Accessible Blood Glucose Monitor
Design 3

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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 Changes:

- The glucose test strips have been changed to a colorimetric method to determine blood glucose concentrations optically.
- The serial DB9 connector has been changed to a USB connector.
- A separate module can be attached through the USB port for scanning insulin vials and audibly outputting the type of insulin.

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)

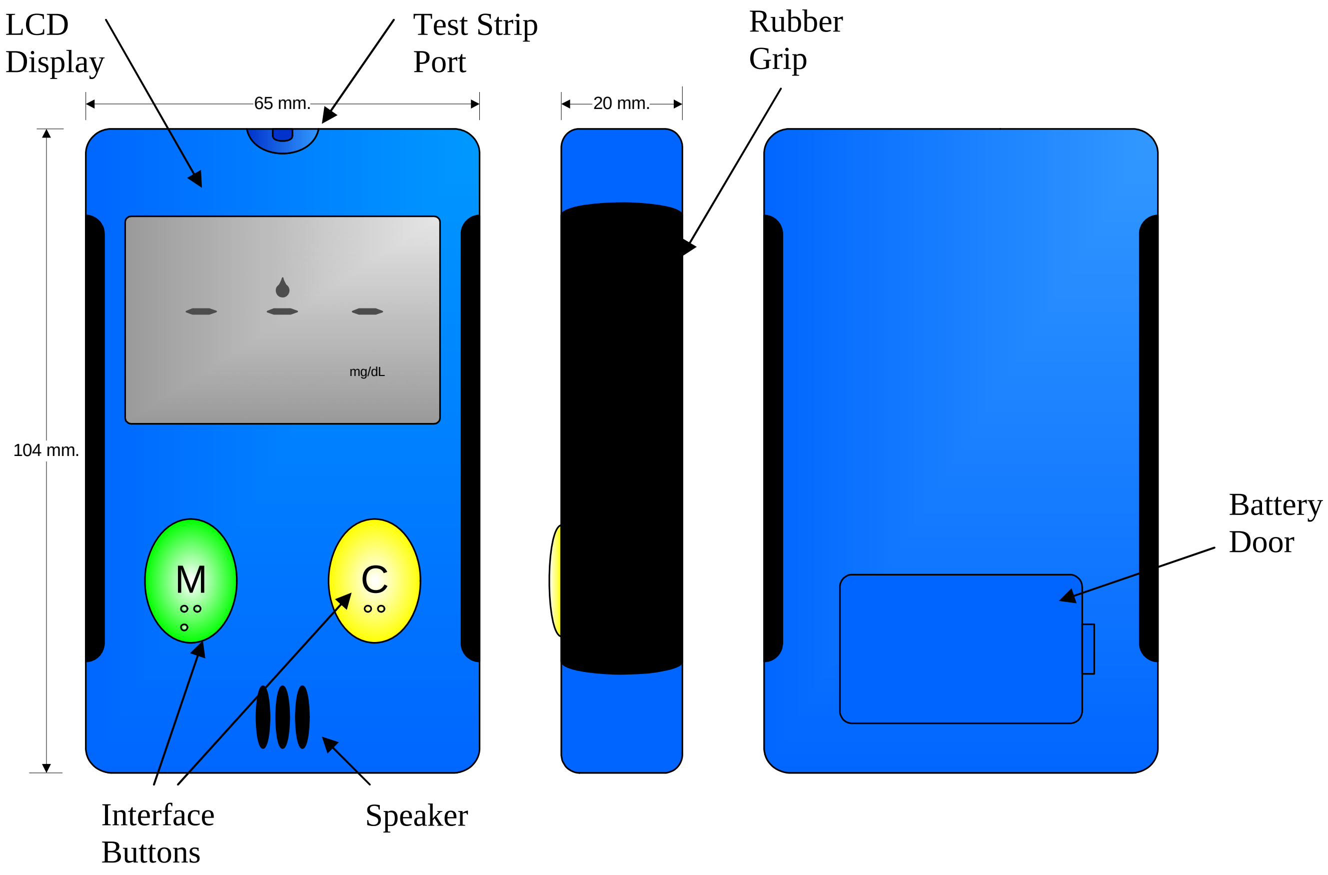
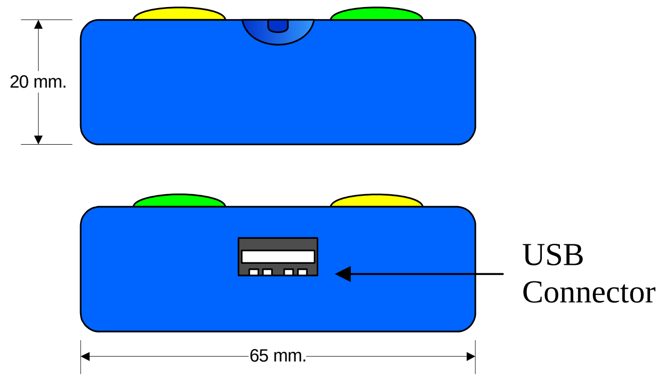
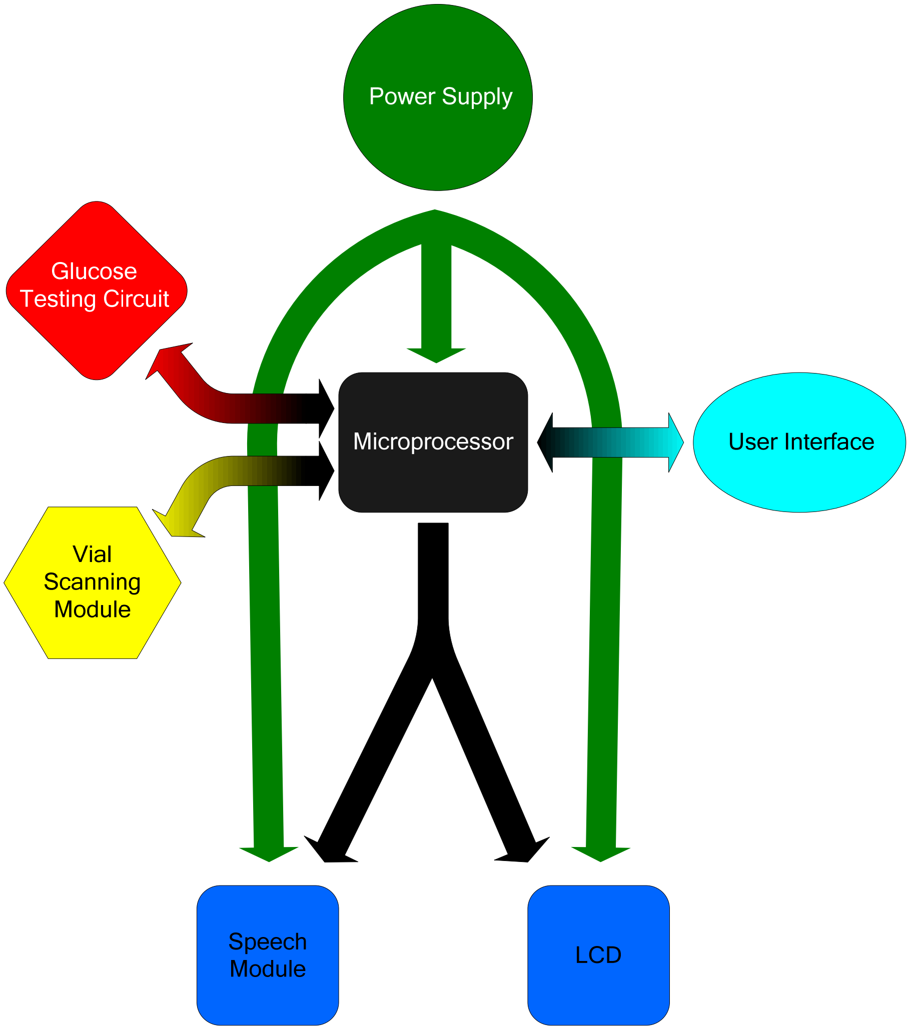


