gPod

Accessible Blood Glucose Monitor

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Biomedical Engineering Senior Design
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Sponsored by the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation (RERC on AMI)

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Introduction:

Diabetes is a disease that currently affects 18.2 million Americans, comprising 6.3% of the American population, with new cases continually developing. It is the fifth leading cause of death in the United States. Diabetes is a disease where the body does not properly use or produce insulin. There are two major types of diabetes, type I and type II. Type I diabetes is where an individual's body does not produce insulin. Type II diabetes is where an individual's body does not properly use insulin combined with a relative insulin shortage within the body. Type II diabetes is by far the more common type with about 90% of people with diabetes having this form. Insulin is a hormone produced in the human body which is needed for the conversion of sugar, starches, and other food into energy. Without insulin the body would not be able to receive the amount of energy needed to function, which is why diabetes is such a serious disease.

The major problem with diabetes is that the underlying causes of it are currently unknown. Various factors have been determined to play a role in diabetes such as genetics, obesity, and lack of exercise. At this time, there is no cure for diabetes so life-long treatment is the only alternative. These treatments can consist of blood glucose monitoring combined with insulin injections, keeping to a strict diet to control sugar intake, and exercise. A diabetic person who does not monitor their blood glucose levels runs the risk of falling into insulin shock and other very serious complications.

The most popular method for monitoring blood glucose levels is through the use of a portable glucose monitor. These devices are made relatively small to maximize their portability, but still perform their intended function. Portable meters are battery operated and can analyze a very small sample of blood to a high degree of accuracy. Over time, these devices have become more user-friendly and more reliable. However, the majority of the meters currently on the market are designed for an individual who has no physical limitations. That is, the meters do not facilitate the population of people who are diabetic and have disabilities. There are many disabilities commonly associated with diabetes such as vision loss, hearing impairment, and motor control impairment which hinder the use of a standard meter. Our assigned patients include a young patient who has partial vision loss, an elderly patient who has total vision loss, a patient who has Parkinson's disease and has tremors, and a patient who has partial hearing loss. While a few meters do take the needs of these disabilities into consideration, they are very expensive and bulky as well.

The design being proposed is an accurate, reliable glucose meter that will incorporate features aimed at catering to the needs of those patients with disabilities. Examples of such features include a large screen, step-by-step audio instructions, simple operation, insulin vial scanning module, and an anti-slip casing design. Diabetic patients have a wide range of age as well as various disabilities which makes the proposed blood glucose meter suitable for a major portion of the market.

Design:

The proposed blood glucose meter will be able to cater to the needs of vision, hearing, and motor control impaired persons through the addition of several key features and modifications. A large, high contrast, liquid crystal display (LCD) will be used for easy viewing of the instructions and results for those patients with hearing loss or slight vision loss. It will have step-by-step audio output for those patients with severe to complete vision loss. This audio output will prompt the user through the complete testing procedure and as well as all other functions of the meter. The meter will also have distinctly colored, textured buttons and rubber side grips for those patients who have motor control difficulties. The size and texture of the buttons will allow the user, regardless of their disability, to easily distinguish between them. This will reduce the chance of user errors from their disabilities. The rubber side grips will allow for enhanced grip on the meter which results in easier handling for those patients with impaired motor control. The meter will be battery powered to maintain portability. The meter will also have the ability to upload test results to a PC using the USB port connection on the bottom. Figure 1 is an illustration of the casing design, and incorporated external features.

The meter will also have a vial scanning module which will allow the user to insert an insulin vial and have its name audibly output by the glucose meter. The vial scanning module will be detachable for those patients who do not need it. This module will connect to the glucose meter through the USB port connection on the bottom.

Figure 1: External Views of Meter (Front, Side, Back)

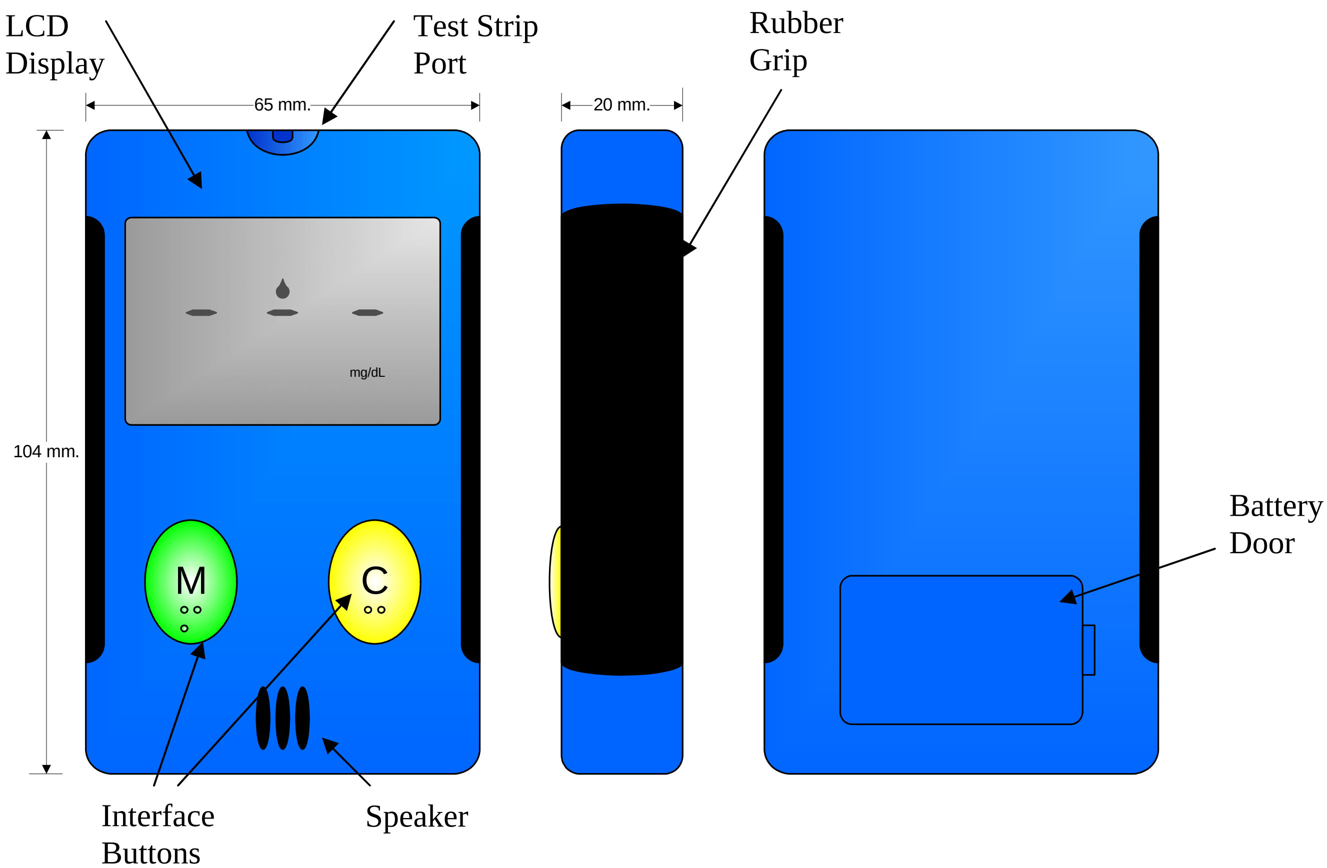
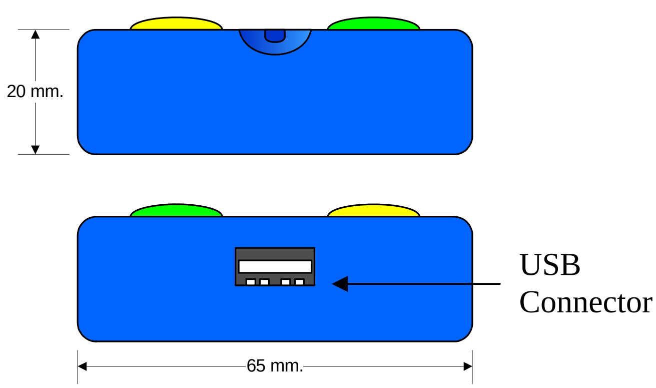
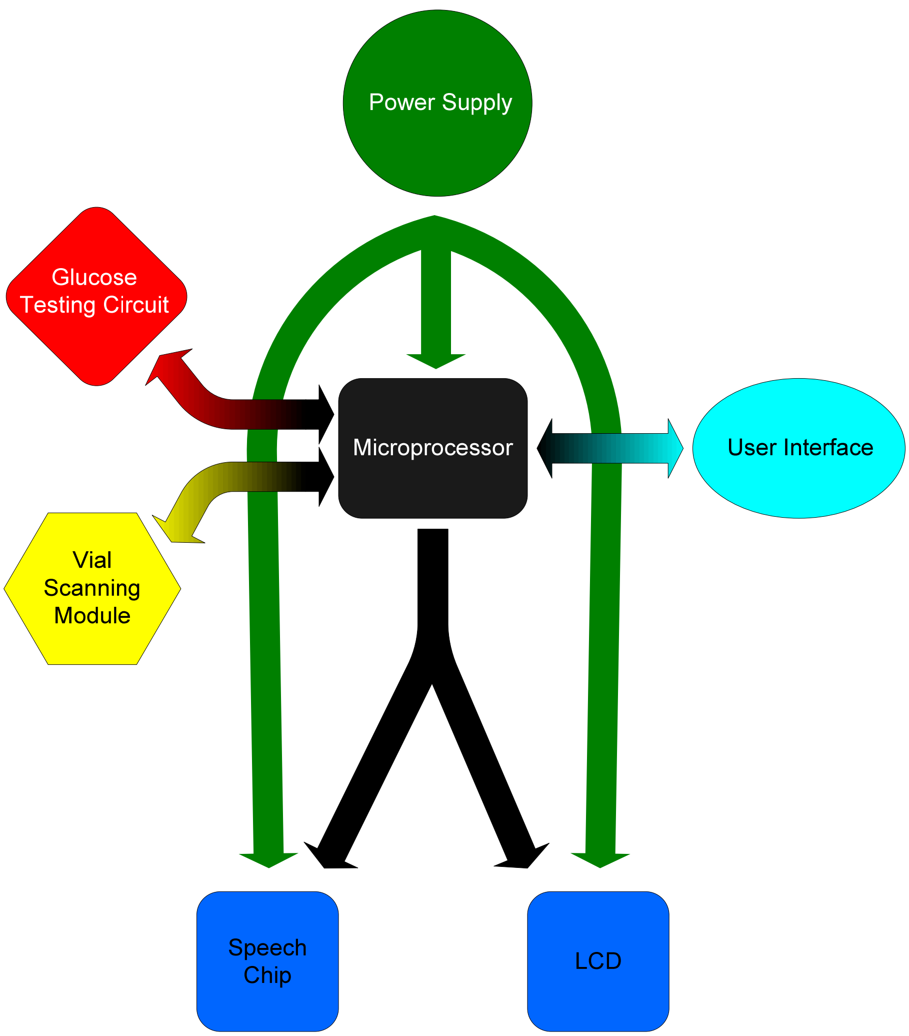


