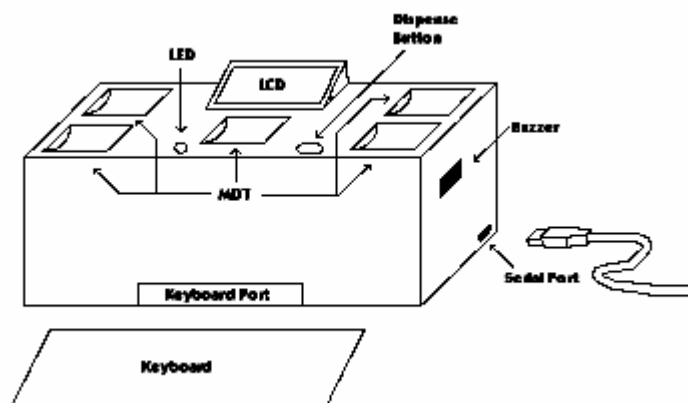


Automated Medication Dispenser System (AMDS)

Submitted to:

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EXECUTIVE SUMMARY

The elderly and sick are typically prescribed several medications each with varying conditions such as dosage amounts and times to be taken. Having to cope with their present condition is already difficult enough without being burdened with keeping track of different medications and their parameters. Several products have attempted to solve this ever growing problem, but only the pill box has achieved mainstream success. It is a set of containers each with a day of the week on it. It requires the user every week to load the correct medication at the correct dosage into its daily container. This system is too reliant upon the user. Even if the medication is loaded correctly the user still has to remember to take the medication. The Automated Medication Dispenser System (AMDS) will significantly improve upon the pill box by dispensing up to five different medications, alerting the user when to take their pills through both audio and visual alarms, displaying the dosage amount, and displaying the medication names.

The AMDS can be programmed in two ways. The first way to program the device is utilizing the onboard keyboard and Liquid Crystal Display (LCD). The second way to program the device will be using a Graphical User Interface (GUI) on a Personal Computer (PC) through a serial connection. It is recommended that a pharmacist or family member program the device if the user is not capable or willing. A microcontroller will be used to operate the entire system. A real-time clock interfaced to the microcontroller through an i^2c bus will keep accurate time for the system of up to 5 seconds. The user must set the time upon system power up. When it is time for a medication to be taken the buzzer will sound, the LED will light up, and the LCD will flash. The user will then press the dispense button ceasing the alarms, and opening the lid of the Medication Dispensing Tray (MDT) containing the medication to be taken. Each MDT will contain the full prescription of the medication, and the user will detract from it the correct dosage amount displayed on the LCD along with the medication name. A solenoid will pull the latch to release the MDT lid of the desired medication whenever the dispense button is pressed. The bottom of each MDT will be rounded out to allow for easy pill retrieval. After the user has consumed their medication, they must then close the lid and the AMDS will alert the user to any future medications. The primary power source of the system will be an 110V AC to 9V DC power converter. The system will also have a 9V battery backup in case of a power outage. The backup battery can power the system for up to five hours. All these components together will make our system run at a price close to \$100.

The prototype of the AMDS operates as described above. The greatest hurdles incurred during this semester have been the PC serial communication, and i^2c real-time clock bus. Next semester the prototype will be packaged, and the user interface and system operation will continue to be refined and optimized.

The AMDS will greatly improve the way of life for the elderly, sick, and their loved ones by helping them take their medication in a timely manner and at the correct dosage. Our product will erase all the worries and stress related to multiple medication prescriptions.

1. PROBLEM

Over the past twenty years there have been major advances in medical science. Better techniques and technical equipment have allowed physicians to provide better care and prolong human life as well as improve the standard of that life. Currently, 12.5% of the population of the United States is 65 years of age or older and by 2010 this figure is expected to reach a total of 20% of the population [1]. One of the tools that physicians have available to them to accomplish this task is an expanded array of potent medications. The FDA has approved an average of 340 new medications per for the past several years. According to Emergency Medicine Reports some 90% of people older than 65 years of age take one or more medications per day [1]. The average number of medications by each patient over the age of 60 years in the American Geriatrics Society study was greater than five per day [2].

For maximum effectiveness of these medications to occur, the medications must be taken properly. And while medical science has leaped ahead in many areas one of the problem areas that remain is that of ensuring patient compliance with taking medications.

Compliance is the consistency and accuracy with which a patient follows the regimen prescribed by a physician or other health professional. Compliance is important to insure improved medical care and lower medical costs. The Nursing Standard states that non-Adherence to medication regimens is a significant problem in older patients, which can lead to therapeutic failure and wastage of medical resources [3]. Gandi found that outpatient drug complications in the ambulatory setting were common, and that this caused an increased use of the medical system which in turn leads to increased cost [4, 5]. Compliance issues are not limited to a specific social economic, educational or cultural level; but affect all cultures [1, 5, 6, 7, 8].

The medical literature indicates that common causes of non-compliance include poor patient memory, physical difficulties, unpleasant side effects of medications, lack of social support, poor and lower education levels, depression, communication problems, medication supply and multiple medications [3, 7, 8, 9, 10, 11]. Several studies show that patients can over utilize or under utilized medications [9, 11, 12]. Golden says that over utilization not only increases medical costs by the patient taking additional medication doses but also increases the risk of adverse drug reactions, for which older patients have an increased risk for [2]. Emergency Medicine Reports estimated that the adverse medication rate for those above the age of 45 is double that of the younger age group [1]. Emergency Medicine Reports have also shown that the medications that older patients are more likely to require, anticoagulants, Antihypertensives, anticonvulsants, digoxin, and anti-inflammatory medications are the medications that are involved in most adverse dosing occurrences [13].

Various methods have been applied to increase patient compliance including verbal and written instructions, home visits, telephone prompting, behavior modification, limited medication access and pill bottle alarms [7, 14, 15]. The International Journal of STD and

AIDS states that these methods have met with various degrees of success but to date pill bottle alarms have been the most effective when single medications are involved [6].

Thus, it is evident that a medication delivery system that was able to be accessed easily by the patient, would deliver the right medication at the right time and thus prevent over utilization as well as under utilization would improve medication compliance with increased patient safety by decreasing medication dosage errors and optimize medication utilization would also decrease medical system costs and patient satisfaction. This next level in outpatient medical care can be met by the development of a device that could notify the patient of the appropriate dose of medication at the appropriate time in a manner that the patient with impaired motor ability could access and handle multiple medications. Emergency access would also need to be available. A device that would have these functions would solve many of the compliance issues that have yet to be resolved by other methods.

