Design Progress Report: x10 Environmental Control System

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Abstract- The x10 Environmental Control System is an assistive technology platform that will allow a physically limited patient to control their home environment around them. This will include control over TV, Lights and other x10 compatible devices. The system is designed around a Cox Communications remote that will communicate via infrared LED signals to control the TV. An 18F452 PIC microcontroller is used to power the platform, which will allow the patient to control everything using a single button. The x10 appliances will be controlled by an x10 firecracker module integrated with our PIC. The firecracker uses RF signals to communicate with the x10 compatible devices. The platform will be powered by one 9 volt battery, two AA batteries for the Cox remote, and will have a port for a DC power adaptor that will convert 120V AC down to a safe 9V DC.

Introduction- The x10 Environmental Control system is being designed from the ground up as a new and improved PowerScan, previously developed as a Capstone Design project. The platform is being designed to suit a patient who has very limited physical mobility, and can only move their thumb across a small range of motion. The x10 ECS should function faster than the old PowerScan, and it will also be easier to use for our patient, and the patient's caregiver. The x10 ECS is being designed so that it will be able to run off of batteries or off of wall power so that it can be set up wherever the patient needs the device in their house. The Cox remote will allow the platform to be compatible with the majority of Televisions that are on the market today, and it can be calibrated very easily to any TV, or TV related device. The x10 firecracker module is originally designed to be plugged into a desktop computer, and will use the serial I/O ports from the computer to control the appliances in a client's house using radiofrequency signals. This will be tied into our platform by connecting the serial I/O pins of the module to our PIC which will be able to tell the firecracker how to communicate with the x10 appliances. The x10 platform will have two options for power supply, it will be possible to power the unit using a DC power adaptor plugged into a wall outlet, and if the unit is not being powered through the adaptor it will be powered from a set of batteries. The complete unit is divided into two devices, the remote and the PIC-controlled x10 firecracker module. The remote is designed to run using 3V DC, supplied by two AA batteries. The PIC device is designed to use 5V DC to operate, the entire circuit integrated with the PIC has operational parameters between 7.5V and 9V so a 5V DC voltage regulator is used to bring the 9V down to 5V for the PIC18F452 chip.

Design Discussion- The initial problem that we are tasked to solve is to design a system that will be able to allow a patient with limited physical mobility to control the appliances in their home, making it easier for both the patient and the caregiver. It will give the patient a greater sense of independence and it will lessen the burden on the caregiver allowing them to focus their efforts on more important tasks than changing the TV's volume level or adjusting a few lights in the house.

We are designing the x10 ECS with many realistic constraints in mind, we are conscious of environmental, economic, health and safety constraints and attempt to design the x10 ECS accordingly by following these constraints. We have listed our Bill of Materials below in the Appendices section, where we have listed that all of the components used so far in our prototype, however we have taken into account the expected number of components for the finalized design. Our prototype is fully compliant with the RoHS guidelines, we do not utilize any components that fail to meet the compliancy standards of the RoHS.

To comply with economic constraints and minimize production costs we will be removing the LCD screen from our final design as it will not provide any additional useful information to the user. Currently the LCD functions as a prototype display to indicate what functions are being performed by the x10 ECS software. This greatly increases the affordability of the x10 ECS as each LCD screen is $20.50, supplied by the SparkFun distributor. The next most expensive piece of hardware is the PIC18F452 microcontroller which is $8.20 per unit if purchased by the single unit. Digi-Key offers a discounted unit price of $5.70 per unit when buying in bulk shipments of 100 units. The breadboard used to design the current prototype has a unit price of $65. This will also be eliminated from the final project design, where it will be replaced by a generic printed circuit board that will be wired exactly the same as the breadboard but in a more compact and practical circuit. Each of the other components used so far in the design of the x10 ECS has a cost that is under $1 per unit, as with all electronic components the unit price drops and costs can be reduced by buying components in larger bulk shipments. The total manufacturing cost of each x10 ECS device is estimated to be around $15-$20, with the breadboard and LCD screen eliminated from the design.