Figure 2: External Views of Meter (Top, Bottom)



The glucose meter will be controlled by a microprocessor. This microprocessor will essentially interface and communicate with each module of the proposed meter. Its main function is to communicate with the user interface and allow the patient to control what function the meter is performing. This will be done visually through the LCD screen, audibly through the speaker. The microprocessor will receive incoming data from the glucose test circuit when a test strip is inserted and a blood sample is applied. The LCD screen will display instructions and test results. The audio output of the proposed meter will be generated from a text to speech chip within the device. This chip module translates the data from the microprocessor and generates an audio output via a speaker for the user to hear. Figure 3 shows the block diagram of these described processes.

Figure 3: Design Block Diagram



Testing Procedure:

The proposed meter will use commercial test strips designed for the One Touch Ultra® glucose meter made by Lifescan. The testing procedure begins when a single glucose test strip is then inserted into the port at the top of the meter. The meter will then tell the user to apply the blood sample to the strip. The measurement will take approximately 10 seconds and the results will then be displayed on the screen and spoken verbally. Instructions to remove and dispose the test strip will follow.

If the meter is due for calibration with a stock glucose solution, the “C” button will initiate calibration routine. The calibration requires a test strip to be inserted into the meter and a stock glucose solution of a known concentration applied to the strip. The meter compares the results with the known concentration and adjusts accordingly. The “M” button serves as a recall button for the stored test results.

Measurement Method:

The glucose concentration in a whole blood sample will be measured amperometrically. The glucose sensor is an electrochemical diagnostic strip which uses glucose oxidase enzymes in conjunction with three electrically conductive electrodes. Two of these electrodes are ‘working’ electrodes meaning they are the measured electrodes, and the third is a reference electrode (Fig 4). With a strip inserted into the meter, a predetermined current (1 µA) is constantly applied between the working and reference electrodes. The potential difference of this current is constantly monitored by the meter while the strip is in place. This current is used to monitor the presence of the blood sample.

The enzymes of the strip are contained in a ‘reaction zone’. When the enzyme becomes active (blood sample is applied correctly), the enzyme and mediator compound transfer electrons to the electrode. This then bridges the gap between the electrodes and results in a rapid voltage drop. When this drop goes below a predetermined threshold, sample detection is initiated (Fig 5). A constant voltage (300 mV) is then applied to the strip, and the electrical response is measured for a predetermined amount of time (Fig 6). If there is a 10% or greater difference in the voltage between the two working electrodes and error has occurred. This requires either more blood or inserting a new strip and repeating the test.

The current that is produced with correct fluid application is proportional to the glucose concentration of the sample. Determination of the glucose concentration comes from comparison to previously obtained control values. The current-to-glucose relationship becomes linear after about 3 seconds from the initiation time. The measurement is taken at around 5 seconds after, to account for any delay. The measurement could be taken at a later time, but keeping the measurement process relatively fast is beneficial to the user. Of course, once a predetermined time is set (5s), accurate and precise results require that the same time be used each time. In any case, the accuracy of the current determination depends on the accuracy of the initiation determination.

Figure 4: Test Strip Schematic

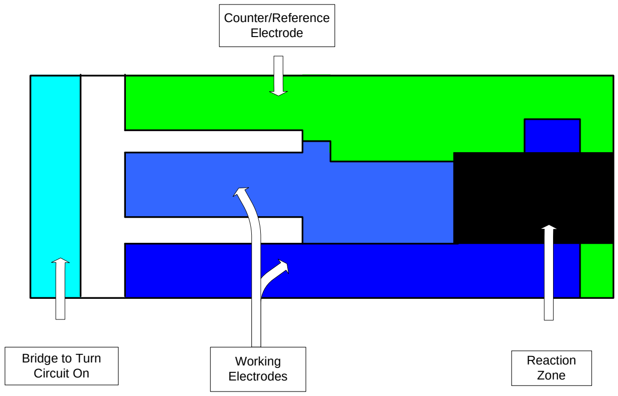
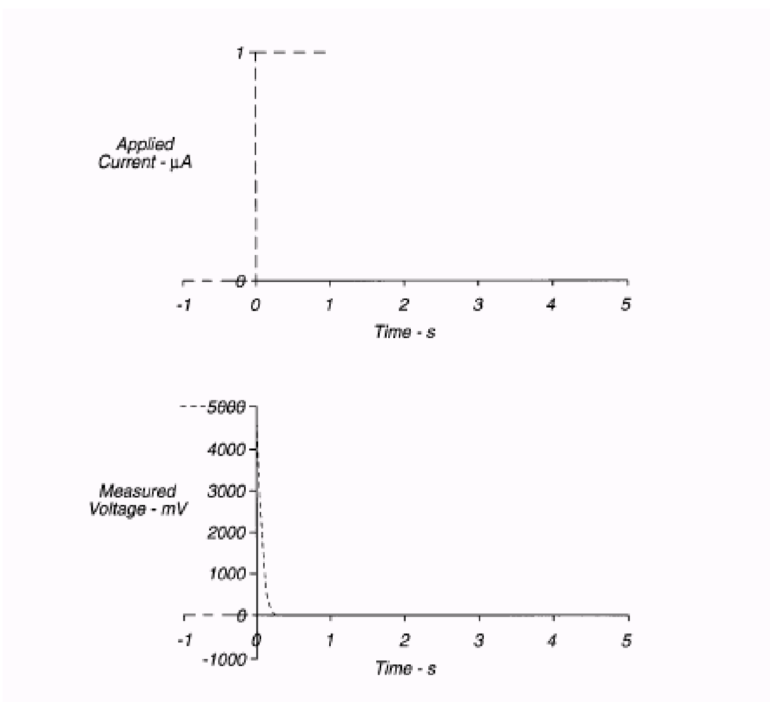


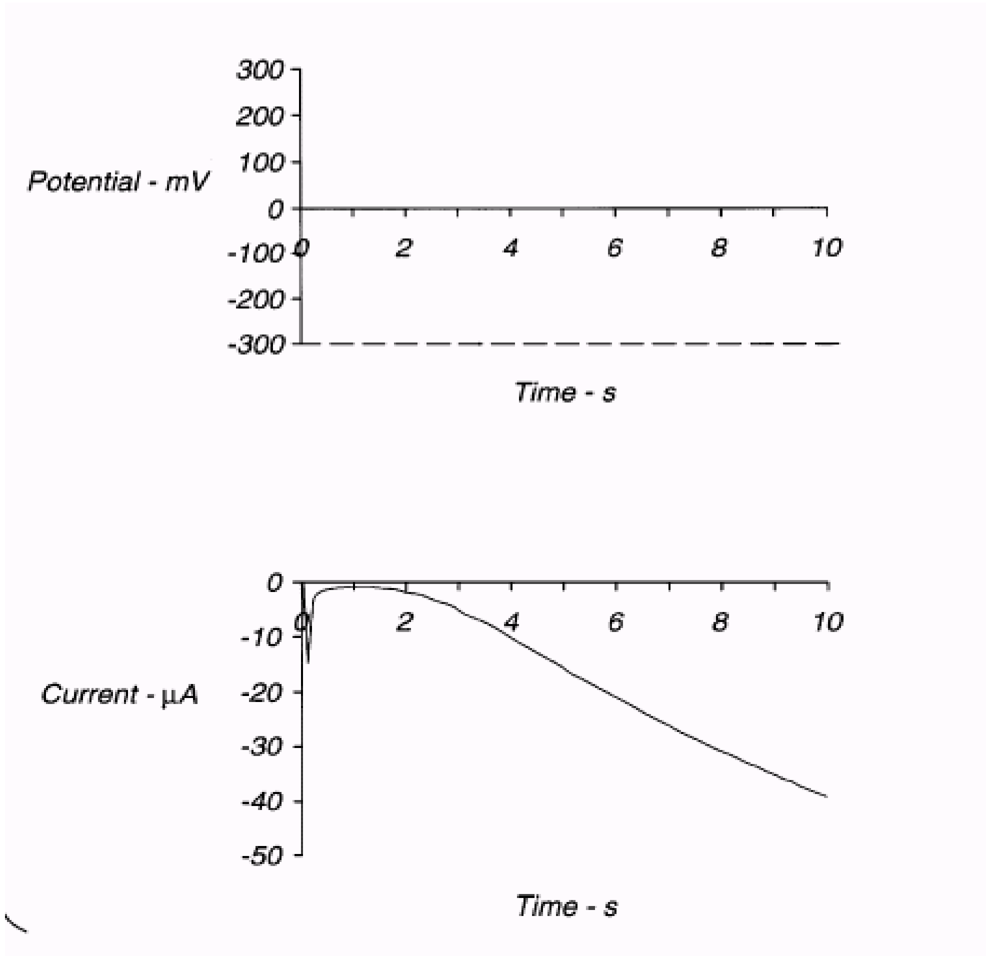
Figure 5 is a plot of applied current and measured voltage that depicts the sample-detection process. Prior to the blood sample being introduced (t < 0), a constant 1 µA) current is applied between the electrodes, but negligible current flows. The measured voltage is determined by the circuit power supply voltage which is 5 volts. When the sample is introduced into the cell (t = 0), the applied current can flow between the electrodes and the measured voltage falls rapidly. When the voltage falls below a threshold voltage, the device switches from constant applied current to constant applied voltage.

Figure 5: Graph of Applied Current and Measured Voltage vs. Time for Sample Detection Process



Source: U.S. Patent No. 4,545,382

Figure 6: Graph of Applied Voltage and Resulting Current Response vs. Time for Measurement Method



Source: U.S. Patent No. 4,545,382

Figure 6 is a graph of the applied potential and measured current as a function of time after sample detection. Sample is detected at time t=0, and a voltage is applied between the working and reference electrodes immediately thereafter. As a result, current flows between the electrodes. The current after a predetermined time, generally at least about 3 seconds for glucose in blood, is a measure of the analyte concentration. That duration generally provides sufficient time to dissolve reagents and reduce an amount of mediator that is readily measurable.

Microprocessor:

The microprocessor we have chosen for this design is the PIC16F874A, manufactured by Microchip. This particular microprocessor incorporates all of the functions necessary to meet our specifications. The microprocessor will be used to control the glucose test circuit, analyze measurements, handle user input from buttons, drive an LCD display, and control a speech module. This chip will be easy to program due to the equipment and development software available in the lab. The microprocessor will be programmed in assembly using Microchip MPLabIDE.

<u>Programming:</u>

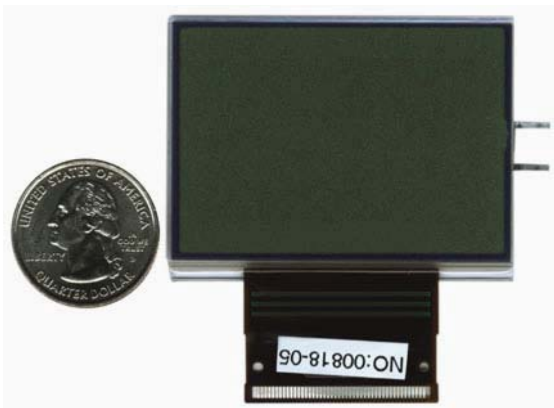
As previously stated, the microprocessor will be programmed using MPLabIDE and Hi-Tech C. Programming modules will be needed for serial communication to the speech module and LCD display drivers. The code will be written in C or C++ and translated into assembly language and transferred to the microprocessor.

The speech module will be connected to two different ports on the microprocessor. One port will be connected to the Inter-integrated circuit (I2C) to relay measurements to the module. The other port contains the digital pins used to select any of the 30 prerecorded phrases stored on the module.

LCD:

The LCD screen that has been chosen for our design is a Crystalfontz CFAX12864C-WGH. This screen is ideal for this system because it will easily integrate with the chosen microprocessor. It is also of sufficient size that is needed to display the intended information. The LCD display will be controlled by the microprocessor using the Parallel Data Port. The screen will show the instructions for proper operation of the meter and display results after test completion. The LCD screens technical specifications are found in Appendix B. Figure 7 is a picture of the LCD screen.