Elderly and sick people have to take medication due to their ailments or illnesses. Typically, they are prescribed several different types of medication, which must be taken in varying dosages. 25% of the elderly population use four or more prescriptions on a daily basis [16]. Patients must keep track of the correct times in which they are supposed to take these medications. 55% of the elderly fail to comply with medication regimens [16], and 50% of all prescriptions filled are taken incorrectly [17]. Oftentimes, age and sickness take their toll on a person's senses, and it is a common occurrence for individuals on medication to suffer from forgetfulness, lack of concentration, and impaired hearing or sight. Studies show that 43% of the general population make errors in taking medication, 58% of the elderly make errors in taking medication, and of these errors 26% are potentially serious according to their doctors [16]. Unfortunately elderly persons whom live alone often have no one to rely upon but themselves. Keeping track of medication is a very burdensome and often dangerous task for these individuals. There is no reason in this day and age of technology that a device cannot be designed to aid in this important task. Our project will solve the prescription medication compliance problem, which is prevalent among the sick and elderly.

Elderly and sick people suffer from the following problems with taking medication:

- Forgetting to take their medication at the proper times.
- Taking the incorrect amount of medication at the proper time.
- Overdosing their medication by taking it more than once because they forget that it has already been consumed.
- Not taking medication on purpose because they are uncertain if they have already taken it.
- Remembering which medication is the correct one to take at the proper time.
- Attempting to open prescription bottles is difficult due to childproof caps or any hand crippling disease such as arthritis.

Having a loved one go through these difficulties with medication is a taxing experience for family members. Generally, family members are involved in overseeing and aiding a

person with his or her medication. 80% to 90% of people requiring care in the US receive it from family members or friends [17]. This care process can be a very time consuming, frustrating, and stressful period for both family members directly and indirectly involved. It is very hard for family members to come into a situation that is alien to them and try to be responsible for a person that may or may not be able to completely communicate all that needs to be done. Having a system that will take care of these problems associated with medication will not only help the patient but also give the family peace of mind.

The most successful product that has attempted to solve the prescription medication compliance problem is the weekday pillbox. The box has seven compartments each corresponding to a day of the week, and all of a patient's medication for that day is contained within that compartment. However, this system is still too reliant upon the person taking the medication. Patients sometimes even make out charts to try to keep track of their medications. This solution is not consistent and requires too much time and effort. A new company called Epill has recently emerged that offers several option-rich systems at high prices [16]. These systems are good, but are too expensive, and tech-savvy for our targeted audience. Our project will combine the technology and ease of use into one package at a reasonable price.

A possible problem people may encounter when using our product is not having the ability or understanding of how to program it correctly. Another problem that may occur might be being able to program the product, but programming it with the wrong time and parameters. Both these problems can be overcome by having someone with a good background in technology program the device for the customer whenever his or her prescription is filled. The biggest design problem for this project will be making the product easy to use, and dispensing the medication in a straightforward fashion. Many parameters and special cases must be considered in designing this product.

The product will face many design issues. The device must have the ability to communicate with a CPU serially to program the LCD. The real-time clock must have an accuracy of five seconds per day to dispense the medication properly. The LCD, solenoid, and voltage regulator must be supplied with enough power to function. The backup battery for the system must be able to sustain the system for six hours. Lastly, all the programmed times and dosages must be met accordingly. The heart of the device is the microcontroller that will be used to operate the system to dispense the medication.

The goal of our project is to correct the problems listed above, and to help people cope with a life of taking medication. Pharmacists will now not only have to fill prescriptions but also program our project with the corresponding times and dosages for each medication. A family member can program the device as well. This eliminates any and all responsibilities of the patient except for actually taking the medication. A person's various medications will be made easily obtainable to individuals at the correct times and in appropriate dosages. Audio and visual alarms will notify a person to take their medication and what appropriate quantity is needed. Our project will help these people and their families lead healthy and happy lives.

2. OBJECTIVES

The purpose of this project is to build an automated medication dispenser. A pharmacist or family member will program the device. When the programmed time has been reached, an audio alarm will sound and a visual alarm will light up, the patient will press a button to open the Medication Dispensing Tray (MDT), and the medication name and dose amount will be displayed on the LCD. The user will then reach into the correct tray, and take his or her medication.

1. **Medication Support:** The device will have the ability to dispense up to five different medications each individually contained within a MDT.
2. **MDT/Container Access:** The device will have a single release button to open any of the five lids individually whenever an alarm goes off.
3. **Dispensing Scheme:** If only one medication needs to be dispensed the lid of the corresponding medication will open. If multiple medications need to be dispensed the various medications will be dispensed sequentially after each lid is closed.
4. **Real-Time Clock:** An accurate real-time clock will be the basis for the alarm circuit.
5. **Alarms:** A buzzer will sound and an LED will light up at the programmed time notifying the user that it is time to take his or her medication
6. **Power:** A 120 VAC – 9VDC converter will be used as a primary power supply, and a 9V alkaline battery will be used as a secondary power source.
7. **Packaging:** The device will be a compact size consisting of 5 MDT's, a LCD, release button, LED, buzzer, serial port, and a keyboard for user interface. The device will be 8.0"(W) x 4.0"(H) x 10.0"(D) and ~2 lbs.
8. **Pull Solenoid Latches:** The latches on each individual medicine container will be opened by the activation of a pull solenoid.
9. **LCD:** The LCD will display the correct dosage amount to take, and the medication name. The LCD will also be used to interface to the user during onboard programming.
10. **Keyboard:** The dispenser will utilize a Targus PDA keyboard for onboard programming.
11. **Serial Programming:** The user will be able to program the device by serially connecting the device to a CPU using a GUI.

12. **Programming:** The user will program the device with various parameters for each medication.

2.1. MEDICATION SUPPORT

The medication will be dispensed through five MDTs mounted on the top of the device. The device will have support for up to five different medications because the elderly and sick usually are prescribed more than one medication to keep up with and take. The average number of medications by each patient over the age of 60 years in the American Geriatrics Society study was greater than 5 per day [2]. Each MDT will have a rounded out bottom to make acquiring pills out of them easier. All of the prescribed medication will be held in each MDT. Having all the medication stored in an MDT will allow the user to see when his or her prescription is running low.

2.2. MDT/CONTAINER ACCESS

When the user presses the button to access his or her medication, a solenoid will pull back a latch holding the top of the lid down thus opening the lid allowing the user to access the MDT. The user then reaches into the MDT and takes the correct dosage of the medication displayed on the LCD screen. One button is used to open all the lids to simplify the design and to have a straightforward approach in which the user can access his or her medication. The user must manually close the lid once it has been opened. The button will have a 10ms debounce delay. If the user does not close the lid the system will be suspended until the lid is closed.

2.3 DISPENSING SCHEME

If one medication needs to be dispensed, the alarms will go off, and the user will press the dispense button to open the lid of the corresponding medication to be taken. If two or more medications need to be dispensed at the same time, the alarms for one medication will go off, and after the user presses the dispense button the lid of the first medication will be opened. After the first medication is taken and the lid is closed, the alarms for the second medication will go off and the user must press the dispense button again.. The remaining medications will open sequentially in this fashion after each lid has been closed until all the scheduled medications have been taken. The device will only dispense medication when the system switch is set to dispensing mode. If the user does not press the dispense button the system will continue to alarm until they do so.

2.4 REAL-TIME CLOCK

A real-time clock will be used to make sure the device alerts the user to take his or her medication at the appropriate time, and that the medication is dispensed in a timely fashion. The clock will be accurate. The real-time clock and 32MHz crystal will be connected to the microcontroller through an I²C bus. The time will be set upon system power up.