We initially decided to design the x10 ECS to be powered by battery power sources, however we realized that this could be problematic for the system. As battery voltages begin to drop hardware components may begin to stop functioning as expected due to the voltage levels being outside of the operational parameters. To make up for the possible problems that may be encountered by using a strictly battery power source we will integrate a 9V DC power adaptor to power the x10 ECS from a wall outlet. The power adaptor will integrate into the x10 ECS system through a port, similar to that of a laptop computer. The connector will automatically switch between which source powers the system. When plugged into the wall outlet the connector will switch off the battery power, saving battery life and when the x10 ECS is no longer plugged into the wall it will switch the power source over to the batteries. We will choose a power supply that will completely meet all compliance requirements from the IEC60601 such that it is a safe power supply device to use with the x10 ECS. This system will be housed in a non-conductive plastic project housing that isolates the circuitry from the outside environment.

Methods- The x10 ECS is being designed around a previous generation Cox Communications cable remote. This remote is compatible with most of the televisions on the market as well as most of the devices that can be integrated with a television. The remote will be controlled by a PIC18F452 microprocessor programmed using C++ in the MPLab IDE. The PIC communicates with MPLab using the ICDE2 connector, which functions as a programmer and debugger. The PIC will use analog switches (HCF4051 BE) and multiplexers (MC14066 BCP) to tell the remote's processor which buttons are being virtually pressed on the remote. This will allow the PIC to control the Cox remote from a single button press. The remote is connected to the PIC using wires that have been soldered onto the circuit board of the remote, connecting different combinations of these wires will simulate a button press to the processor used by the remote, which will send an infrared signal to the TV executing the selected function IE power on/off, channel up/down, volume up/down.

The x10 ECS program is designed around the concept that every function can only be controlled by a single push button. This is accomplished by using a series of timers that systematically cycle through all of the possible functions with a one second delay between each function. Each individual function will be designated by an LED that light up sequentially depending on which function is currently being cycled through. The push button will execute the function that is being represented by the lit LED. Thus far we are using two stages of timer cycles named menu1 and menu2. When the system is initially turned on it begins to cycle through the main functions, lighting up the respective LED lights. The initial stage is menu1, where the program cycles between TV control, x10 control and the sleep function which turns all of the appliances off or on. While in menu1 the program will continue to run while it waits for user input. When the button is pressed the program shifts to the second stage, menu2 and it begins to cycle through the subset of functions under the main function selected.

While in menu2 the program will cycle through the different options available for the selected function, if the Television Controls were selected then the program will cycle through toggle power on/off, volume up, volume down, channel up and channel down. There is a one second delay between each function, however if that window of time is too rapid for the patient it can be adjusted to accommodate their needs and abilities. The program will execute the function that is being designated by the lit LED when the push button is pressed by the user. Pressing the button will also reset the timer that tells the program to continue to cycle through the options. If there is no user input for a period of time the program is designed to cycle through these available options for four cycles before returning to the menu1 stage. The program will continue to stay in the standby stage of menu1, repeating the main function cycle until another button press is detected.

The same cyclic pattern is applied to the other main functions available, when a main function is selected the program shifts to the second stage of timers where the functional options are available. For the x10 devices function the program will cycle through power on and power off, it is possible to add a third option as well if the patient needs to control an appliance with different levels of output intensity such as a fan, or a multistage light source. The third and final main function is the sleep command. Selecting this function will toggle the power on or off for all of the appliances being controlled by the x10 ECS. Both of these functions will follow the same principles of the others with a one second delay between each option and both utilize the

same time out timer that brings the program back to the initial menu1 stage where it will wait for further user input.

The x10 firecracker module will be integrated into the system by connecting the serial I/O ports of the x10 module to our PIC microprocessor. We will need to develop the customized software required for the PIC to communicate with the x10 firecracker module. This will allow us to use the firecracker as an RF signal broadcasting antenna to control all of the x10 appliances accordingly. This subsystem will be integrated in such a way that will still allow the user to execute each of the desired functions from the same single push button.

