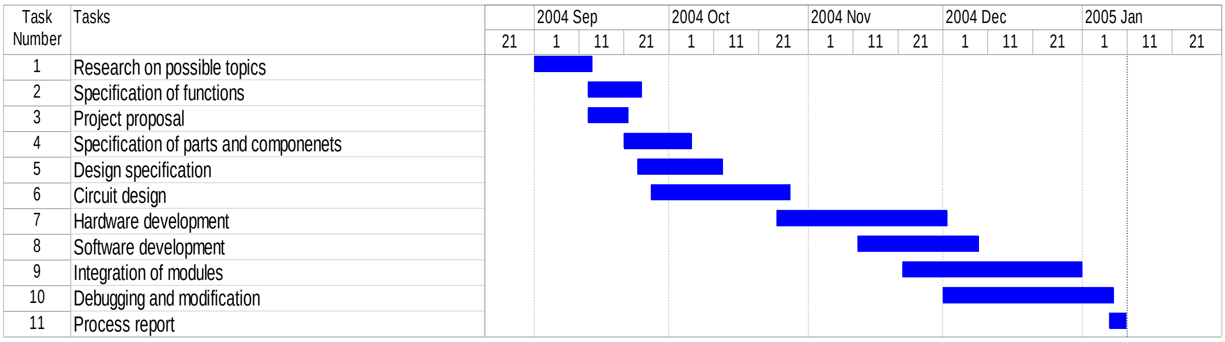

Figure 16: Actual Timeline

The project has been deferred by one month due to unexpected delay to develop the circuits and to integrate all modules. As shown in Figure 15, the time schedules for module integration and debugging are proved to be too ambitious. During these two phases we have encountered many unexpected obstacles and, hence, have faced difficulties in meeting the scheduled deadlines. Lastly, by completing this project we have learned that in future scheduling we must account for unanticipated problems.

7. Future Expansions

This section drafts out some future works and improvements that can be applied on the HomePA in order to bring our project closer to a better and complete product.

7.1. Multi-lingual User Interface

In our prototype design, due to memory availability on the voice recording device, our user interface is provided in English only. This situation creates problems and troubles for using the HomePA system if the user does not understand English.

For future works, we will implement additional Flash memories in our CCU design, which allows us to record the same user menu but in different languages, such as French, Mandarin, and Japanese, depending on region of sales. Thereby, the user may select his/her preferred language menu while accessing the HomePA system.

7.2. Remote Controller

HomePA is designed such that it must be dialled-in from a different telephone line/number, and cannot be accessed by simply picking up the telephone in the house and pressing the telephone keypad. This brings up the concern that if a user, when at home, wants to access and control home appliances using the HomePA; he must call-in from a telephone line different from that of the HomePA is connected to, for example he must use his cell-phone.

Considering the possibility that a user might not have a different telephone line, we will design and implement a wireless remote controller in the future. The purpose of an additional remote controller is to directly control home appliances without accessing the HomePA when the user is at home. The remote controller can by constructed using a simple keypad with the same PIC microprocessor, wireless transmitter and antenna used in the CCU. Therefore, the user no longer requires a telephone for controlling home appliances if he is currently at home.

7.3. AC-Powered Appliances

The initial prototypes are all powered by 9-volt batteries. Using DC batteries will constrain us on the number and type of appliances our HomePA is able to control. Moreover, batteries will eventually run out of power, and users will need to change new batteries for the home appliances after a period of time.

In order to resolve the power constraint of batteries, we will research household AC power lines in the future, and adapt it towards our home appliances. The goal is to modify our CAU such that they will be AC powered, and the need to replace batteries after a period of time will no longer be necessary, which in turn increases the convenience and serviceability of our product.

7.4. Additional Home Appliance Modules

Currently, for presentation purposes and limited time constrains, our prototype consists of only four different client appliance units, namely, door lock, window, light switch, and temperature control. Evidently, there are still numerous home appliances that can be integrated for our HomePA system in order to provide a better assistance and security for users.

As mentioned in the previous section, one of the future expansions of our HomePA system is to have AC-powered appliances. Once home appliance modules are capable of being powered from the AC line, further investigation and research on existing home appliances, such as microwave oven and washing machine, will easily allow us to integrate them with our HomePA system. Thus, slight modification of existing home appliances and implement wireless transmission device on them, we can increase the number of home appliance modules controlled by our HomePA system.

8. Interpersonal and Technical Experiences

Our project team, Trax Technologies, is comprised of five initiative, enthusiastic and industrial engineering students. Group members include Sean Hou, Jack Lin and Fred Yu, David Chen, and Howard Chang. Each student has brought their diverse knowledge and talents to the team. The following subsections discuss some of the interpersonal and technical experiences that each member has acquired throughout the development of the project.