2.5 ALARMS

The device has both audio and visual alarms because the user may have either a hearing or sight impairment. When it is time to take the medication, a single LED will light up, the buzzer of the device will sound, and the LCD will flash. All alarms will cease once the dispense button is pressed.

2.6 POWER

The device will be powered by a 9VDC source. A 120 VAC – 9VDC converter will be used as a primary power supply, and a 9V alkaline battery will be used as a secondary power source. The 9V battery backup will have a battery life of approximately 6 hours. The backup battery will power the system in case the power goes out or if the user wants to travel with it thus making the device portable. A single 9V battery will be used as a backup power source. The device will use a single 9V battery instead of AA batteries for the following reasons:

- A 9V battery provides sufficient levels to power the 5V regulator, solenoids, and LCD.
- One 9V battery is equivalent to 6 AA batteries.
- One 9V battery is half the cost of 6 AA batteries.
- A 9V battery will last at least 6 hours based on a 100 Ω load and running the battery to a voltage of 5.4 volts.

2.7 PACKAGING

The device's dimensions will be 8.0"(W) x 4.0"(H) x 10.0"(D) and approximately 2 lbs in weight. This device is designed to be portable. The components of the device will be strategically mounted to the device for easy access. The LCD will be mounted in a raised position for easier viewing. The 5 MDT will be mounted around the LCD. The LED will be positioned in the front of the device for better viewing. The dispense button will be located at the front of the device as well for easy access. The keyboard will be attached to the bottom of the device in the front. It will slide out and the user can then unfold the keyboard. The serial port for CPU programming will be located on the right side of the device.

2.8 PULL SOLENOID LATCHES

A pull solenoid latch will hold down each MDT's lid. To open a lid voltage will be supplied to the solenoid, which will pull away the latch holding down the spring-loaded lid. The latches have been designed to function in a low power system. This scheme will increase the battery life of the 9V DC backup battery.

2.9 LCD

The LCD screen will be used as an interface when programming the device. It will display all the options/menus for programming the device's times, dosages, MDTs, and names of the medications. The LCD will display the name of the medication, and how much of that medication to take. The LCD will be positioned in the back center of the device at a titled angle for optimal viewing. The LCD is a standard 24 character by 4-line backlit display. It uses a serial connection to receive data from the microcontroller to display the medication information.

2.10 KEYBOARD

The main function of the keyboard will be programming the device. The AMDS will make use of a Targus PDA keyboard for its size, compactability, and input capabilities. It will allow the user to easily input the medications MDT, name, dosage, and times. It will be attached to a chaise in the bottom of the device. It can be pulled out of the device and unfolded anytime the device needs to be programmed. The keyboard should only be accessed for programming purposes. Not all of the keys on the keyboard will be recognized by the microcontroller in order to minimize the overhead associated with programming the device.

2.11 SERIAL PROGRAMMING

The user will have the ability to program the device using a CPU instead of with the onboard keyboard. The main reason for this option is so the device can be programmed using a GUI instead of the LCD interface. The device will communicate with the CPU through a RS232 serial cable.

2.12 PROGRAMMING

The user will program the device whenever the system switch is set to programming mode. The user will be prompted to input the MDT number, medication name, dosage amount, start time, interval time, and end time. After the user has inputted these parameters, they will be redisplayed and the user will be asked for their correctness. The start time is the time when the user should first take the medication each day. The interval time is number of hours from when a medication is taken to when it should be taken again. The end time is the last time a user should take his or her medication for a day. This will allow the user to sleep without being woken up by the alarms. The device can be programmed both onboard and offboard. The user will use the LCD and PDA keyboard for onboard programming, and the user will use a serial connection and GUI for off board programming.

3. APPROACH

Elderly, sick, and mentally handicapped people have to take multiple medications to deal with their ailments. Keeping track of these medications is very burdensome and can be life threatening. Our project will attempt to assist these people in taking the correct dosage at the appropriate times. The AMDS will have the capability to dispense up to five different medications. It will alert the user to take the medication through audio and visual alarms. These alarms will go off at the time to take the medication programmed by the user. The medication name and dosage amount will be displayed during pill consumption. The pills will be retrieved from medical dispensing trays (MDT).

3.1 HARDWARE APPROACH

The heart of the project is the Cypress CY8C26443 microcontroller. The pinout of the chip after being programmed for the AMDS can be found in Figure 3-1. In it you can see the UART ports for serial communication, and the I²C bus. You can also see the various control lines for all the components.

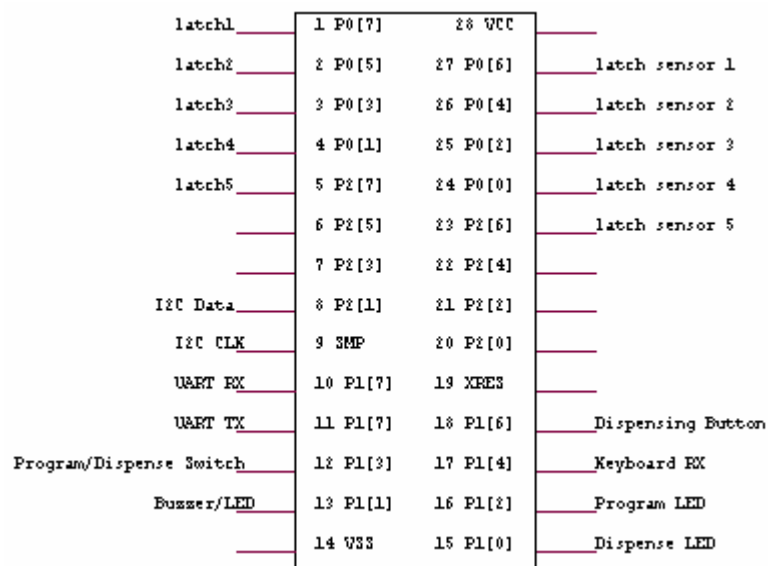


Figure 3-1. Cypress CY8C26443 AMDS Pinout.

Another key component to the AMDS is the latching of the MDTs. This is accomplished through the use of pull solenoids. The hardware schematic for the pull solenoids can be found in Figure 3-2. Notice the snubber diodes in place to protect the rest of the circuit from back EMF. Each solenoid plunger will be attached to a spring-loaded latch. The solenoid will be used to pull the latch off of the MDT lid thus opening it.