Figure 2: External Views of Meter (Top, Bottom)



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 speech module within the device. This speech module translates the data from the microprocessor and generates an audio output via the attached speaker for the user to hear. Figure 3 shows the block diagram of these described processes.

Figure 3: Design Block Diagram

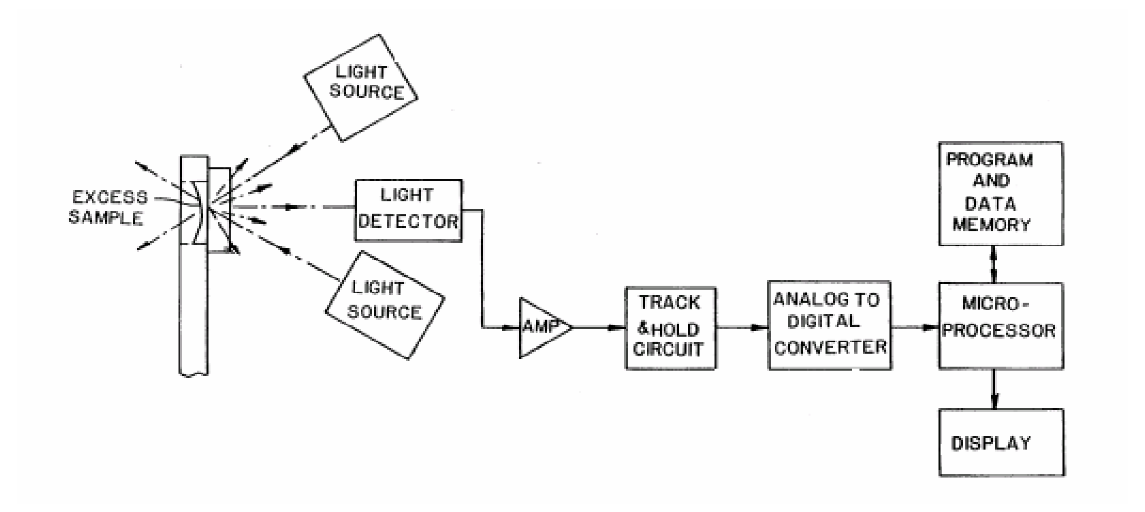


Testing Procedure:

The glucose test circuit used to make the reflectance readings contains a light source, a reflected light detector, an amplifier, an analog to digital converter, a microprocessor, and a display.

The designed meter is essentially a diffuse reflectance spectrophotometer. With appropriate software, the spectrophotometer can then be made to automatically read reflectance at certain points in time, calculate rate of reflectance change, and output the level of glucose in the blood sample. The schematic for this method is shown in Figure 4. The light source of the meter is simply a high intensity light emitting diode (LED). Using two different LED's provides the two different wavelengths used to make the measurement. These LED's project a beam of light onto the reagent pad. A substantial portion of this light is diffusively reflected from the reagent pad and is detected by light detector. This detector is a phototransistor that produces an output current proportional to the light it receives. Readings from the phototransistor are typically taken every 0.2 seconds. The output of the detector is then passed to an amplifier which converts the phototransistor current to a voltage. The output of amplifier is fed to a track and hold circuit. This circuit tracks the incoming voltages along with their respective times and then sends them to be converted into a digital signal. Upon command from the microprocessor, these values can be interpreted into a glucose concentration and output.

Figure 4: Glucose Sensor Block Diagram



Source: US Patent No.: 4,935,346

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 40 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 process begins with a whole blood sample (about 5-10 microliters) being applied to the application site of the test strip. This application site is a single-layer, hydrophilic membrane that is reflective and porous. In addition, it is bound a signal-producing system made up of glucose oxidase, peroxidase and a dye indicator. This system reacts with glucose to form a reaction dye product.

The meter continuously monitors reflectance at the reading site for a decrease in reflectance. Reflectance measurements are made at two separate wavelengths in order to eliminate interferences. These interferences can be caused by hematocrit, blood oxygenation, and other variables which may affect the result. The appropriate wavelengths to do so are 635 nm and 700 nm.

The initial measurement is made prior to application of the blood sample to the matrix. The reflectance value is evaluated by the microprocessor, and then following values can then be compared to this initial unreacted value. When the aqueous solution penetrates the reagent matrix, the drop in reflectance signals the start of the measuring time interval. The change in reflectance that occurs is a measure of dye product formed which directly correlates to the amount of glucose in the sample.

The raw data necessary for calculating a result in a glucose assay are a background current reported as background reflectance, R_b, a reading of the inactive test strip, R_{dry}, and an endpoint measurement. The endpoint is not particularly stable and must be precisely timed from the initial application of blood. For glucose concentrations below 250 mg/dl, a suitably stable endpoint is reached in 20 seconds, and a final reflectance, R_{20}, is taken. For glucose concentrations up to 450 mg/dl, a 30-second reflectance reading, R_{30}, is adequate. Longer reaction times should provide more suitable readings for the higher levels of glucose concentration.