Figure 7: LCD Screen



Source: www.crystalfontz.com

Circuit:

The electrical circuit to measure glucose concentrations must perform several functions. First, a current is applied between the working and reference electrodes. The circuit will monitor the potential difference across the electrodes to determine the presence of the blood sample. When the potential drops below a predetermined threshold, the circuit switches to a constant voltage across the electrodes. The resulting current from the test strip is monitored and input to the microprocessor's analog-to-digital converter. Figure 8 shows the overall glucose test circuit.

Figure 8: Overall Circuit

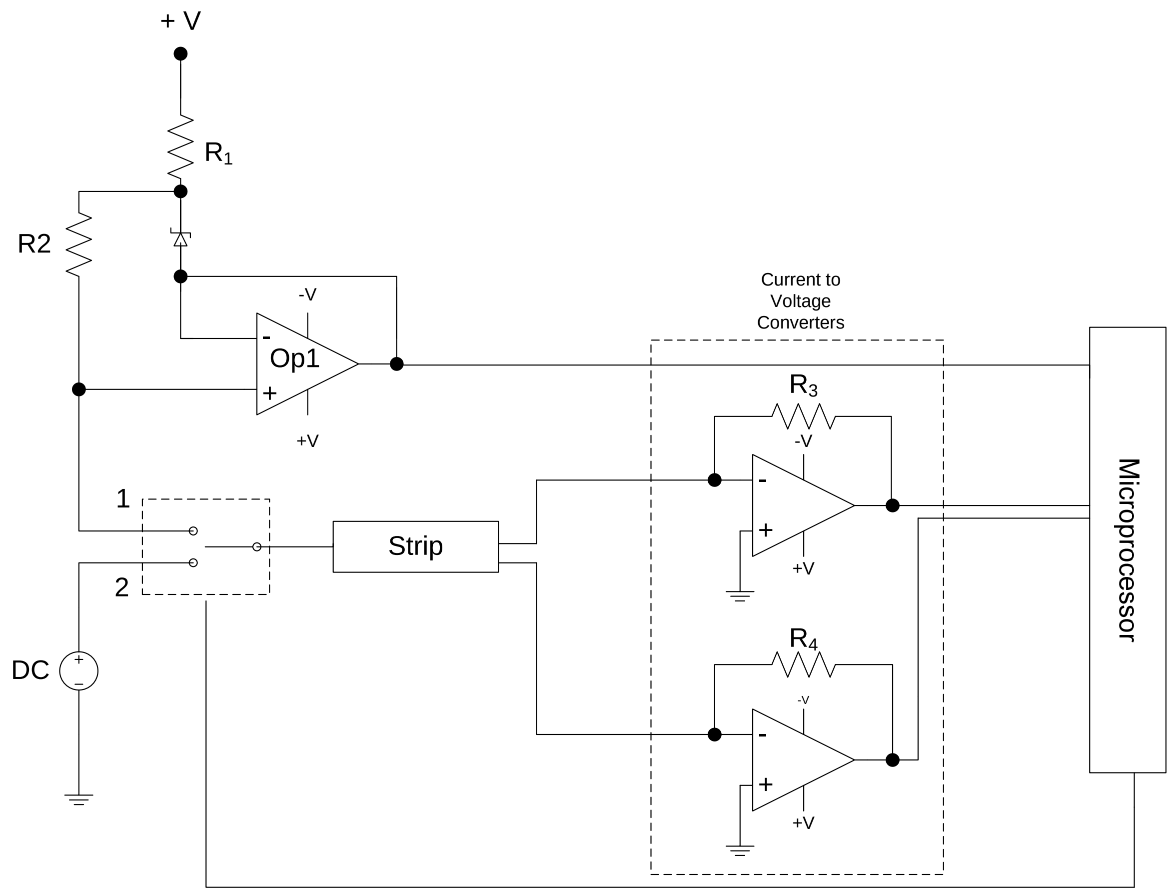
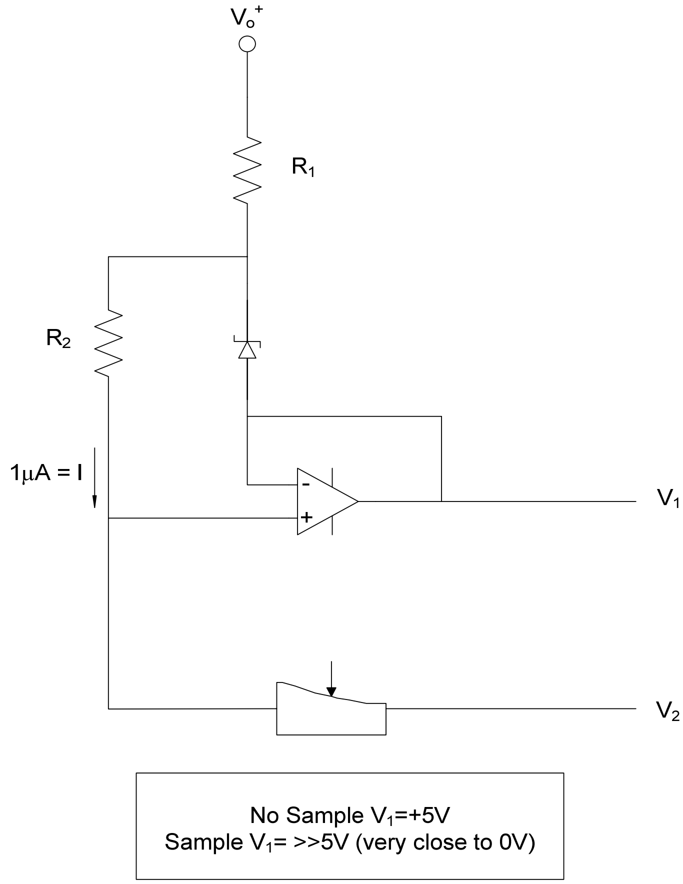
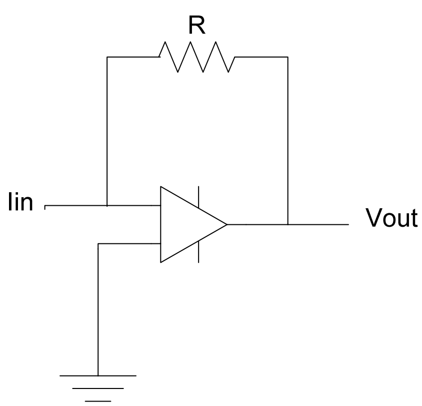


Figure 9: Negative Feedback Circuit



$R=R_1+R_2$
$V=IR$
$R=V/I$

Figure 10: Current to Voltage Converter Circuit



$V_{out} = I_{in} R$

Speech Chip:

The Winbond WTS701 speech-to-text synthesizer is a single chip that converts text inputs to spoken audio outputs. The chip can be programmed through an SPI port allowing downloading of different languages as well as multiple voices. These phrases can be instructions to operate the meter, as well as the glucose reading at the end of a test. The audio output of the chip is stored as an uncompressed analog waveform which delivers high quality, natural sounding speech. The chip also allows variable speech playback and changeable pitch control. Figure 11 is picture of the WTS701 chip.

Figure 11: Winbond WTS701 Chip

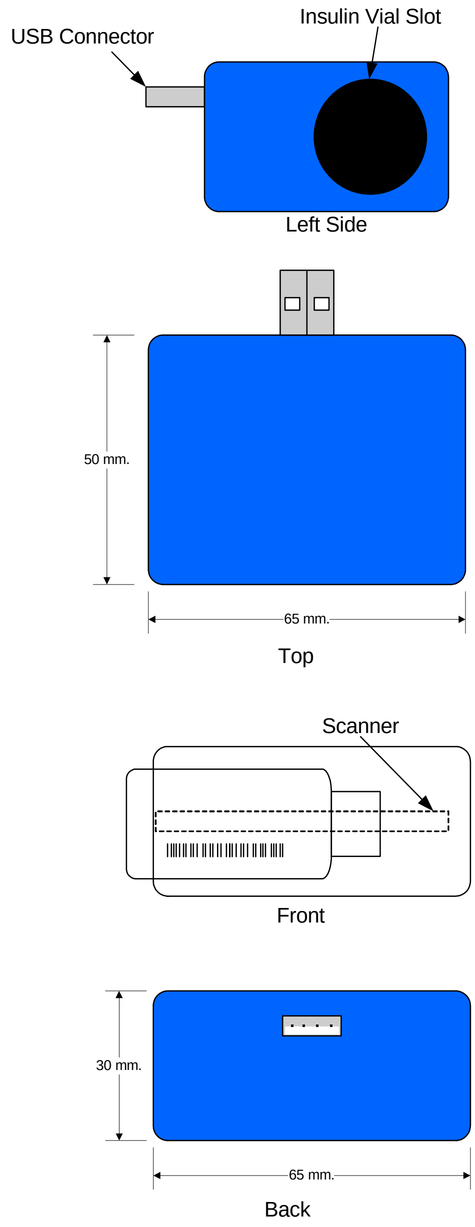
Source: www.winbond.com

Vial Scanner Module:

The meter will also come with an available attachment to identify vials of insulin through the use of a barcode scanner. An FDA mandate in 2004 required that all insulin vials be labeled with a barcode of the National Drug Number for that product. The modular attachment consists of a USB connector, barcode reader, and an insulin vial slot.

The module attaches and communicates with the meter using the USB interface. The user inserts a vial of insulin into the vial slot and rotates the vial until the type of insulin is output by the speaker. Rotation of the vial is necessary to ensure proper scanning. Figure 12 shows the vial scanner module.

Figure 12: Insulin Vial Scanner Module



A handheld CCD barcode scanner will be modified to fit into the modular design of the vial scanner. The POS-X Xi 1000 handheld scanner will be well suited for the task. The scanner is approximately 60mm wide, is able to automatically distinguish between Code 39/Full ASCII, Codabar, Code II, Code 32, Industrial 205, UPC A & E, and outputs the results through a USB interface. Figure 13 is a picture of the POS-X Xi 1000 scanner.

Figure 13: POS-X Xi 1000 Handheld Barcode Scanner

Source: http://www.posguys.com/images/Catalog/Xi1000_WEB.jpg

Cost:

The total cost of the meter has been estimated to be about $271.00 as shown in Table 1. This $271 cost is broken down into the essential components that are listed. As the project moves forward, there may be significant variance in this overall cost due to unplanned events and design changes.

Table 1: Glucose Meter Estimated Design Costs

Part	**Cost**
Microprocessor	$7.00
Winbond WTS701 (Speech Chip)	$32.00
LCD Screen	$26.00
Circuit Boards	$17.00 each $51.00 for 3
Case(s)	$20.00
Other components	$50.00
Total	$152.00

Table 2: Vial Scanner Module Estimated Design Costs

Part	**Cost**
Barcode Reader	$80
Circuit Board	$17
Case	$20
Other Components	$20.00
Total	$119.00

Safety Issues/Constraints:

The device should take into consideration user safety. The user should be protected from the risk of electrical shock through proper or improper handling. The meter should not have any sharp edges or dangerous pieces. The meter should not be used in extreme temperatures or extreme moisture.

Conclusion:

Current blood glucose meters do not adequately accommodate all of the needs of diabetic clients. The proposed Accessible Blood Glucose Meter will incorporate features to assist blood sugar monitoring in patients with vision impairment, hearing loss, tremors, and motor control difficulties. The user interface will be easy to learn for clients of all ages and abilities. The proposed meter will be easy to calibrate, operate, and handle. The on-screen and audio instructions will make blood glucose monitoring more accessible for patients. The available insulin scanner module will aid visually impaired patients in insulin administration. The device will also be an attractive lower cost alternative to commercially available blood glucose meters.

Appendix A

PIC 16F874A Microprocessor

Processor Features

- Operating Speed: 20 MHz clock input
- FLASH Program Memory: 4096 words
- Data Memory: 192 bytes
- EEPROM Data Memory: 128 bytes

Peripheral Features

- Synchronous Serial Port (SSP) with SPI (Master mode) and I2C (Master/Slave mode)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI)
- Parallel Slave Port (PSP) 8-bits wide with external Read, Write, and Chip Select controls

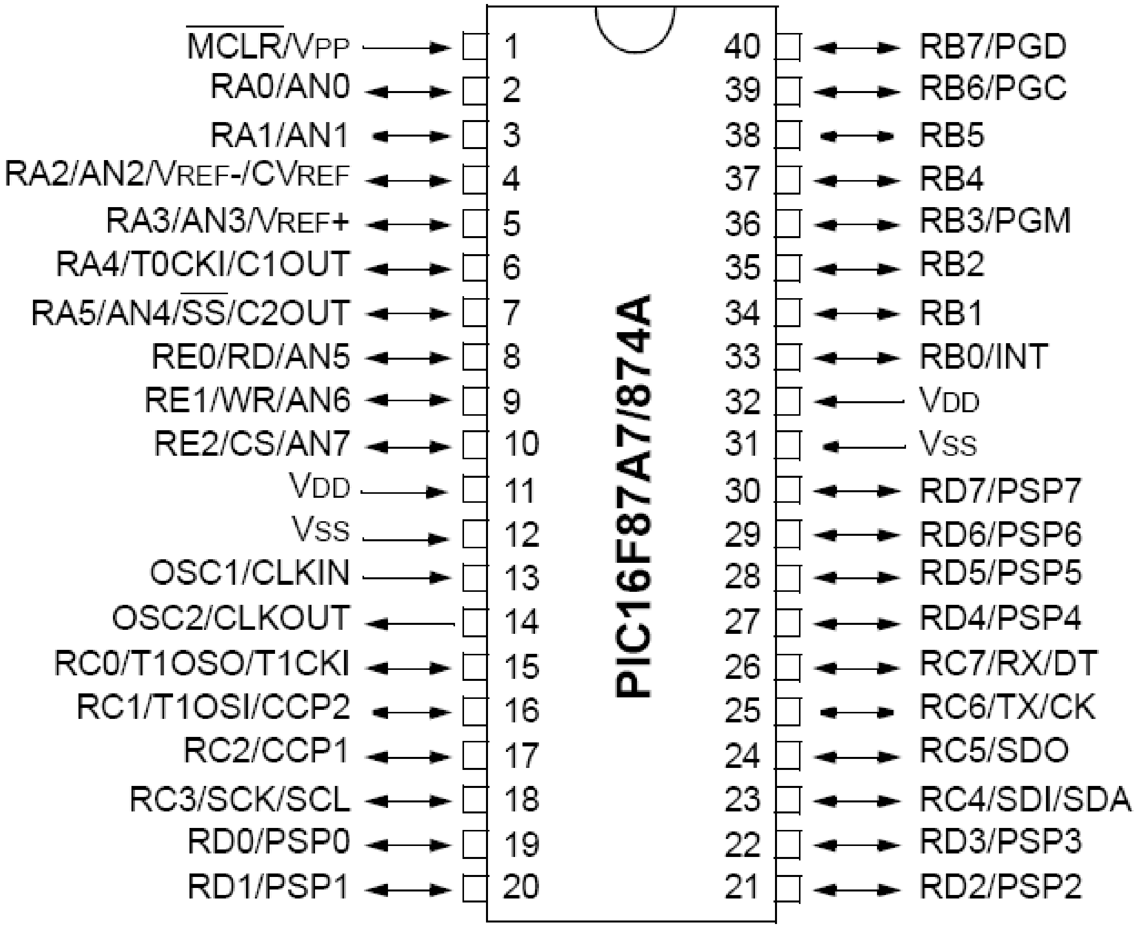
Analog Features:

- 10-bit, 8 Channel Analog-to-Digital Converter (A/D)
- 2 Analog Comparators
- Programmable on-chip voltage (Vref) module
- Programmable input multiplexing from device inputs and internal voltage reference

Special Features:

- 100,000 erase/write cycle Enhanced FLASH program memory
- 1,000,000 erase/write cycle Data EEPROM memory
- In-Circuit Serial Programming
- Programmable code protection
- Power saving SLEEP mode
- In-Circuit Debug

Figure A-1: Microprocessor Pin Diagram



Source: www.microchip.com

Figure A-2: Processor/Module Block Diagram

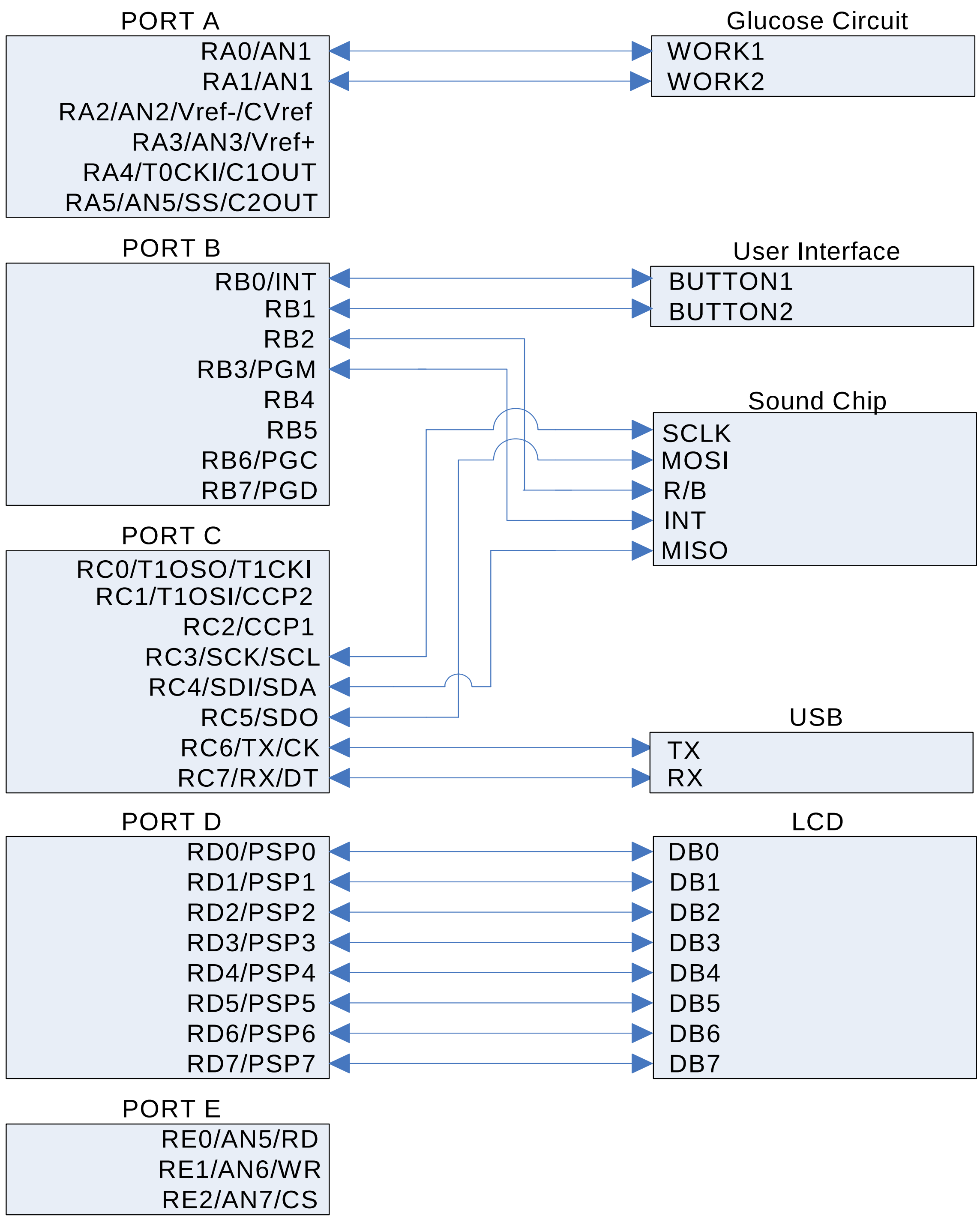


Table A-1: Module Pin Descriptions

Module Pin Names	Description
WORK1	Voltage from working electrode 1
WORK2	Voltage from working electrode 2
Button 1	User Button 1
Button 2	User Button 2
SCLK	SPI Serial Clock
MISO	SPI Serial Data Out
MOSI	SPI Serial Data In
INT	Interrupt Output
R/B	Module busy speaking
RX	Serial Receive
TX	Serial Transmit
DB0	Parallel Data In for LCD
DB1	Parallel Data In for LCD
DB2	Parallel Data In for LCD
DB3	Parallel Data In for LCD
DB4	Parallel Data In for LCD
DB5	Parallel Data In for LCD
DB6	Parallel Data In for LCD
DB7	Parallel Data In for LCD

Table A-2: Microprocessor Pin Descriptions

PIC16F87XA Pin Name	Description
RA0/AN0	Analog Input 0
RA1/AN1	Analog Input 1
RB0/INT	Digital I/0
RB1	Digital I/0
RB2	Digital I/0
RB3/PGM	Digital I/0
RC3/SCK/SCL	Serial Clock Input/Output for SPI Mode
RC5/SDO	SPI Data Out
RC6/TX/CK	USART Asynchronous Transmit
RC7/RX/DT	USART Asynchronous Receive
RD0/PSP0	Parallel Slave Port Data
RD1/PSP1	Parallel Slave Port Data
RD2/PSP2	Parallel Slave Port Data
RD3/PSP3	Parallel Slave Port Data
RD4/PSP4	Parallel Slave Port Data
RD5/PSP5	Parallel Slave Port Data
RD6/PSP6	Parallel Slave Port Data
RD7/PSP7	Parallel Slave Port Data

Figure A-3: Sample Code for Serial/USB Communication

```
Interface PIC
Designed by Shane Tolmie Feb 2001.
Microprocessor: Microchip PIC16F87x
Compiled with:    Hitech-C v7.87, developed using MPLAB v5.3
Note: all references are to PIC16C7X PDF version of Microchip manual,
DS30390E
Overall goal:     serial comms using USART to comm port of an ibm pc
compatible computer
*/
#include    <pic.h>
#include    <conio.h>
#include    <stdio.h>
#include    "always.h"
#include    "delay.h"
void serial_setup(void)
{
      /* relates crystal freq to baud rate - see above and PIC16F87x
data sheet under 'USART async. modes'
      BRGH=1, Fosc=3.6864MHz        BRGH=1, Fosc=4MHz      BRGH=1,
Fosc=8MHz    BRGH=1, Fosc=16MHz
      ----------------------    -----------------      ----------------
-    ------------------
Baud  SPBRG        Baud  SPBRG        Baud  SPBRG        Baud  SPBRG
1200  191          1200  207.3        1200   415.7        9600   103
2400  95           2400  103.2        2400   207.3        19200   51
4800  47           4800  51.1         4800   103.2        38400   25
9600  23           9600  25.0         9600   51.1         57600   16
19200 11           19200 12.0         19200  25.0         115200   8

* Comms setup:
*/
      #define BAUD 19200
      #define DIVIDER ((PIC_CLK/(16UL * BAUD) -1))
      #define HIGH_SPEED 1

      SPBRG=DIVIDER;
      BRGH=HIGH_SPEED;  //data rate for sending
      SYNC=0;                                  //asynchronous
      SPEN=1;                                  //enable serial port
      pins
      CREN=1;                                  //enable reception
      SREN=0;                                  //no effect
      TXIE=0;                                  //disable tx interrupts
      RCIE=0;                                  //disable rx interrupts
      TX9=0;                                   //8-bit transmission
      RX9=0;                                   //8-bit reception
      TXEN=0;                                  //reset transmitter
      TXEN=1;                                  //enable the
transmitter
}
unsigned char dummy;
#define clear_usart_errors_inline
if (OERR)
```

```
{
      TXEN=0;
      TXEN=1;
      CREN=0;
      CREN=1;
}
if (FERR)
{
      dummy=RCREG;
      TXEN=0;
      TXEN=1;
}
//writes a character to the serial port
void putch(unsigned char c)
{
      while(!TXIF)                  //set when register is empty
      {
            clear_usart_errors_inline;
            CLRWDT();
      }
      TXREG=c;
      DelayUs(60);
}
writes a character to the serial port in hex
if serial lines are disconnected, there are no errors

void putchhex(unsigned char c)
{
      unsigned char temp;
      // transmits in hex
      temp=c;
      c=(c >> 4);
      if (c<10) c+=48; else c+=55;
      putch(c);
      c=temp;
      c=(c & 0x0F);
      if (c<10) c+=48; else c+=55;
      putch(c);
}
void putinthex(unsigned int c)
{
      #define ramuint(x)
      (*((unsigned int *) (x)))
      #define ramuint_hibyte(x)
      (*(((unsigned char *)&x)+1))
      #define ramuint_lobyte(x)
      (*(((unsigned char *)&x)+0))
      #define ramuchar(x)
      (*((unsigned char *) (x)))
      putchhex(ramuint_hibyte(c));
      putchhex(ramuint_lobyte(c));
      #undef ramuint(x)
      #undef ramuint_hibyte(x)
      #undef ramuint_lobyte(x)
      #undef ramuchar(x)
}
```

Appendix B

Crystalfontz CFAX12864C-WGH LCD Screen

Table B-1: LCD Screen Technical Specifications

3. General Specification

Item	Dimension	Unit
Number of Characters	128 characters x 64 Lines	—
Module dimension	56.0 x 42.5 x 2.4(MAX)	mm
View area	52.0x 33.5	mm
Active area	47.76x 30.29	mm
Dot size	0.37 x 0.42	mm
Dot pitch	0.35 x 0.4	mm
LCD type	STN, Positive, Transflective, Gray	
Duty	1/64	
View direction	6 o'clock	
Backlight Type	EL, White	

4. Absolute Maximum Ratings

Item	Symbol	Min	Typ	Max	Unit
Operating Temperature	T_{OP}	-20	—	+70	℃
Storage Temperature	T_{ST}	-30	—	+80	℃
Input Voltage	V_I	V_{SS}	—	V_{DD}	V
Supply Voltage For Logic	V_{DD}-V_{SS}	2.4	—	5.5	V
Supply Voltage For LCD	V_O-V_{SS}	4.0	—	15.0	V

5. Electrical Characteristics

Item	Symbol	Condition	Min	Typ	Max	Unit
Supply Voltage For Logic	V_{DD}-V_{SS}	—	2.4	—	5.5	V
Supply Voltage For LCD	V_{DD}-V_0	Ta=-20℃	—	—	9.2	V
		Ta=25℃	-	8.2	-.	V
		Ta=+70℃	7.2	—	—	V
Input High Volt.	V_{IH}	—	0.8 V_{DD}	—	V_{DD}	V
Input Low Volt.	V_{IL}	—	—	—	0.2 V_{DD}	V
Output High Volt.	V_{OH}	—	V_{DD} -0.4	—	—	V
Output Low Volt.	V_{OL}	—	—	—	0.4	V
Supply Current	I_{DD}	V_{DD}=5V	—	1.5	—	mA

Source: www.crystalfontz.com

Table B-2: Pin Assignments for LCD Screen:

Pin No.	Symbol	I/O	Description
1	NC	—	No connection
2	TEMPS	I	Selects temperature coefficient of the reference voltage TEMPS="L": -0.05%℃, TEMPS="H": -0.2%℃
3	INTRS	I	Internal resistors select pin This pin selects the resistors for adjusting V0 voltage level. INTRS="H": use the internal resistor. INTRS="L": use the external resistor. V0 voltage is controlled with VR pin and external resistive divider.
4	HPM	I	Power control pin of the power supply circuit for LCD driver. HPM="H": high power mode HPM="L": normal power mode This pin is valid in master operation.
5	DCDC5B	I	5times boosting circuit enable input pin. When this pin is low in 4 times boosting circuit, the 5-time boosting voltage appears at VOUT.
6	BSTS	I	Select input voltage of the built-in voltage converter. Voltage converter input BSTS="H": 4V (VDD>4V) BSTS="L": VDD (2.4V≦VDD≦5.5V) When BSTS pin is "L", VDD must be higher than 4V in our 4-time boosting.
7~11	V0~V4	I/O	LCD driver supply voltages. The voltage determined by LCD pixel is impedance-converted by an operational amplifier for application. Voltages should have the following relational; V0≧V1≧V2≧V3≧V4≧VSS
12	VR	I	V0 voltage adjustment pin. It is valid only when on-chip resistors are not used(INTRS="L")
13	C2-	O	Capacitor 2 negative connection pin for voltage converter.
14	C2+	O	Capacitor 2 positive connection pin for voltage converter.
15	C1-	O	Capacitor 1 negative connection pin for voltage converter.
16	C1+	O	Capacitor 1 positive connection pin for voltage converter.
17	C3-	O	Capacitor 1 negative connection pin for voltage converter.
18	C3+	O	Capacitor 1 positive connection pin for voltage converter.
19	VOUT	I/O	Voltage converter input/output pin.
20	VDD	—	Power supply pin for logic.
21	VSS	—	Ground pin, connected to 0V

22	PS	I	Parallel/Serial data input select pin. Interface / Data / Read/Write / Serial clock PS="H": Parallel / DB0~DB7 / E_RD,RW_WR / - PS="L": Serial / SID(DB7) / Write only / SCLK(DB6) In serial mode, it is impossible to read data from the on-chip RAM. And DB0 to DB5 are high impedance and E_RD and RW_WR must be fixed to either "H" or "L".
23	MI	I	Microprocessor interface selects pin. MI="H": 6800-series MPU interface MI="L": 8080-series MPU interface
24	CLS	I	Built-in oscillator circuit enable/disable select pin. CLS="H": enable CLS="L": disable(external display clock input from CL pin)
25	MS	I	Master or Slave mode operation select pin. MS="H" : master operation MS="L" : slave operation
26 27	DUTY1 DUTY0	I	The LCD driver duty ratio depends on the following table DUTY1 / DUTY0 / Duty ratio L / L / 1/33 L / H / 1/49 H / L / 1/65
28~35	DB7~DB0	I/O	8-bit bi-directional data bus that is connected to the standard 8-bit microprocessor data bus. When the serial interface selected(PS="L") DB0~DB5: high impedance DB6: serial input clock (SCLK) DB7: serial input data (SID) When chip select is not active, DB0~DB7 may be high impedance.
36	E_RD	I	When connected to 80-family MPU: Read enable clock input pin. When /RD is "L", DB0~DB7 are in an output status When connected to 68-family MPU: RW = "H": When E is "H", DB0~DB7 are in an output status RW = "L": The data on DB0~DB7 are latched at the falling edge of the E signal
37	RW_WR	I	When connected to 80-family MPU: Write enable clock input pin. The data ON DB0~DB7 are latched at the rising edge of the /WR signal. When connected to 68-family MPU: RW = "H": read RW = "L": write
38	RS	I	Register select pin RS="H": DB0~DB7 are display data RS="L": DB0~DB7 are control data
39	RESETB	I	Reset input pin When RESETB is "L", initialization is executed.
40 41	CS2 CS1B	I	Chip select input pins Data/instruction I/O enable only when CS1B is "L" and CS2 is "H". When chip select is non-active, DB0~DB7 may be high impedance.