8.1. Sean Hou (Chief Executive Officer)

Sean was initially responsible for researching on an appropriate microcontroller that will best fit the purpose of the HomePA. He chose the PIC16F877A from Microchip and then investigated on how to program in assembly language and how to load the software onto the chip.

In addition, Sean was also involved in the software development for all CAU with Fred. He also worked on the wireless encoding and decoding algorithm with the team to come up with the best solution.

As a CEO of the company, Sean would like to thank his group members for their tremendous effort towards this project. Endless hours in the laboratory and sacrifice for short holidays allow the team to come up with an excellent product – the HomePA system.

8.2. Jack Lin (Chief Financial Officer)

Jack was responsible for the financial portion of the project, which included controlling the budget and monitoring the cash flow.

Jack initially worked with Howard in constructing the four CAUs. He assisted the mechanics group in building more reliable and simpler models for the modules. In addition, Jack contributed to the circuit designs for the H-bridges and metal-contact sensors.

Upon the completion of the four modules, he then worked on the hardware group, responsible for many of the soldering and wiring tasks. On top of that, Jack worked with David in programming the software and testing the CCU.

8.3. Fred Yu (Chief Technology Officer)

Fred was initially responsible for researching on the client appliance units. He investigated several possibilities of building the client appliance units. He was also involved in the design of the CAUs and picking the suitable component parts for the CAUs. As well, Fred contributed on the circuit designs for IR sensors, H-bridges, and potentiometer.

Then, Fred teamed up with Sean on writing the software programs for each CAU. Fred learned the assembly language used by the PIC16F877A microcontroller and worked on encoding and decoding the wireless signals between CCU and CAU. In the latter stage of the product development, Fred was in charge of testing and debugging the CAUs. Then, he joins the whole group on the final integration of the four CAUs and the CCU.

Fred would like to thank all his group members for their ongoing help. In the end, he believes the bonds between each group member are strengthened as a result of their disagreements and struggles. Fred will always cherish his experience with Trax Technologies Inc.

8.4. David Chen (Chief Operating Officer)

David was initially responsible for researching telephone technologies, including DTMF, telephone networks, and suitable solutions for telephone interface device. He decided to use a Data Access Arrangement device for telephone interfacing instead of using the traditional hook-switch method. His attention was then devoted to the circuit design and the hardware implementation of the CCU.

David was also involved in programming the PIC microprocessor for decoding and generating DTMF tones, as well as telephone controlling and interfacing. Moreover, he later assisted Jack in programming the voice playback device and in implementing algorithms for synchronizing wireless transmission between the CCU and CAU.

Near the end of the project, David was involved in testing the reliability of the CCU and the communication between the CCU and the CAU. He also assisted in refining the circuit layout and program algorithm in order to achieve higher reliability and precise control.

8.5. Howard Chang (Chief Information Officer)

Howard was initially responsible for researching the voice playback and recording module used for the voice-menu interface of the HomePA. As a CIO, Howard applied his sounds grasp in formatting and stylistic issues in editing most of the documents prepared for the project. He then joined Fred in proposing the blueprints for the four client appliance units, which involved the architectural design and the determination of suitable components for each CAU module. At the early stage, he also assisted Fred in implementing the Manchester encoding and decoding techniques for the wireless module in assembly language.

Howard's knowledge on mechanical design, craftsmanship and usability engineering was extremely helpful in constructing the mechanical and user interface aspects of the entire HomePA system. In the development of each CAU module, Howard devoted his enthusiasm in building the physical bodies and assembling all the mechanical components such as gear trains, pulley systems, and motor systems. He was also chiefly responsible for troubleshooting H-bridges to solve the motor driving problem. From the middle of the project, Howard was also in charge of handling all the electronic parts ordering from DigiKey.

In the end of the product development, Howard teamed up with the rest of the group members in testing the functionality of each CAU module. He also created a professional website for Trax Technologies Inc. Finally, Howard would like to thank all his group members for their kind advices and criticisms throughout the development of the HomePA.

9. Conclusion

Despite the project deferral due to the unexpected delay in developing the circuits of all modules and integrating them together, the engineers of Trax Technologies Inc. managed to accomplish the development of its first wireless assistive product, the HomePA, with slight modifications from the early-proposed design specifications. This product offers an economical mean to bring convenience to any household; not only does it benefits the general public, but also allows elder citizens, minors, and some physically disabled people to control and monitor multiple home appliances with a few key presses on any telephone. This innovative solution developed by Trax Technologies Inc. is unmatched by any products currently in the market because of its simplicity and versatility. Finally, the successful completion of this project allows each engineer in Trax Technologies Inc. to expand their horizons in various aspects of computer engineering, electronics, and communications, as well as strengthens the team dynamics.

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