The 700 nm reflectance reading for the dual wavelength measurement is typically taken at 15 seconds (R_{15}). By this time blood will have completely saturated the reagent pad. Beyond 15 seconds the dye reaction continues to take place and is sensed, to a small part, by a 700 nm reading. Dye absorption by the 700 nm signal causes inaccuracies; readings beyond 15 seconds are ignored in the calculations.

The raw data described above are used to calculate parameters proportional to glucose concentration which can be more easily visualized than reflectance measurements. A logarithmic transformation of reflectance analogous to the relationship between absorbance and analyte concentration observed in transmission spectroscopy (Beer's

Law) can be used if desired. A simplification of the Kubelka-Monk equations is used to determine analyte concentration. In this derivation K/S is related to analyte concentration with K/S defined by Equation 1.

$K/S\text{-}t=(1-R^*t)^2/(2 \times R^*t)$ (Eq. 1)

R*t is the reflectivity taken at a particular endpoint time, t, and is the absorbed fraction of the incident light beam described by Equation 2, where R_t is the endpoint reflectance, R_{20} or R_{30}.

$R^*t=(R_t - R_b)/(R_{dry} - R_b)$ (Eq. 2)

R*t varies from 0 for no reflected light (R_b) to 1 for total reflected light (R_{dry}). The use of reflectivity in the calculations greatly simplifies the meter design as a highly stable source and a detection circuit become unnecessary since the components are monitored with each R_{dry} and R_b measurement.

For a single wavelength reading K/S can be calculated at 20 seconds (K/S-20) or 30 seconds (K/S-30). The calibration curves relating these parameters can be precisely described by the third order polynomial equation outlined in Equation 3.

$YSI=a_0 + a_1 (K/S)+a_2 (K/S)^2 + a_3 (K/S)^3$ (Eq. 3)

The algorithm for dual wavelength measurement is by necessity more complex than for single wavelength measurement but is much more powerful. The first order correction applied by the 700 nm reading is a simple subtraction of background color due to blood. In order to make this correction, a relationship between absorbance at 635 nm and 700 nm due to blood color can be and was determined by measuring blood samples with 0 mg/dl glucose over a wide range of blood color. The color range was constructed by varying hematocrit, and fairly linear relationships were observed. From these lines the K/S-15 at 700 nm was normalized to give equivalence to the K/S-30 at 635 nm. This relationship is reported in Equation 4, where K/S-15n is the normalized K/S-15 at 700 nm.

K/S-15n = (K/S-15 x 1.54)-0.133 (Eq. 4)

Note that the equivalence of the normalized 700 nm signal and the 635 nm signal is only true at zero glucose. The expressions from which the calibration curves are derived are defined by Equations 5 and 6.

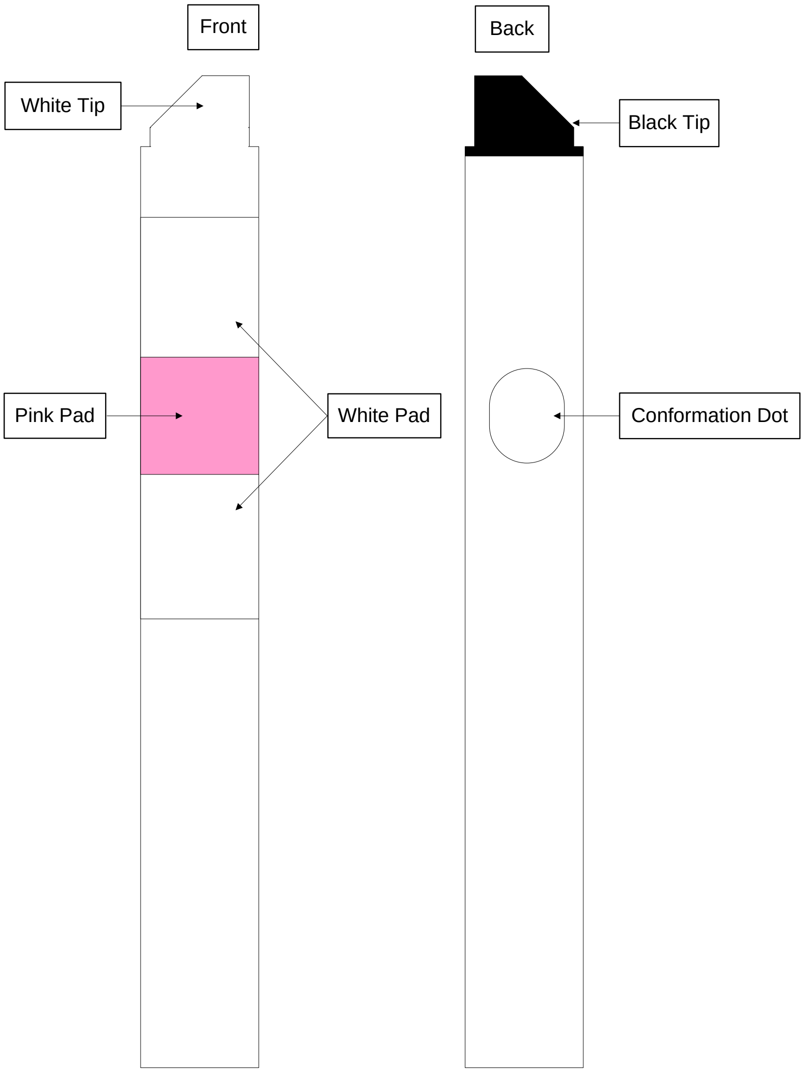
K/S-20/15=(K/S-20)-(K/S-15n) (Eq. 5)

K/S-30/15=(K/S-30)-(K/S-15n) (Eq. 6)

Test Strip:

The method for measuring the glucose concentration in a whole blood sample will be of the colorimetric type. The glucose sensor is a diagnostic strip containing an inert porous matrix that is saturated with one or more reagents. These reagents will interact with the glucose to produce a light-absorbing reaction product. One function of the matrix is to filter out large particles, such as red blood cells. This is an advantage because the strip does not require previous separation of red blood cells from serum or plasma. When a blood sample is applied to the porous matrix, and is allowed to penetrate, it creates a change in the initial amount of reflectance of the matrix. This initial decrease in reflectance caused by the wetting of the surface triggers the timing circuit of the meter. A reading is then taken at one or more times after to relate the resulting change in reflectance.

Figure 5: Test Strip Schematic



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.

Programming:

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. Additional programming support may come from National Instruments LabView and the Application Builder toolkit. The Application Builder is capable of converting a virtual instrument (VI) into a Windows Shared Dynamic Link Library (DLL). The DLL may then be called in C routine and then converted to assembly.

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.