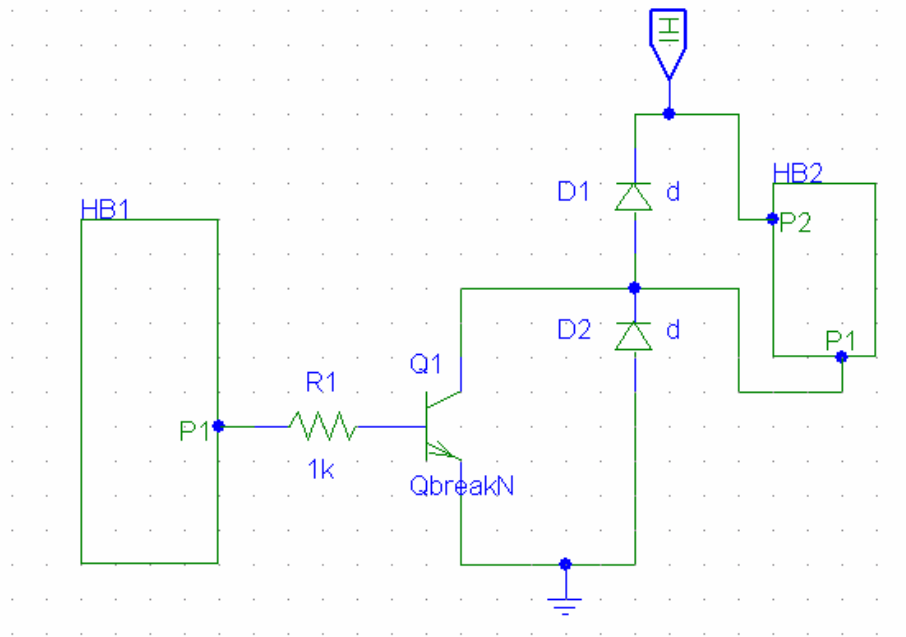


Figure 3-2. Pull Solenoid Schematic.

In case of a power outage the AMDS will have a backup battery that can run the system until power is restored. This way if the power goes out the user can still be dispensed medication. There will be no drop out from switching from the main power to the backup and vice versa. The schematic for the backup battery can be found in Figure 3-3.

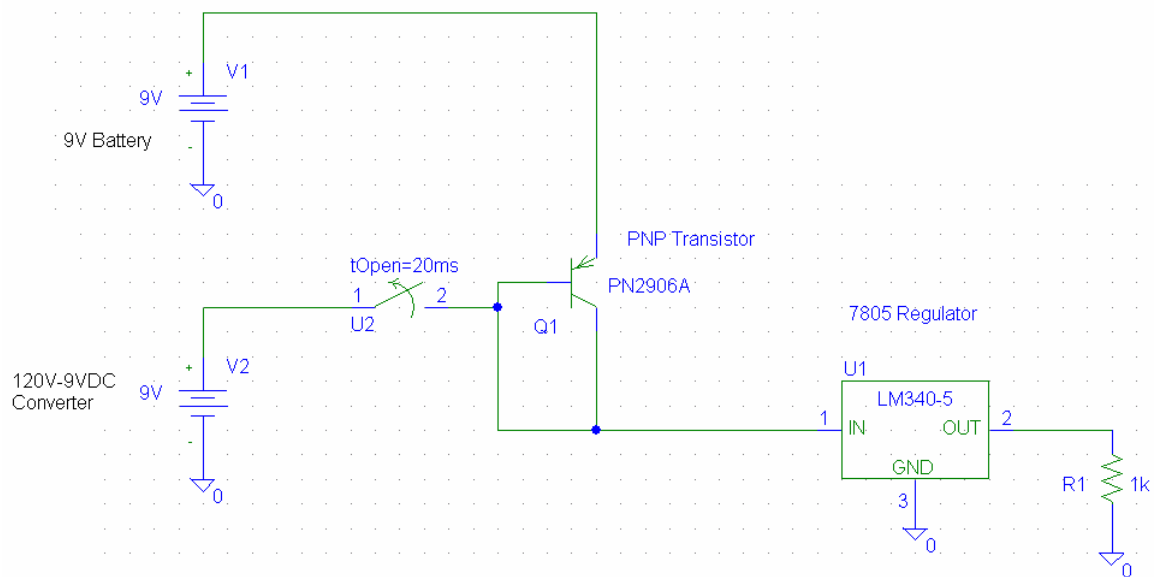


Figure 3-3. Backup Battery Schematic.

The real-time clock will be interfaced with using I²C bus communication. This format is easy to implement and occupies few pins on the microcontroller. It also keeps very accurate time when interfaced with 32KHz crystal. The pinout for the real time clock can be found in Figure 3-4, and the pinout for the 32KHz crystal can be found in Figure 3-5. Another reason this format was chosen for the real-time clock is that several team members have experience using it from Micro II.

PIN ASSIGNMENT

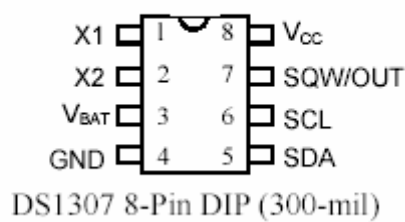


Figure 3-4. DS1307 Real-time Clock Pinout.

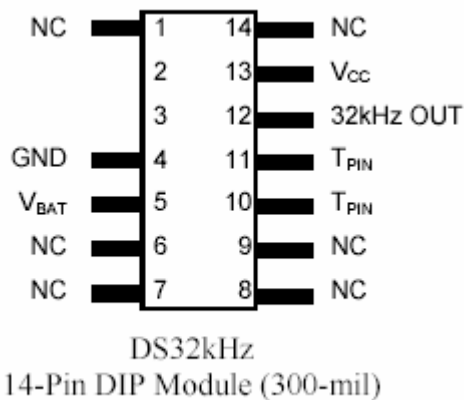


Figure 3-5. 32KHz Crystal Pinout.

The AMDS can also be programmed by a CPU through a serial cable. To communicate serially with the CPU we chose to go with RS232 format. The pinout for the RS232 can be found in Figure 3-6. Serial communication is an easy to implement format that does not require too many pins on a microcontroller.

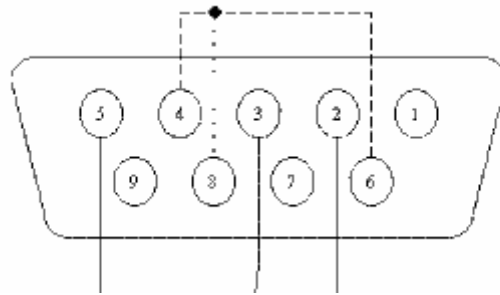


Figure 3-6. RS232 Pinout.

Each of the five MDT lids will be held down using a spring-loaded latch. The latch will be connected to a pull solenoid plunger. The lids of the MDTs will be spring loaded as well. The solenoid will be used to pull the spring-loaded latch away from the lid long enough to have the spring attached to the lid pop it open. The lid and latch will both contain a pin. When the lid is open the resistance across the two pins is infinite, while closed the resistance across the two pins is negligible. This resistance allows the system to know whether or not the lid is closed. A picture of latches can be found in Figure 3-7.

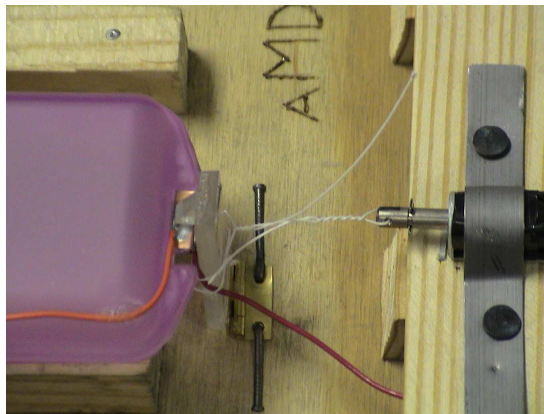


Figure 3-7. Picture of AMDS Latch.

To get a better overall idea of the AMDS system and its components refer to Figure 3-8. This system diagram shows all the major components of the AMDS and how they are connected.

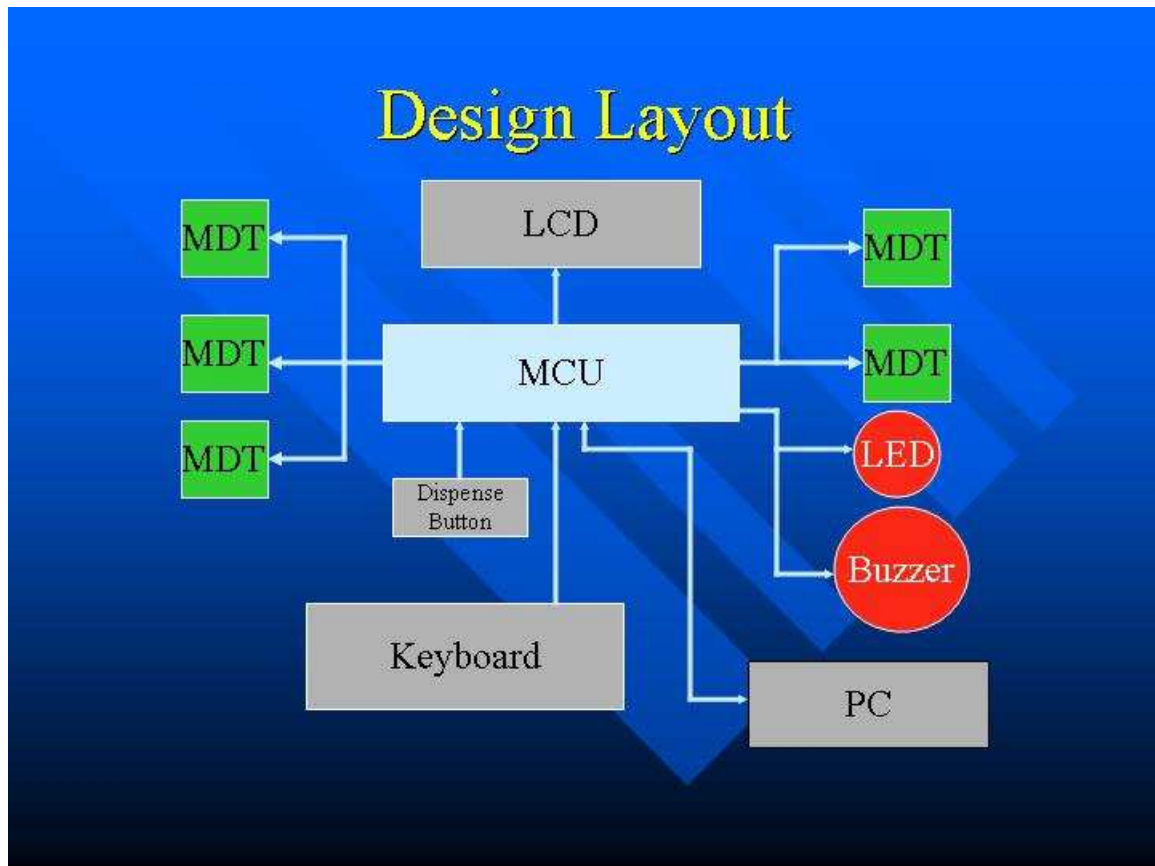


Figure 3-8. System Diagram

3.2 SOFTWARE APPROACH

All the code written for the Cypress CY8C26443 microcontroller for this project was done in C program language. This was chosen for ease of programming, and because the microcontroller contains enough program space to the point where code size does not become an issue on this project. For the complete code please check the Mississippi State University CPE Senior Design I webpage.

The AMDS will have two modes of operation, dispensing mode and programming mode. These will be determined by the system switch. Upon system power up the user will be asked to input the time. Note that when entering the time for one's digit values that the ten's digit should have a zero placed in it. When inputting in a time the user will be prompted to press 1 for AM and 2 or PM. When the system switch is set to programming mode the user can program the device to dispense a medication. If the system switch is not in programming mode, the system will constantly be checking to see if an MDT alarm time has been reached. If an MDT alarm time had been reached the system goes into dispensing mode. Switching between these two modes is the responsibility of the main, which can be shown in Figure 3-7.

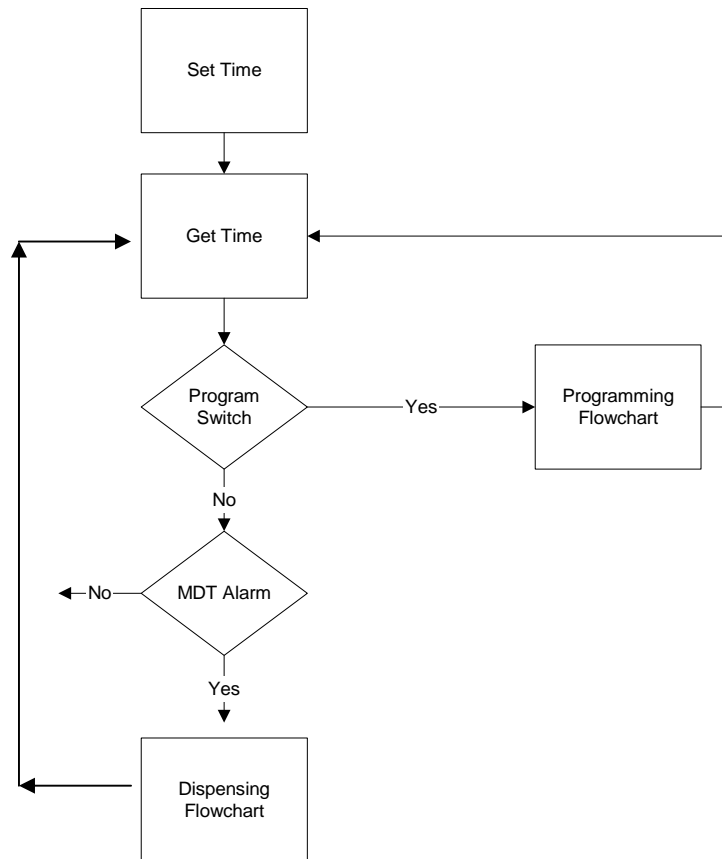


Figure 3-7. Main Flowchart.

The AMDS can be programmed by the setting the system switch to program mode. The user is first asked to enter in the MDT number that they want to program. If the MDT is already programmed the user is asked if they want to overwrite the existing program. If the user does not wish to overwrite the existing MDT they can select another. The user then prompted to enter the medication name. After the name has been inputted it is redisplayed to the user for correctness. If the name is not correct the user must input it again. After the name has been inputted the user is asked to input the medication's dosage amount. The user is then redisplayed what he or she entered and asked if it is correct. If it is not correct the user can input in the correct dosage amount. The user is then prompted for the start time. The start time is the first time during the day when a user should take his or her medication. It is typically when the user wakes up in the morning. The user is then asked to verify the correctness of the start time. If the start time is not correct the user can input the correct start time. The user is then asked to input the interval time. The interval time is the time in between when a pill is taken and when it should be taken next. Note this interval can only be inputted in as hours. The user is then asked to verify the correctness of the interval time. If the interval time is incorrect the user can input in the correct one. After that, the user is prompted for the end time. The end time is the last time during the day in which the user should take his or her medication. This is typically when the user goes to bed. The user is then asked whether or not the end time is correct. If it is not correct, the user can enter in the correct end time. Lastly, the user is redisplayed all the parameters he or she has entered in and asked to verify their correctness. After

programming one MDT the user has the option to program another, if not the program returns to main. If an MDT alarm time has occurred while the user has been programming the device the system will go into dispensing mode once the system switch is set off of programming mode. Note that the backspace, delete, and arrow keys do not work. If the user has encountered an error in inputting a parameter he should input it again upon data verification. Also note that when entering the time for one's digit values that the ten's digit should have a zero placed in it. When inputting in a time the user will be prompted to press 1 for AM and 2 or PM. The flowchart for programming mode can be found in Figure 3-8.

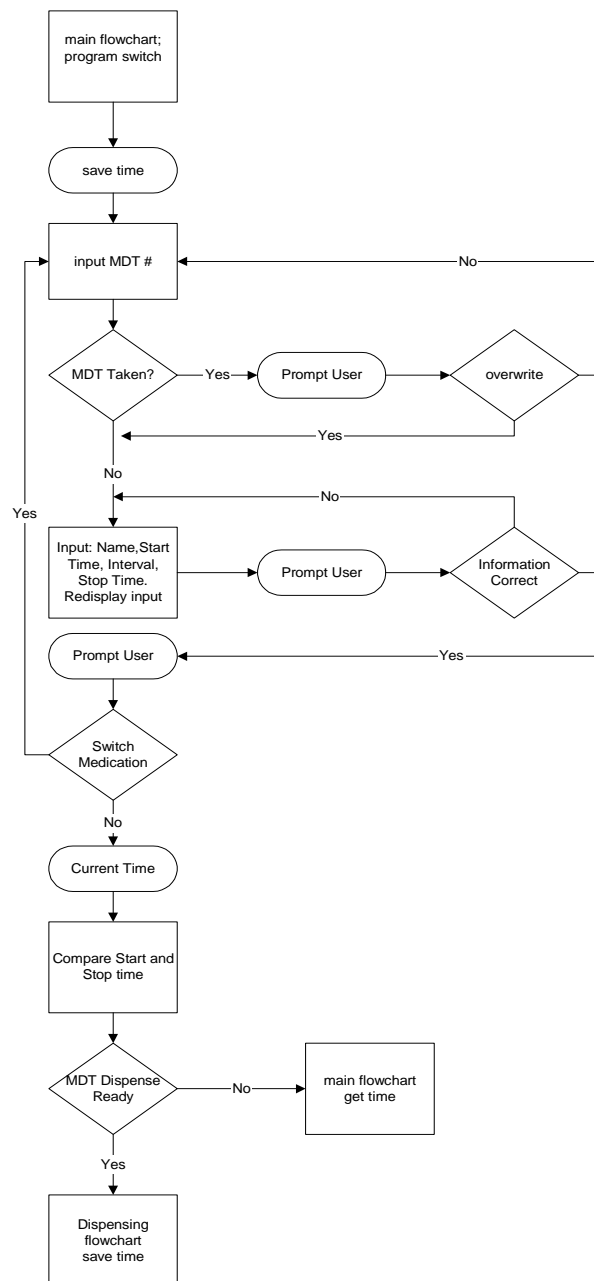


Figure 3-8. Programming Mode Flowchart.

Once an MDT alarm time has been reached the system goes into dispensing mode. First the alarms will go off alerting the user that it is time to take his or her medication. The alarms will not cease until the dispense button is pressed. During this time the buzzer sounds, the LED lights up, and the LCD flashes. Once the dispense button is pressed the medication name, and dosage are written to the backlit screen, and the lid to the corresponding MDT is opened using a pull solenoid. The program will then wait for the lid to close assuming the user has take his or her medication and is now closing the lid. The system will then check to see if another MDT alarm time has been reached. If so dispensing mode will be repeated all over again. If no other medication is to be taken the time is then redisplayed on the LCD and the program returns to main. Dispensing mode can be better visualized using Figure 3-9.

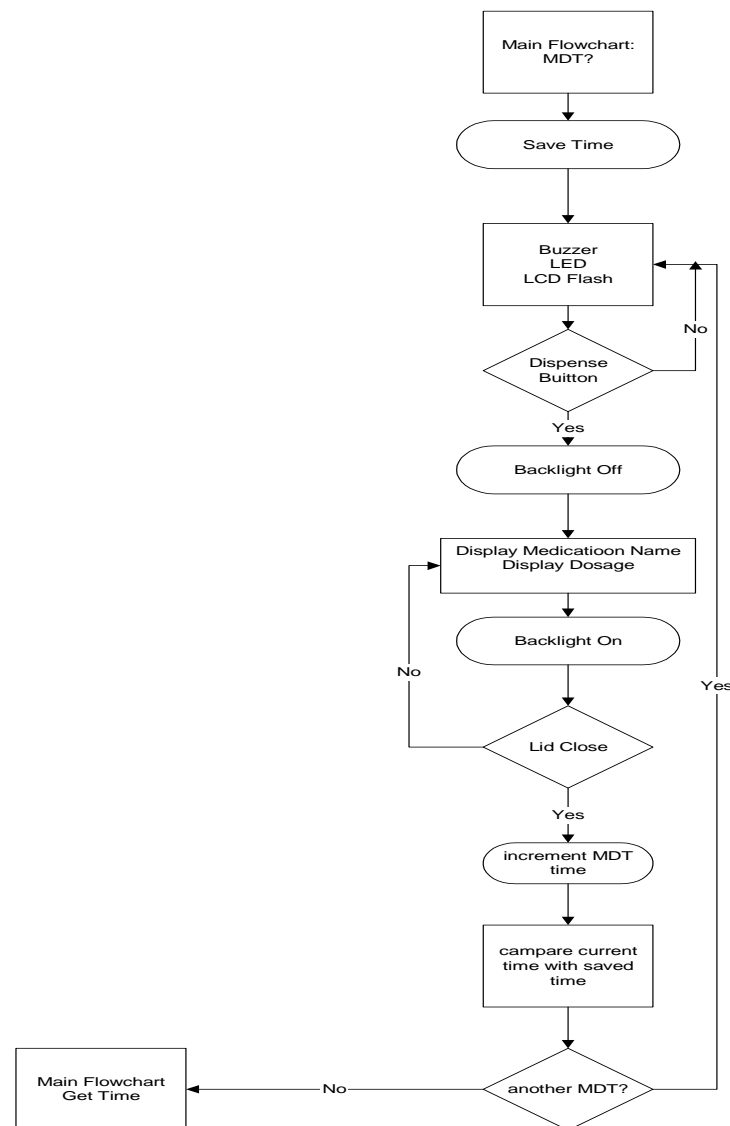


Figure 3-9. Dispensing Mode Flowchart.

The user also has the option to program the AMDS using a GUI on a CPU. The AMDS will communicate to the CPU through a serial connection. The GUI will allow the programming of the device to be less tedious. A picture of the GUI can be found in Figure 3-10. Visual Basic was used to program the GUI. The GUI has all error checking and options of programming the device onboard.

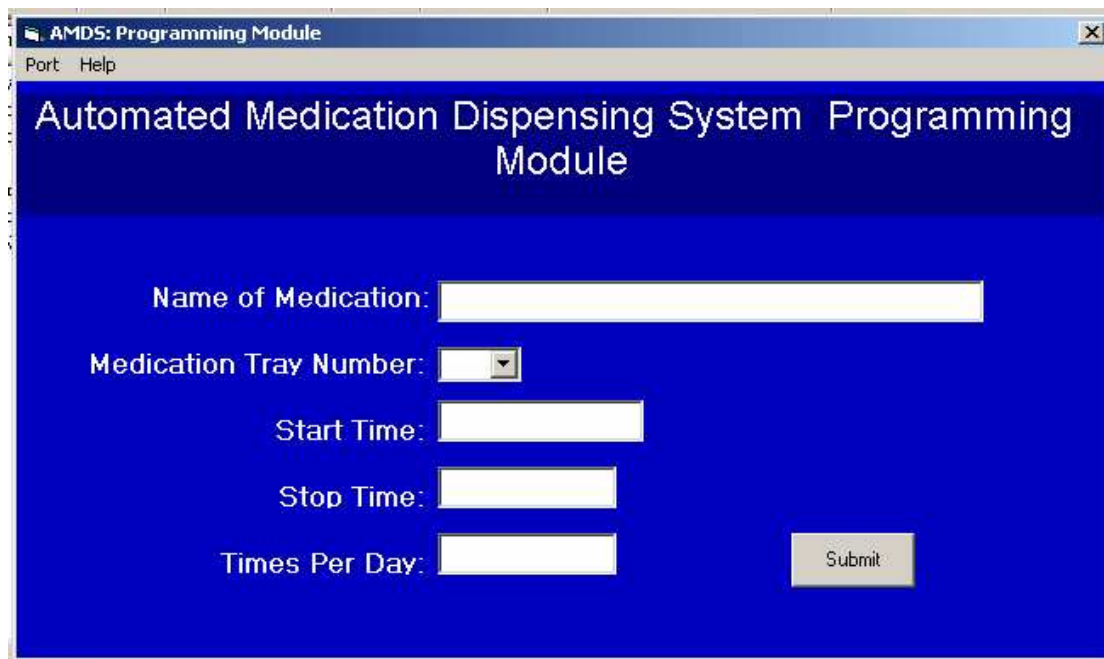


Figure 3-10. AMDS GUI Interface

The user makes use of a PDA keyboard to program the device onboard. The keyboard uses TTL level communication but does not send ASCII characters but instead sends X and Y coordinates. The keyboard sends one byte of data upon key depression, and sends another byte of data upon key release. The X coordinate consists of three bits, while the Y coordinate consists of four bits. Figure 3-11 shows the format of the keyboard data.

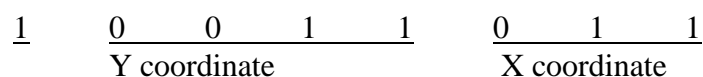


Figure 3-11. PDA Keyboard Byte Data Format.

The I²C bus real-time clock returns its values in BCD format. To display characters on the LCD they need to be in ASCII format. Therefore, a BCD to ASCII converter was written to overcome this obstacle and allow the microcontroller to communicate with the real time clock. This was an essential key in having the capability to set the time and to get the time.

Incrementing the time also proved to be a challenge. The real-time clock had to be told if it was in 12 hour or 24 hour mode. This was done by setting a bit in the byte data stream.

Our system always operates in 12-hour mode so the bit always needed to be set. The AM and PM had to be kept track especially when the MDT alarm time was supposed to rollover. Also the time had to be programmed to rollover correctly once it went past 12 at anytime. A function called increment was created to take care of all these parameters.

The Cypress CY8C26443 has capabilities of implementing a full duplex UART (Universal Asynchronous Receiver Transmitter). For our project the UART was used in communicating with components serially. The UART was used in interfacing to the CPU, and to the PDA keyboard. This capability of the microcontroller made using serial communication much easier, and significantly contributed to our project.

4. TEST SPECIFICATION

The AMDS will be tested using various test processes and tools. Each individual functionality will be thoroughly tested. The table below displays the equipment and processes by which we will test all functions of the AMDS. These test will be performed and evaluate at different times during the course of the design.

Requirements	Digital Multimeter	C Compiler	Oscilloscope	Simulator
LCD Interface		X		X
Accuracy of Real Time Clock			X	X
LED Visual Alarm	X			X
Audio Alarm	X			X
Lid Sensor	X			X
Dispense Button \ Solenoid	X			X
Keyboard		X		X
Power Source	X		X	

Table 1

4.1 LCD INTERFACE

A compiler and debugger/simulator will be used to verify LCD code correctness. Once the LCD code has been compiled and tested in software, it will be uploaded to the Cypress CY8C26443 microcontroller. During usage, the LCD will be tested to display the medication's name, and the correct dosage. During programming, the LCD will be tested to prompt the programmer for the following items:

- a MDT (1 –5) to hold the medication
- the name of the medication
- a dosage amount for the medication
- a start time for taking the medication each day
- a time interval in hours for which the next dosage should be taken
- an end time for taking the medication each day

4.2 ACCURACY OF REAL TIME CLOCK

The real time clock of the Cypress CY8C26443 microcontroller will be connected to an oscilloscope. The waveform of the clock will then be analyzed for accuracy against a known time period. The I²C bus communication will be tested for accuracy to make sure it is properly communicating with the microcontroller.

4.3 LED VISUAL ALARM

The voltage across the LED will be measured using a digital multimeter. A voltage will be measured across a known resistance. The current will be determined using the voltage obtained from this known resistance. The current will then be compared to current specifications to make sure it is within the tolerances of the LED. The LED of each MDT will be tested. The LED should light up at the programmed dispense times. Voltage will be supplied to the LED when the real time clock reaches the programmed dispense time. The voltage will cease once the user has pressed the dispense button. Testing the LED will occur in the following three stages:

- Testing that the microcontroller outputs an activation signal to the transistor at the correct time
- Testing that the current through provided by the transistor in operation is within the allowed specifications for the LED
- Inserting the LED into the system after passing the first two tests and checking that it operates properly within the system

4.4 AUDIO ALARM

The voltage across the buzzer will be measured using a digital multimeter. The known resistance of the buzzer will be used with this data to calculate the power being consumed by the buzzer to make sure that the values are within the tolerances of the buzzer. The buzzer should light up at the programmed dispense times. Voltage will be supplied to the buzzer when the real time clock reaches the programmed dispense time. The voltage will cease once the user has pressed the dispense button. Testing the buzzer will occur in the following three stages:

- Testing that the microcontroller outputs an activation signal to the transistor at the correct time
- Testing that the current through provided by the transistor in operation is within the allowed specifications for the buzzer
- Inserting the buzzer into the system after passing the first two tests and checking that it operates properly within the system

4.5 LID SENSOR

The lid sensor will be tested using the continuity checking function of the digital multimeter. When the lid is closed, the resistance across the two pins of the lid sensors

should be negligible. When the lid is opened, the resistance should be infinite. If multiple medications need to be taken, the closure of a lid will indicate to the controller that it needs to open the next lid in the medication sequence.

4.6 DISPENSE BUTTON/SOLENOID

The dispense button and solenoids will both be tested using the digital multimeter. The dispense button will require a continuity test to verify that it operates correctly. The solenoids will be tested to determine that the correct operating voltage is being applied to the device. If one medication is to be taken, the lid of the corresponding MDT will only open when the dispense button is pressed. If one or more medications need to be taken at the same time, the lids will open sequentially one after the other only after each lid has been closed, and the dispense button pressed. The dispense button will only open the lids of the correct MDTs once the alarms have gone off at the programmed times. It will not release any lids if pressed at other times. Pressing the dispense button will connect the circuit allowing voltage to the solenoid which will pull the latch and thus open the lids. This will only happen whenever the alarms go off at the programmed times.

4.7 KEYBOARD

The keyboard will be tested and simulated in software first using a C compiler. Then the keyboard will be connected to the microcontroller and ran through the different states. The functionality of each key will be tested. Some keys should have no functionality at all.

4.8 POWER SOURCE

The power source will be tested with an oscilloscope to ensure that the signal is clean and is configured in a DC waveform. The digital multimeter will be used to verify that the power source is at the correct voltage level. The 9V DC backup battery will be tested to ensure that it has a battery life of six hours. To perform all these tests the power source will be hooked up to an emulated load.

5. TEST CERTIFICATION

The following section includes test data showing that the AMDS has met its design constraints. The details of how each individual test procedure was carried out can be found in section four of this document. The AMDS is an embedded system therefore all its components are digital. The only way to test such a system is on a does it or does it not work basis. Please keep that in mind when reading the Test Verification portion of this document.

5.1 LCD INTERFACE

When switched into program mode, the LCD prompts the user for the MDT number, medication name, dosage amount, start time, interval time, and end time. If an MDT is already programmed the user is asked if they wish to overwrite that MDT. After each field is inputted the user is asked whether it is correct or not. Once everything is programmed the user is displayed with all the data he or she has inputted and asked about its correctness once again. During dispense mode, the LCD screen correctly displays the medication name and dosage amount when a MDT alarms.

5.2 ACCURACY OF REAL TIME CLOCK

The real-time clock is accurate and did not deviate from the known time it was measured against. The time is inputted upon system power up and is correctly displayed in the upper right hand corner of the LCD during dispense mode.

5.3 LED VISUAL ALARM

The LED lights up at the correct programmed time for each MDT. It remains on until the dispense button is pressed.

5.4 AUDIO ALARM

The buzzer sounds at the correct programmed time for each MDT. It remains on until the dispense button is pressed.

5.5 LID SENSOR

When the lid is open the resistance between the two pins is infinite. Upon lid closure the resistance between the two pins is negligible. The LCD stops displaying the medication name and dosage amount, and displays the time once the lid is sensed closed. If more than one medication is to be taken at the same time the system alarms after the first medication lid is sensed closed. The dispense button also works correctly for multiple medications. The pull solenoid pulls the spring-loaded latch away from the lid far enough and long enough to pop it.

5.6 DISPENSE BUTTON/SOLENOID

When the system is alarming the pressing of the dispense button will activate the pull solenoids opening the correct MDT lid, and the LCD will display the medication name and dosage. The dispense button does not open a lid at any other time.

5.7 KEYBOARD

Each letter and number key as well as the space bar on the keyboard displays the correct character. All the other keys do not work.

5.8 POWER SOURCE

The power source is sufficient for the running of the system except when a solenoid is activated. The solenoids require too much power consumption and bring down the entire system. Therefore to reach the power constraints outlined in this document the system has to be run off of two separate power supplies. The backup battery system had to be implemented utilizing two 9V batteries. This increases the battery lifetime but is not sufficient for the constraints.

6. SUMMARY AND FUTURE WORK

For Senior Design I, the AMDS team was able to get a fully functional working prototype. All of the design constraints were met except for one. The pull solenoids required too much power consumption when activated to open the lids. This brought the entire system down. The prototype worked off of two power supplies. This also meant that the backup battery would have to consist of two 9V batteries. This is unacceptable and will be corrected in Senior Design II. The design constraints that were met are the following:

- Real-time clock / I²C
- Serial Communication
- Alarms (LED, buzzer, flashing LCD)
- User Interface (LCD)
- Dispensing of five medications
- Latching

The AMDS prototype will require two fixes in its transition to a final product in Senior Design II. To correct the power supply constraint servomotors will be implemented into the system instead of pull solenoids. Servomotors will have a significantly less current draw to operate. The motors will be positioned parallel to the latches and will move one click to open the lid and then move one click back to close the lid. On a key press the keyboard sends out one byte of data. Upon a key release the keyboard sends out one byte of data. Our device ignores the release data of keys. However if two or more keys are pressed simultaneously the data is corrupted and must be corrected. A simple software fix will take care of this bug in Senior Design II.

The AMDS team had two significant trouble areas in developing the AMDS prototype. The first hurdle the team encountered was with serial communication. The original cable we used was defective, and we had trouble with the pin out of the RS232 chip. The second trouble area the team had, was communicating with the PDA keyboard. The team was under the impression that the keyboard used TTL level serial communication with ASCII characters. Upon further research it was revealed that the keyboard sent X and Y coordinates instead of ASCII characters. Three bits corresponded to the Y position, and four bits corresponded to the X position. To overcome this a jump table was constructed for each key.

The AMDS will also see a couple of changes from its prototype form to the final product. To prevent a possible user error, the system will alarm if a lid once opened is not closed after a certain amount of time remaining open. The LCD will display the MDT number of the MDT, which contains the medication to be taken. The interval time will have the capability of minutes to give the user more flexibility in the times he or she can take their medication.

Overall, the AMDS prototype was a huge success with a minor setback that will be easily fixed in Senior Design II. Upon completion, the AMDS will be a significant contribution to the medical community.

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