Discussion- We are still in the prototype design stages of the x10 Environmental Control System. We are currently working on the software that allows the PIC microcontroller to communicate with the Cox remote. Thus far we have the core of the software developed including our systematic timer system that cycles through the available functions and executable options under these functions. We also have a very small proof of concept design that proves that our method of simulated button presses on the remote will work as expected. It is a simple system of push buttons soldered onto a small piece of printed circuit board. We wired the circuit board and buttons in a way that when each individual button is pushed the corresponding connections are made between the wires that will simulate the desired button being pressed physically on the remote. This small proof of concept was fully functional and able to control the television in the laboratory using the external PCB control system. This success proves the concept that we will be able to control the remote using the PIC to electronically connect the wires using binary analog switches controlled by multiplexers.

We are currently developing our software so that the PIC will communicate with our HCF4051 binary analog switch to accomplish the desired task. The idea we are working on is that we want to send a binary signal to the 4051 chip to designate which pins we are selecting. Each pin will be connected in a way so that they each represent a specific wire connected to the physical remote circuitry. Then we would like to send the signal from the selected pins to the MC14066 multiplexer that would simulate making the physical connection on the remote by pushing one of the buttons. When this has been finalized and fully developed this will allow our PIC to communicate with the Cox remote in the desired fashion so that it will be controlled externally from the single push button.

To further improve the final design of the x10 ECS, as part of a redesign we plan to add a power saver feature which is not critically important, but will be very useful for the patient as the x10 system will not always be powered on, running the program and cycling the LED's on and off. This will greatly increase the life of the batteries powering the main circuitry. We plan to accomplish this by having a background timer always running, counting down a 45 second period of time of no user input where the system will then be set to a low power state, or become virtually powered off. This timer will be reset every time the push button is pressed, that way the user will never be cut off by the power saver function.

Another possible redesign idea is to eliminate the push button all together. This would be made possible by collaboration with another Capstone Design team who is designing an Android powered voice-activated switch. If the patient is able to speak loud enough for the phone's microphone to detect, then this could be a viable option to replace the tactile push button switch. It would also become easier and faster for patients with limited physical mobility

to control the x10 ECS by speaking the commands they wish to use instead of systematically selecting and waiting through the individual levels of cycles that the x10 ECS currently utilizes.

References-

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Mosebrook, Donald R., Richard C. Compton, and Joel S. Spira. Compact Radio Frequency Transmitting and Receiving Antenna and Control Device Employing Same. Lutron Electronics Co. Inc., assignee. Patent 5,736,965. 7 Apr. 1998. Print.

Appendix-

Bill of Materials:

Company	Part	Part Number	Compliance	Quantity	Cost per Unit (USD)
Digi-Key	PIC18F452 MicroController	PIC18F452-I/P-ND	Lead free / RoHS Compliant	1	8.20
Digi-Key	LM7805 Voltage Regulator	LM7805CT-ND	Lead free / RoHS Compliant	1	0.67
Digi-Key	4 MHz Ceramic Resonator	X902-ND	Lead free / RoHS Compliant	1	0.70
microcontrollershop	6 Pin ICSP Header	FH6PM-10	Lead free / RoHS Compliant	1	0.09
Digi-Key	470 Ω Resistor	CF18JT470RCT-ND	Lead free / RoHS Compliant	15	0.09
Digi-Key	10 KΩ Resistor	CF18JT10K0TR-ND	Lead free / RoHS Compliant	3	0.09
Digi-Key	LED	751-1116-ND	Lead free / RoHS Compliant	20	0.44
NXP	4051 8-Channel Analog Multiplexer	74HCT4051N,112	Lead free / RoHS Compliant	4	0.20
ON Semiconductor	14066 Quad Analog Switch/Multiplexer	MC14066BCPG	Lead free / RoHS Compliant	8	0.23
Digi-Key	9v Snap Connector for Battery	2239K-ND	Lead free / RoHS Compliant	2	1.05
Digi-Key	9v Battery	P647-ND	Lead free / RoHS Compliant	2	1.98
Digi-Key	Solderless Breadboard	922318-ND	Lead free / RoHS Compliant	1	65.84
Digi-Key	Perforated Prototype Board	V2025-ND	Lead free / RoHS Compliant	4	6.26
Digi-Key	LCD Display	NHD-0216SZ-FL-YBW-ND	Lead free / RoHS Compliant	1	20.50
Digi-Key	Tactile Switch	450-1650-ND	Lead free / RoHS Compliant	2	0.10

Schematic: