Wireless Glucose Monitoring System

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Abstract:-The world of medical electronics is shifting fundamentally. Equipment designs have traditionally lasted 20 years, with years of heritage and testing behind each design. We know that the diabetes is a growing and costly problem worldwide. Our goal is to develop a system to measure, record, and perform analysis on the glucose level of diabetics, both homebound and mobile. The device and corresponding software will be able to record the glucose measurement of the diabetes patient when it is taken, and wirelessly transmit it to be saved as medical records. This will be done by first sending the data to an email address specified by the doctor, and accessing it through software running on the computer used to hold all the patients' information.

I. Introduction

First Dr. Valdes from the UIC College of Medicine speak in class about his idea for a system to wirelessly monitor medical patients, we felt like it would be a great project since we could help out people in the world while gaining relevant experience in electrical engineering and project management. From there, we narrowed the focus of the project to wirelessly monitoring the glucose levels of diabetics since diabetes is a growing and costly problem worldwide. Essentially, the system will function similar for diabetics as On Star does for motor vehicles. It will log the patients' glucose level readings and send them to a medical database so that their doctor can monitor their levels and identify trends to enhance the treatment they are able to provide. All in all, just being able to help out many people all over the world is enough motivation for us to work on this exciting project.

A. *Benefits to End Customer:-*

- Patient glucose level will be logged automatically
- Doctor will automatically be sent an email with glucose levels within seconds of the level being tested, including a time and date stamp
- Patient glucose level history will be stored electronically
- Wireless design allows for an active lifestyle
- Can be recharged just like a cell- phone

B. *Product Features:-*

- Runs on rechargeable Lithium-Ion battery
- Uses low-power microcontroller for battery life of at least 1 week
- Data will be automatically sent via text message to patient email address and doctor email address
- Works with AT&T and T-Mobile
- SIM cards

II. Design

A. *Block Diagram:-*

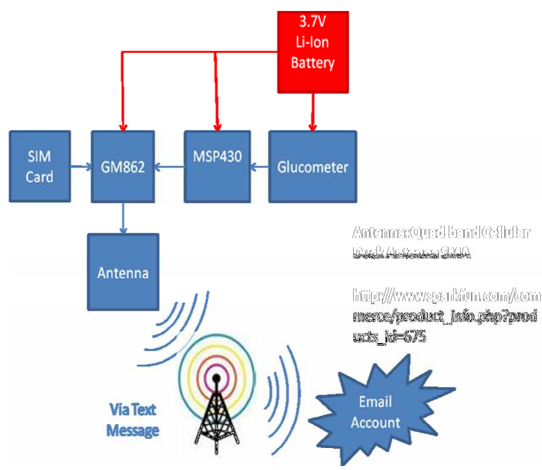


Fig.1. Wireless Glucose Monitoring Sys Block Diagram

B. *Block Description:-*

1. *MSP430-F2274(User):-*

The low-power microcontroller that will save the data read by the glucometer as well as saving the date and time the test was taken to protect against data being lost if the GM862 cannot send the text message. It will also send AT commands to the GM862 which are the instructions to send out a text message to the email account as well as the information to be sent in the text. Essentially, it acts to control the flow of information in the system.

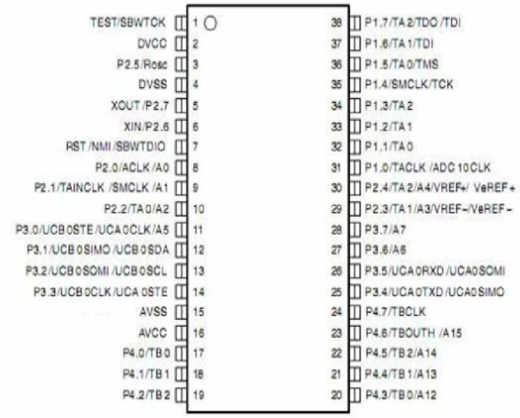


Fig.2.MSP430 Pin Diagram

2. *Lithium-Ion Rechargeable Battery:-*

The power source for the entire user device, which will provide 3.7 V to the GM862 and 3 V to the glucometer and MSP430 after appropriate voltage regulation using an LDO. We chose a rechargeable power source since the transmission of text messages on the cellular network by the GM862 will use a considerable amount of energy. Thus, to prevent the patient from having to swap out batteries every few weeks, we chose to use a Lithium-Ion battery (it was also recommended by the GM862 user's guide). The battery we will be using supplies 750 mAh, allowing for approximately 17 days of use on one charge (see calculations in the Simulations section).

3. *Glucometer:-*

The device that will collect glucose level readings (in mg/dL) through drops of blood from the diabetes patient when they normally test it, typically 3-7 times a day for a patient with type I diabetes. The glucometer in this case is a True Track Blood Glucose Monitoring System bought at a local drug store.

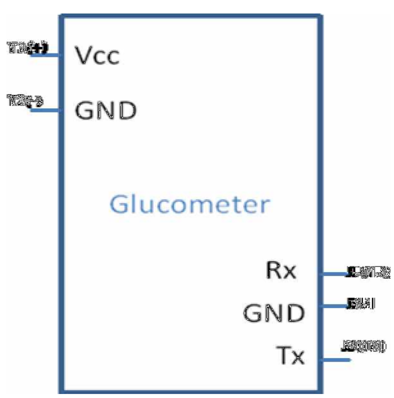


Fig.3.Glucometer Pin Diagram

4. *GM862:-*

The quad-band GSM module that can act as a cell phone and send data over the cellular network. Built in it is a SIM card holder so when it gets commands from the MSP430, it can make and receive calls. For our project, we will only be using it to send text messages to email accounts. The commands to perform these tasks (in the form of AT commands) will be sent by the MSP430 microcontroller over the UART serial port. The picture below shows how the **antenna** (GSM Antenna Connector) and the **SIM card** will be connected to the GM862.

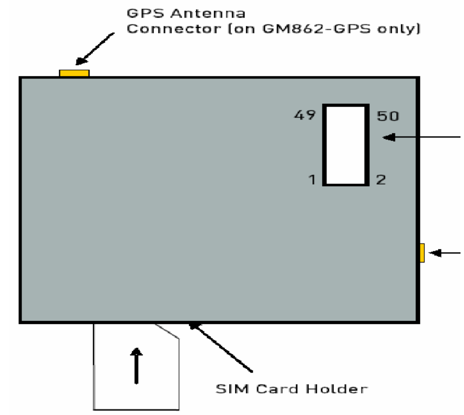


Fig.4. GM862 Interface Connections

5. *SIM Card:-*

This is simply a SIM card that comes with cell phones now-a-days, and will allow the GM862 to utilize the cellular networks already in place across the world. Each SIM card has a unique number so doctors can distinguish patient glucose levels. The SIM card will be connected to the GM862 in the SIM card slot that is already on the module.

6. *Email Account:-*

Because cell phones are capable to send SMS messages to email accounts, the SMS text message will be sent to the doctor's email address which is convenient in that all the data will be saved and easily searchable through features that most email providers have.

7. *Antenna:-*

The antenna will send the AT command from the GM862 into the GSM network which is what the cell phone network. With the SIM card described earlier, the data will be received by the cell phone network as if our product is a phone and will send the text message to the appropriate destination.

III. Testing Procedures

For our project, most blocks are already assembled for us, the more complex issue is getting all the blocks properly connected and to have them interact with each other in the specific ways we want them too. Conveniently, the GM862 has a slot for the SIM card and an interface for the antenna. But we will still test the three of these devices together by connecting the GM862 to the evaluation board and connecting that via USB to the computer. Then, using Hyper-Terminal, we will send an AT+CMGS command to the GM862 to send a text message to an email address. If this works, then we will know that the combination of the GM862, SIM card, and the antenna are functioning.

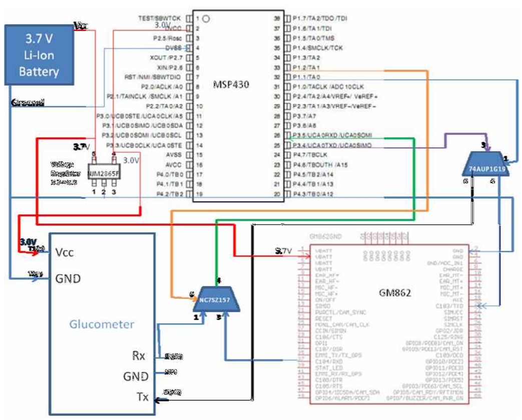


Fig.5. Connecting the GM862, MSP430, Glucometer, and Lithium-Ion Battery

The next part is to add on the MSP430 to the previous group of devices. We will connect the MSP430 to the development board and through the use of HyperTerminal again, we will send a AT+CMGS command to the MSP430 that will transmit the data to the GM862 and if an email shows up in our inbox, this connection works as well.

To test the glucometer to MSP430 connection, we will measure the glucose level of someone with the MSP430 target board and the USB debugging interface connected to the computer instead of running it on battery power. From there, we can verify that the MSP430 got the data correctly from the glucometer by utilizing software breakpoints in IAR Embedded Workbench and verifying the memory values of the MSP430.Once all blocks and connections have been verified, the last step is to make sure all parts work together. To verify this, we will have everything plugged in and make sure that a file is being created with the correct data shown on the glucometer, and also that it is hosted online.

Finally, once our projectis functional we will need to test the performance requirements lay out before. To test the expected battery life of the user device, we will use an ammeter to measure the current to the MSP430 from the batteries while the device is idle and transmitting and calculate the power dissipated. From there we can find the total energy by the device per hour and determine the battery life by the amount of energy contained in the power source.

$$Energy_{IDLE/HR} = V_{BATTERY} \times I_{IDLE} \times t_{IDLE/HR}$$
$$Energy_{trans/HR} = V_{BATTERY} \times I_{Trans} \times t_{trans/HR}$$
$$Energy_{HR} = Energy_{IDLE/HR} + Energy_{trans/HR}$$
$$Battery\ Life = Energy_{BATTERY} / Energy_{HR}$$

IV. Simulations/Flow Charts

A. Battery Life Estimation:-

1. Glucometer:-

The manual states that the TrueTrack glucometer uses 8.6 mW when active, and that it automatically shuts itself down every 2 minutes. Thus we will assume that the patient reads their glucose level a maximum of 7 times a day, which causes the glucometer to be on for about 2 minutes.

$$I = \frac{P}{V} = \frac{8.6\ mW}{3\ V} = 2.87\ mA$$
$$Capacity\ Use = \frac{7\ readings}{day} \times (2.87\ mA)(2\ min)\left(\frac{1\ hr}{60\ min}\right) = 0.670\frac{mAh}{day}$$

2. MSP430:-

Through clever programming, we can ensure that the MSP430 remains in a lower power mode for the majority of the time. Specifically, we will use lower power mode 3 since it turns off the main and sub-main clocks and the DCO, leaving only the auxiliary clock running at 32,768 Hz to handle communication interrupts.

$$Capacity\ Use = (1\ \mu A)\left(24\frac{hr}{day}\right) = 0.024\frac{mAh}{day}$$

3. GM862:-

With this device, we have the ability to turn it off through hardware and software. Thus, when we are not transmitting we will shut the device down through software, which uses only 26 µA.

$$Capacity\ Use_{OFF} = (26\ \mu A)\left(24\frac{hr}{day}\right) = 0.624\frac{mAh}{day}$$

In order to transmit the glucose reading through the cellular network, we will need to send a transmission to the server, and wait for the server to acknowledge that it has received the message. Thus, we have to account for the power used to transmit the data and to receive the acknowledgement. Assuming the maximum amount of current consumption for transmitting, the GM682 will use about 200 mA, and assuming the same for receiving, the GM682 will use about 50 mA. Finally, we made the assumption that the transmission will take no longer than 1 second, given that we will be using a baud rate of 9600 kbps and the maximum number of characters per text message is 160, which is equal to 1280 bits. Thus, the ideal transmission time would be 0.133 seconds if only the data bits were sent, but we are estimating using a worst case scenario.

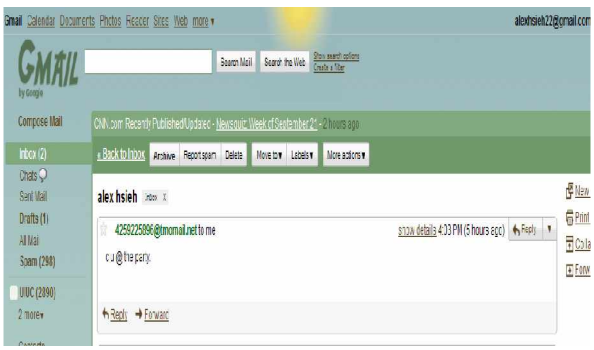
$$Capacity\ Use_{TX} = \left(\frac{7\ readings}{day}\right)(200\ mA)(1\ sec)\left(\frac{1\ hr}{3600\ sec}\right) = 0.389\frac{mAh}{day}$$
$$Capacity\ Use_{RX} = \left(\frac{7\ readings}{day}\right)(50\ mA)(1\ sec)\left(\frac{1\ hr}{3600\ sec}\right) = \frac{0.097mAh}{day}$$
$$Capactity\ Use = 0.624 + 0.389 + 0.097 = 1.11\frac{mAh}{day}$$

From these calculations, we can estimate the battery life of the device, given that we have chosen a Lithium-Ion Battery with a capacity of 750 mAh.

$$Battery\ Life \approx \frac{750\ mAh}{1.80\frac{mAh}{day}} = 17\ days$$

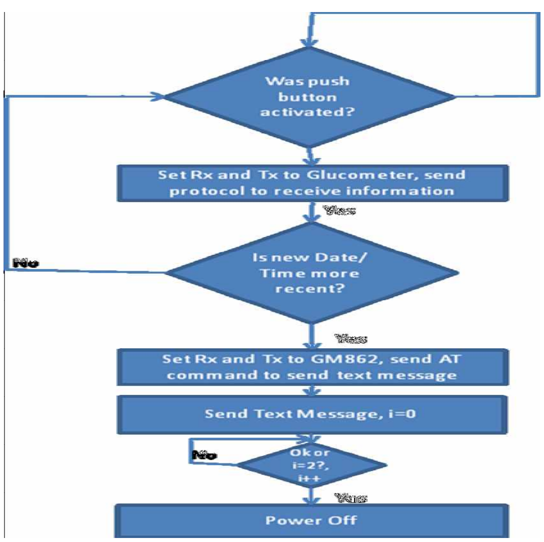
B. Text Message to E-mail Simulation:-

We wanted to verify that sending a text message to an email address was feasible. It turns out that by sending the text message to a certain gateway number for T-Mobile and AT&T providers made all this possible. Here is an example of what was sent in the text message. To:500 Message:alexhsieh22@gmail.com#alex hsieh#c u @ the party. Here's a screenshot of the email that was sent to alexhsieh22@gmail.com.



Notice we were able to set the subject as the patient name, and with this capability, we can send the date, time, the measured glucose level, as well an average glucose level to the doctor's email.

C. Flow Chart for the select line for 2:1 Mux:-



D. Sending Text Messages from the GM862:-

The GM862 accepts AT commands. The AT+CMGS command is the command to send a text message. The format is shown below:

AT+CMGS=*address*[,*address_type*]<*CR*>*sms_message_body* <*Ctrl+z*>

with these commands, we can send a text message to an email address with the following example: AT+CMGS=500<CR>genericdoctor@gmail.com#patient name#09/24/2009 10:37pm 300mg/dL Average: 372mg/dL<Ctrl+z>

E. Retrieving Glucose Data:-

We will be retrieving data from the glucose using the protocol used by the Glucometer's data port, which is still in process of being reverse-engineered.

V. Conclusion

This paper is designed to develop a system to measure, record, and perform analysis on the glucose level of diabetics; both homebound and mobile becoz diabetes is a growing and costly problem worldwide. The device and corresponding software will be able to record the glucose measurement of the diabetes patient when it is taken, and wirelessly transmit it to be saved as medical records. This will be done by first sending the data to an email address specified by the doctor, and accessing it through software running on the computer used to hold all the patients' information.

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