42	DISP	I/O	LCD display blanking control input /output When KS0713 is used in master/slave mode (multi-chip), the DISP pins must be connected each other. MS="H": output MS="L": input
43	CL	I/O	Display clock input/output pin When the KS0713 is used in master/slave mode (multi-chip), the CL pins must be connected each other.
44	M	I/O	LCD AC signal input /output pin When KS0713 is used in master/slave mode (multi-chip), the M pins must be connected each other. MS="H": output MS="L": input
45	FRS	O	Static driver segment output pin This pin is used together with the M pin.
46	NC	—	No connection.

Source: www.crystalfontz.com

Appendix C

Winbond WTS701 Speech Chip

Table C-1: WTS701 Pin Descriptions

PIN NO.	SYMBOL	I/O	FUNCTION
13	INT\	O	Interrupt Output; an open drain output that indicates that the device wishes an interrupt service. The device can request an interrupt when it finishes an operation or needs more data to process. Under what conditions the device generates an interrupt can be configured through the user configuration registers. This pin remains LOW until a Read Interrupt command is executed.
26	R/B\	O	Ready/busy signal; This pin defaults HIGH indicating the device is ready for data transfer. The pin is driven LOW to handshake a pause in SPI data transfer.
7	XTAL2	O	CRYSTAL 2: This is the crystal oscillator output. It is the inversion of XTAL1.
8	XTAL1	I	CRYSTAL 1: This is the crystal oscillator input. This pin may be driven by an external clock. The clock to the WTS701 processor is configured by a clock configuration register, which is set by the host processor during the initialization phase.
15	SS\	I	SPI Slave Select input. This is an active LOW input used to select the device to respond to an SPI transaction.
16	SCLK	I	SPI Serial clock input.
6	MISO	O	SPI **M**aster **I**n, **S**lave **O**ut pin. Serial data line used to communicate with SPI master. Pin is tri-state when SS\=1.
14	MOSI	I	SPI **M**aster **O**ut, **S**lave **I**n. Serial data input from Master
25	CS\	I	Chip Select (active LOW) Pin must be LOW to access WTS701 device.
27	RESET	I	Global reset signal.
3	VCLK	I	CODEC master clock
4	VFS	I	CODEC frame synchronization signal
5	VDX	O	CODEC data output. This pin puts data out in the linear PCM unsigned or 2's complement format. It is tri-stated until the user requests a CONVERT operation.
52	AUXIN	I	Analog input pin. This pin should be capacitively coupled.
54	AUXOUT	O	Analog Output for single ended output from the device.
46	SP+	O	Differential Positive Speaker Driver Output.
42	SP-	O	Differential Negative Speaker Driver Output.

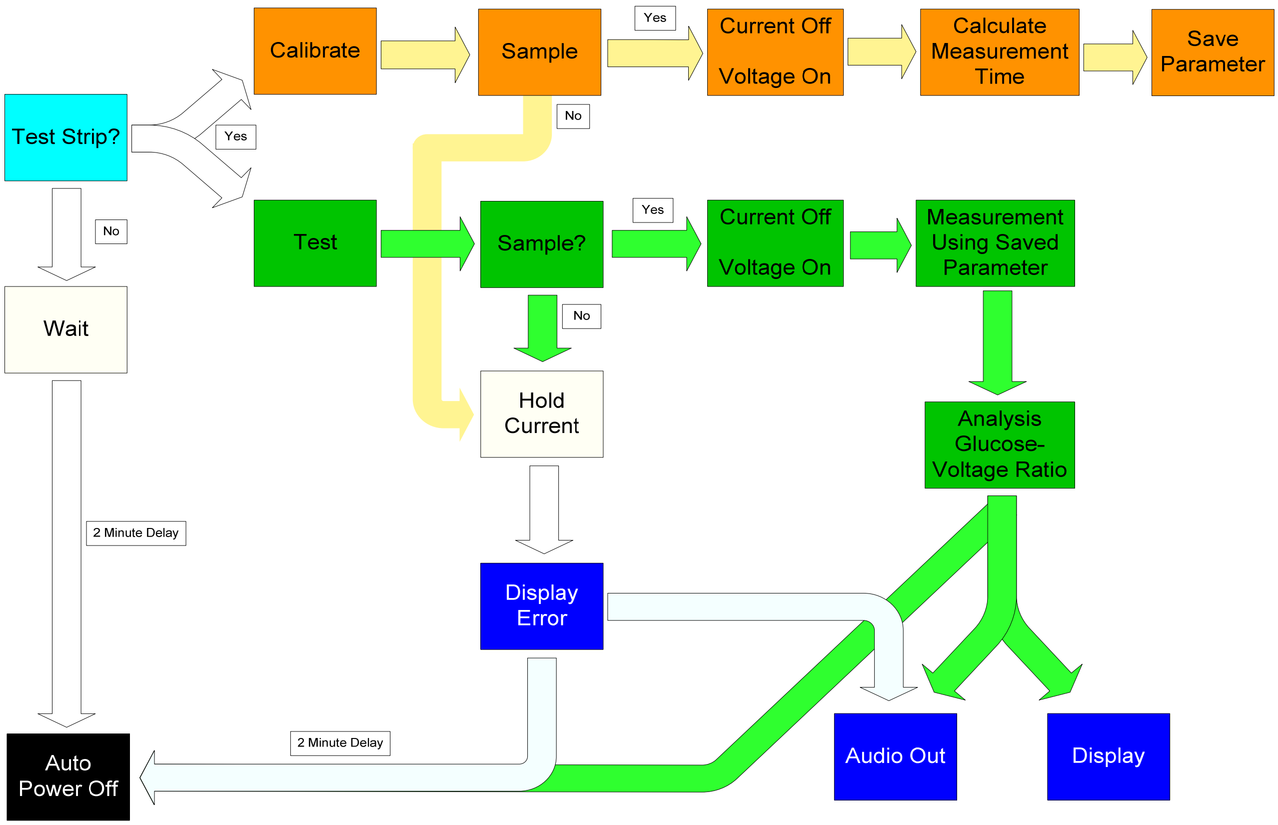
40	ATTCAP	I/O	AutoMute Capacitor Pin. Should have a 4.7uF capacitor to VSSA.
11,12	VCCD	P	Positive Digital Supply pin. These pins carry noise generated by internal clocks in the chip. They must be carefully bypassed to Digital Ground to ensure correct device operation.
9,10	VSSD	G	Digital Ground pin.
2,36,44	VSSA	G	Analog Ground pins.
48	VCCA	P	Positive Analog Supply pin. This pin supplies the LOW level audio sections of the device. It should be carefully bypassed to Analog Ground to ensure correct device operation.
1,17-24,28-35,37-39,41,43,45,47,49-51,53,55-56	NC		Not Connected – must be floating.

Source: www.winbond.com

Appendix D

Software

Figure D-1: Software Flowchart



Accessible Blood Glucose Monitor

University of Connecticut
Biomedical Engineering Senior Design
Team 2

Sponsored by the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation (RERC on AMI)

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