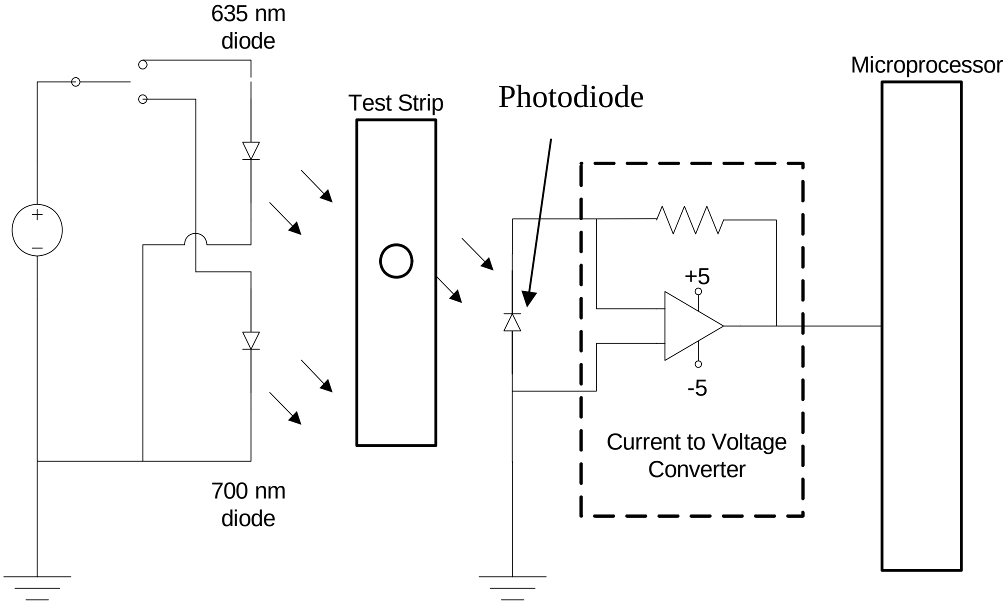
LCD:

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 displayed below:

Glucose Testing Circuit:

The glucose testing circuit consists of two LED's (635nm, 700nm), a photodiode, a current-to-voltage converter, and the microprocessor. Initially the 635nm diode is illuminated to measure a background reading. Once the background reading has been taken the microprocessor switches from the 635nm LED to the 700nm LED for the glucose reflectance measurement. Figure 6 shows the general system for measuring blood glucose concentrations optically.

Figure 6: Blood Glucose Test Circuit



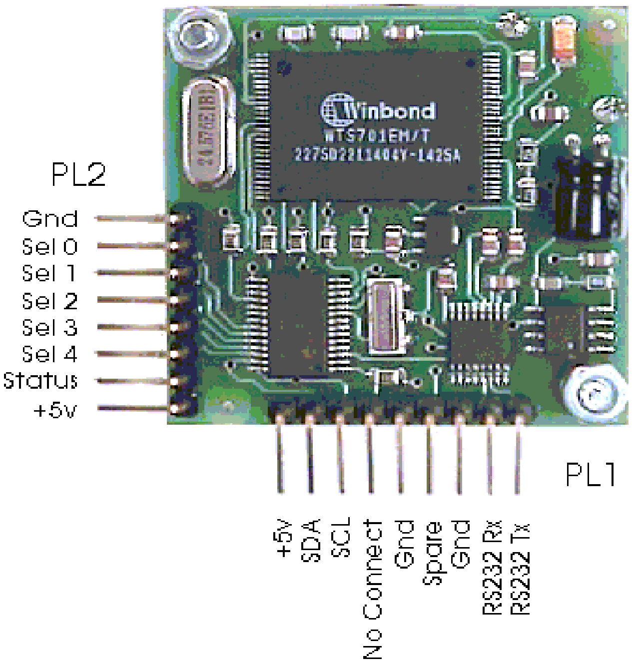
Speech Module:

Of the estimated 18.2 million Americans who have diabetes, more than half are at risk for vision loss. After 20 years of diabetes without strict control of blood glucose levels, there is a 90 percent chance of developing eye disease. Ocular complications of diabetes include retinopathy, vitreous hemorrhage, cataract, and glaucoma. About 40 percent of people with diabetes will have at least mild retinopathy, which is characterized by leakage of fluid or blood from vessels in the retina. Retinopathy causes blurred or hazy vision and can even lead to complete blindness if damage to the eye has progressed to hemorrhaging and scarring.

With this direct correlation of diabetes to vision loss, it is evident that personal glucose meters are used by individuals with impaired eyesight. Thus, a glucose meter with an incorporated voice output would prove to be very useful. An SP03 speech synthesizer is a voice module that allows for output of audible numbers, words, and phrases. Shown in Figure 11, the module can be programmed to output up to 30 predefined phrases. These phrases can be instructions to operate the meter, as well as the glucose reading at the end of a test.

There are 32 serial commands that can be sent to the SP03. Thirty of these (commands 1 to 30) are used to speak one of the thirty predefined phrases. To speak any phrase, it is a matter of sending a single command byte to the SP03. When the SP03 is finished speaking, it will return the command as an acknowledgement. When the command is acknowledged, the module will be ready to receive another command. Once programmed, the SP03 will be controlled by the microprocessor to implement the necessary phrases with the corresponding screens.

Figure 7: SP03 Text to Speech Synthesizer with Pin Description

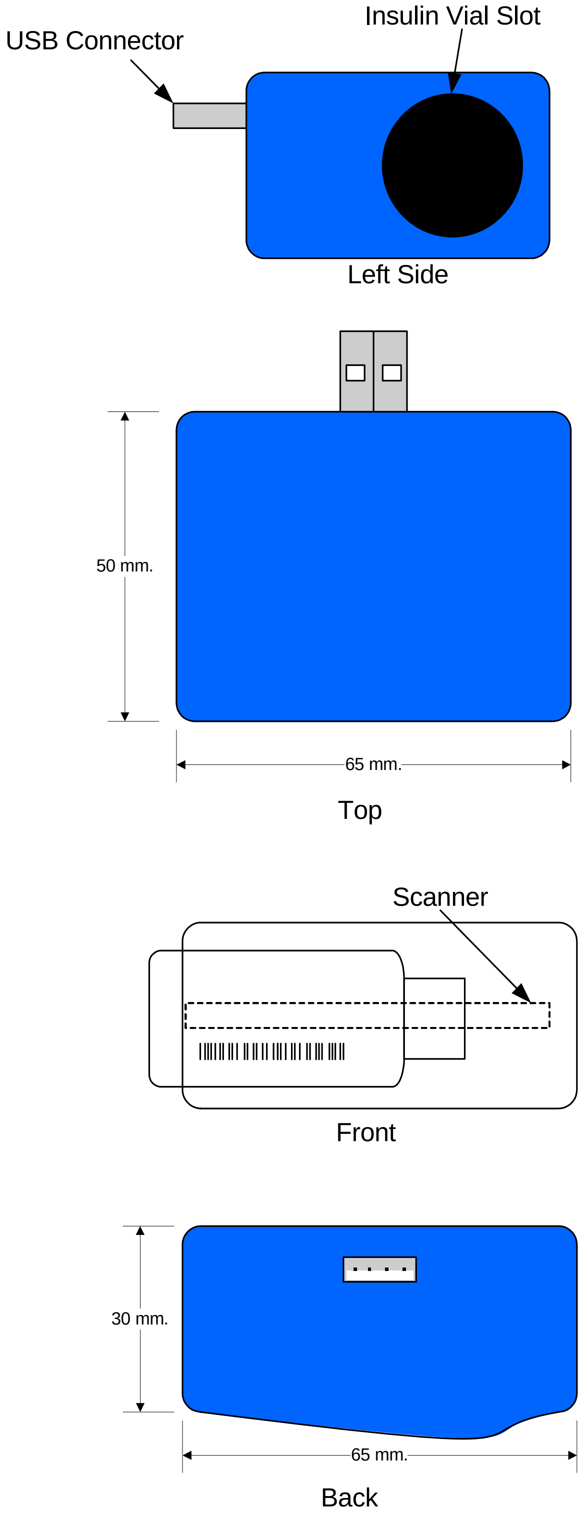


Vial Scanner Module

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 8 shows the vial scanner module.

Figure 8: 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.

Cost:

The total cost of the meter has been estimated to be about $260.00 as shown in Table 4. This $260 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
SP03 Speech Module	$102.00
LCD Screen	$26.00
Circuit Boards	$17.00 each $51.00 for 3
Case(s)	$20.00
Other components	$50.00
Total	$222.00

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

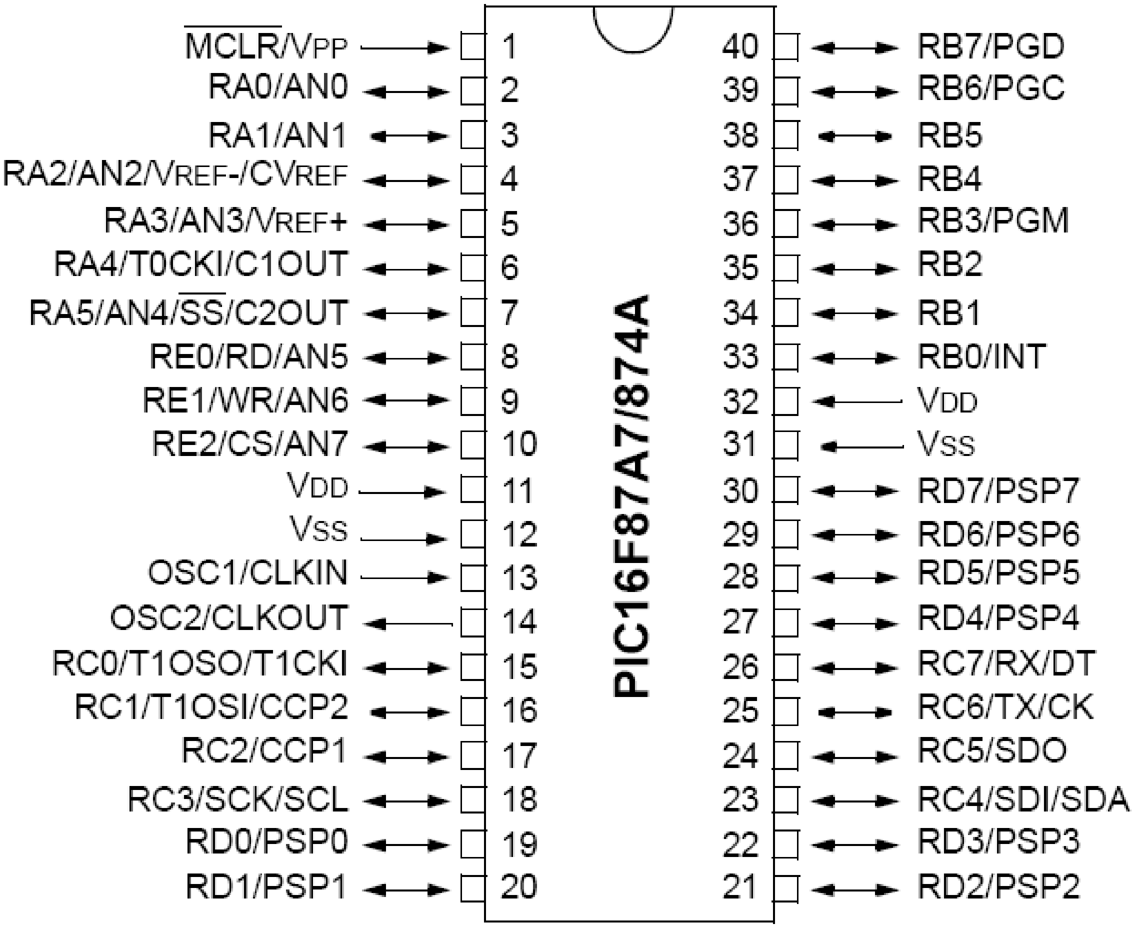


Figure A-2: Processor/Module Block Diagram

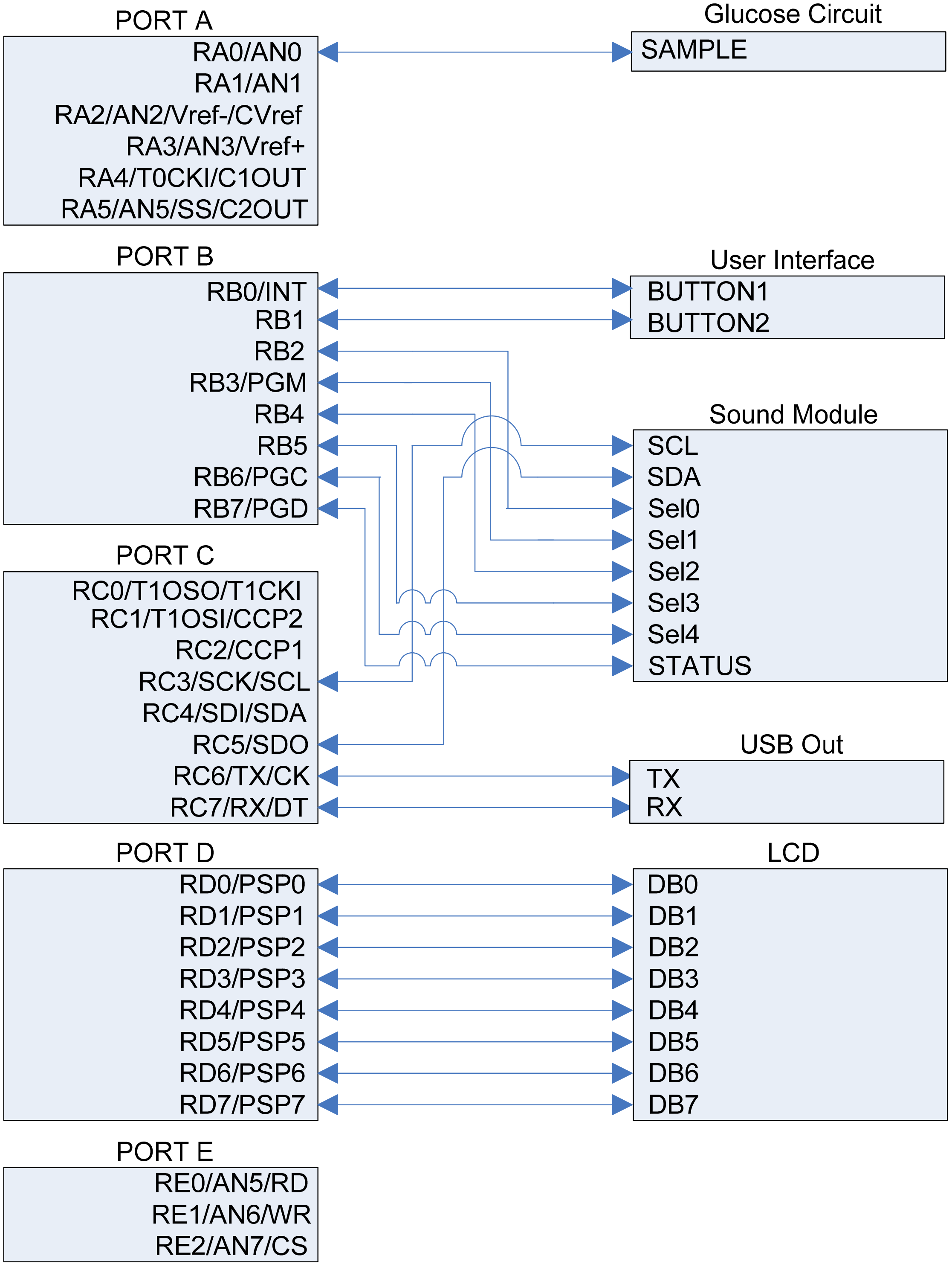


Table A-1: Module Pin Descriptions

Module Pin Names	Description
SAMPLE	Sample voltage from test circuit
Button 1	User Button 1
Button 2	User Button 2
SCL	SPI Serial Clock
SDA	SPI Serial Data In
Sel 0	Bits for Predefined Phrase Selection
Sel 1	Bits for Predefined Phrase Selection
Sel 2	Bits for Predefined Phrase Selection
Sel 3	Bits for Predefined Phrase Selection
Sel 4	Bits for Predefined Phrase Selection
STATUS	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
RA3/AN3/V_{REF+}	Analog Input 3
RB0/INT	Digital I/0
RB1	Digital I/0
RB2	Digital I/0
RB3/PGM	Digital I/0
RB4	Digital I/0
RB5	Digital I/0
RB6/PGC	Digital I/0
RB7/PGD	Digital I/0
RC3/SCK/SCL	Synchronous 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

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)
```

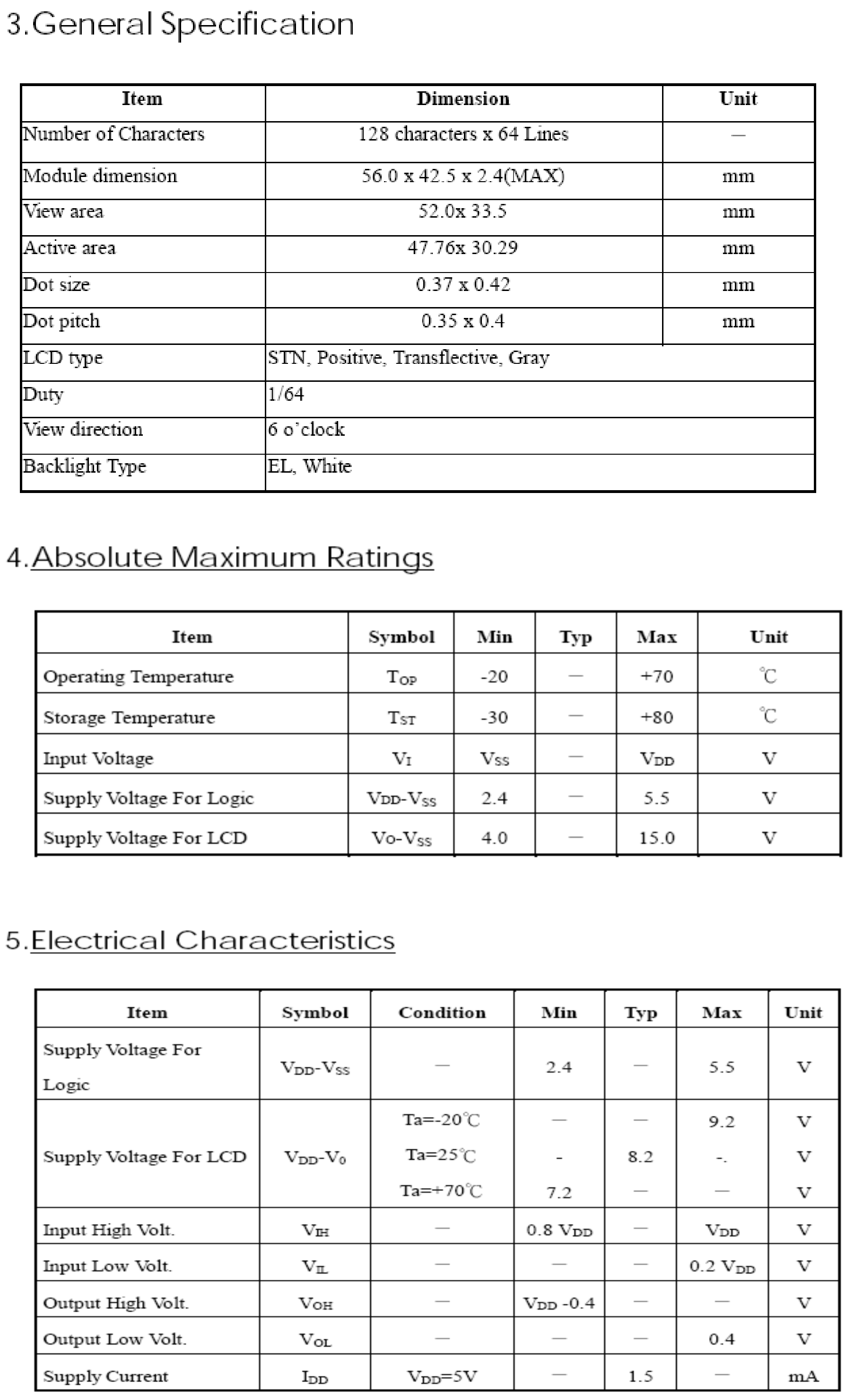
```
{
      TXEN=0;
      TXEN=1;
      CREN=0;
      CREN=1;
}
if (FERR)
{
      dummy=RCREG;
      TXEN=0;
      TXEN=1;
}
//writes a character to the serial port
void putch(unsigned char c)
{
      while(!TXIF)                  //set when register is empty
      {
            clear_usart_errors_inline;
            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	

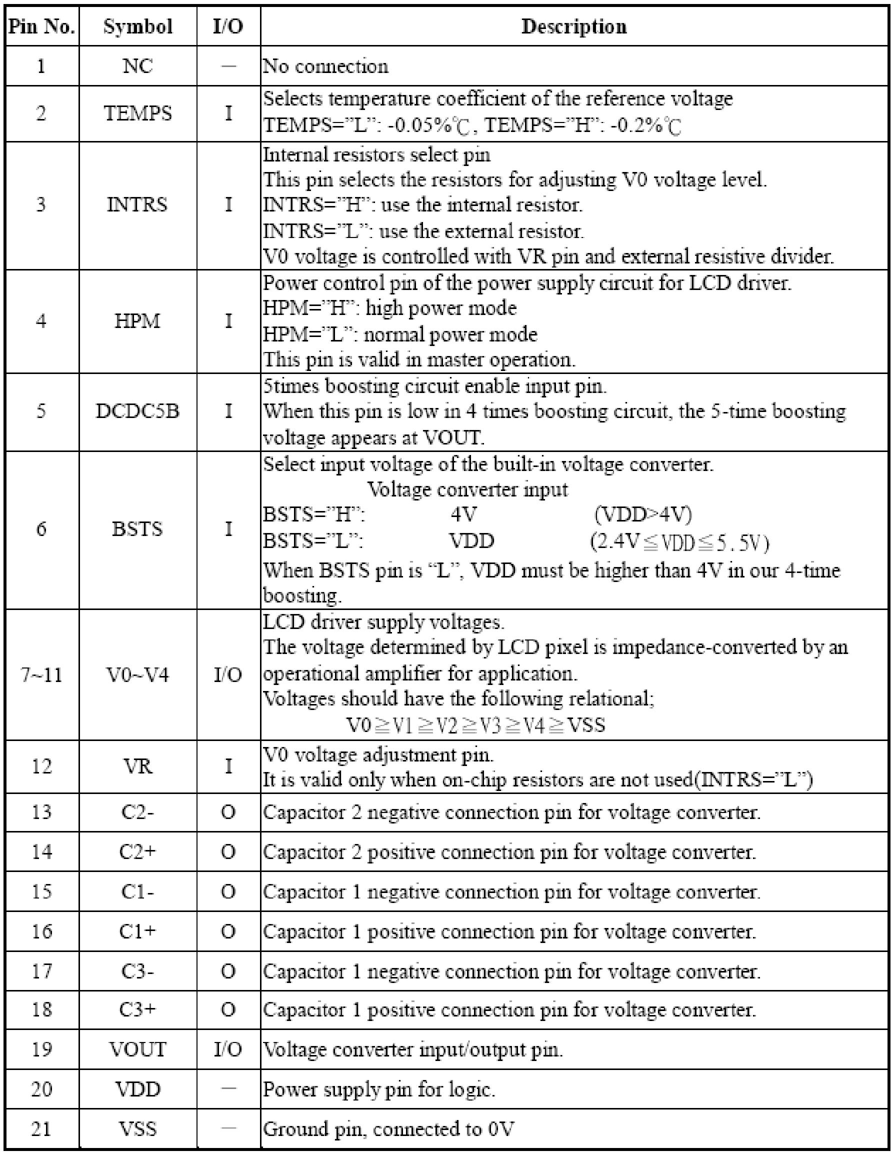
4.Absolute Maximum Ratings

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

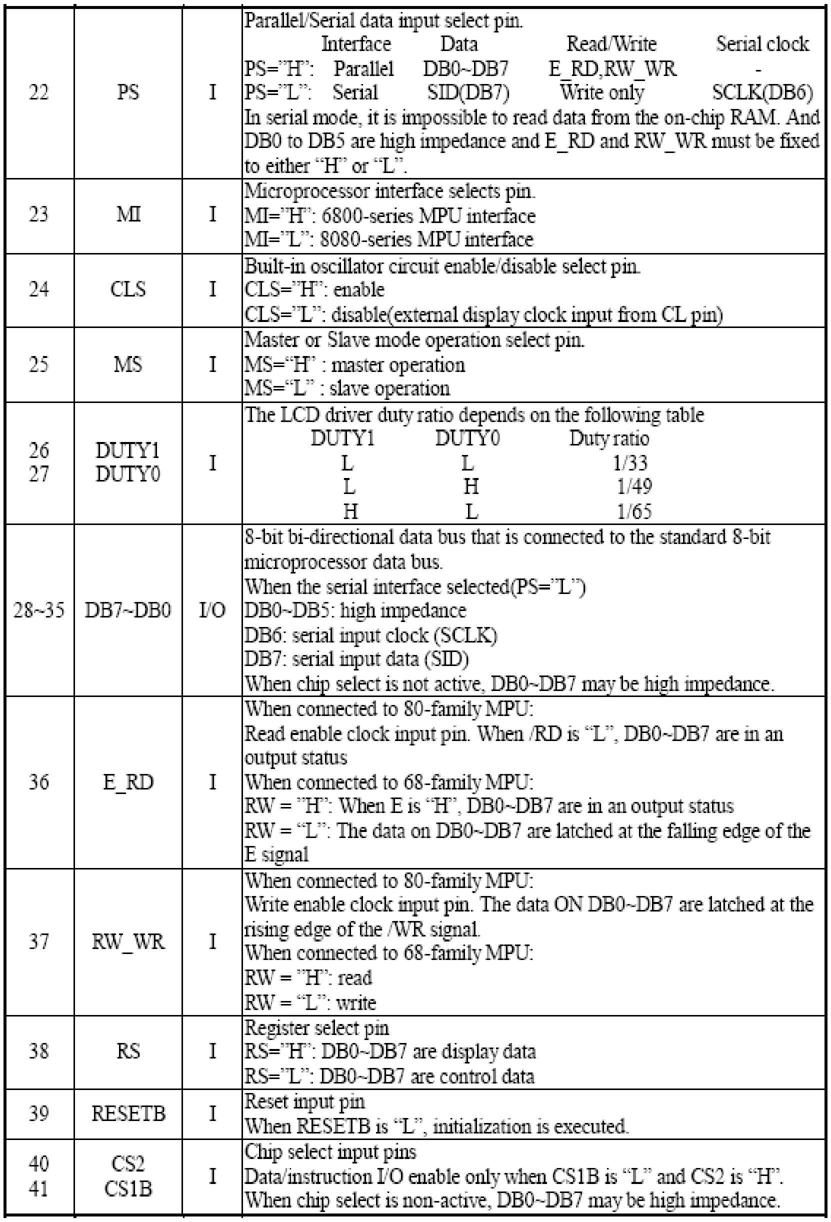
5.Electrical Characteristics

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

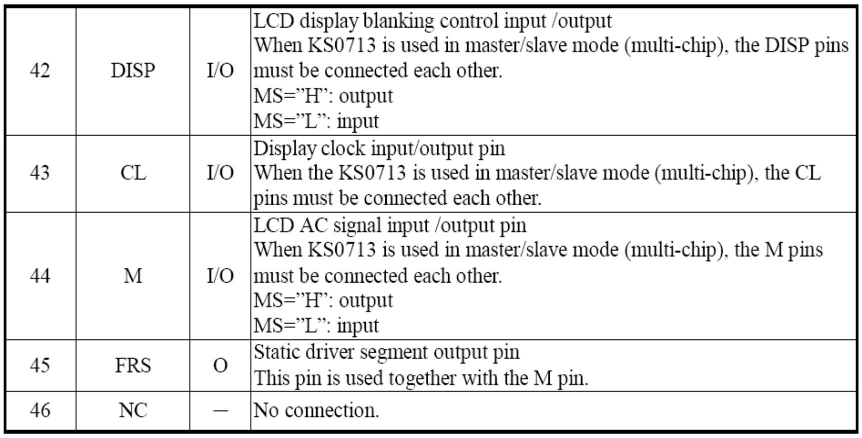
Figure B-2: Pin Assignments for LCD Screen:



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.

Appendix C

SP03 Speech Module

Table C-1: SP03 Pin Descriptions

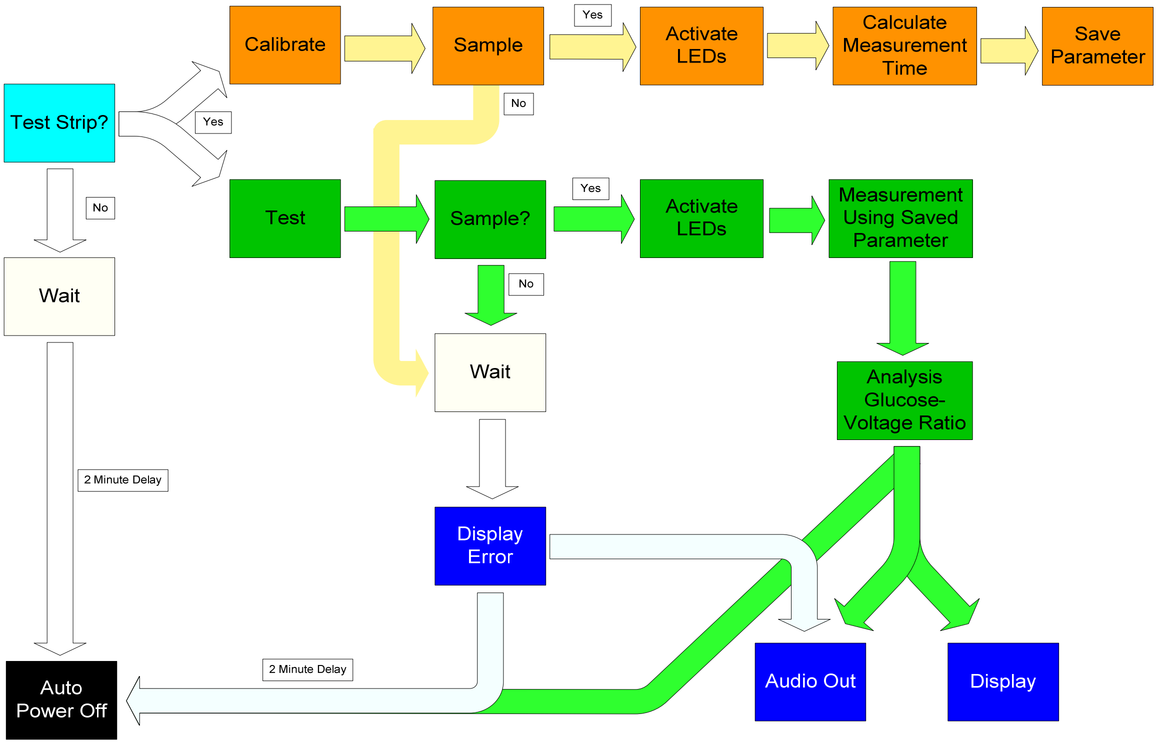
PL1	
Pins	**Description**
+5V	5V Power Supply - up to 100mA
SDA	IC2 bus SDA connection
SCL	I2C bus SCL connection
Gnd	The 0 volt Ground line
Spare	
Gnd	The 0 volt Ground line
RS232 Rx (receive)	Connect to Tx on the PC
RS232 Tx (transmit)	Connect to Rx on the PC
PL2	
Gnd	The 0 volt Ground line
Sel 0	These are the binary select inputs. They select one of the 30 predefined phrases.
Sel 1	
Sel 2	
Sel 3	
Sel 4	
Status	High when speaking, Low when done
+5V	5V Power Supply - up to 100mA

Source: http://www.robot-electronics.co.uk/htm/Sp03doc.shtml

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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