Operators Manual

Accessible Home Vital Signs Monitor

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Project For
RERC National Design Competition

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**Important Safety Instructions**

When operated properly, the Accessible Home vital signs monitor can provide a safe, easy, and convenient way to provide a patients healthcare provider with important medical information. Prior to operating this device, it is important to carefully read this manual in order to eliminate any chance of injury to the patient or anyone else. When operating this monitor, it is advised to follow the following safety precautions:

- Keep away from liquids
- Keep in a low humidity environment
- Keep vital sign probes away from young children
- Keep device away from extreme heat
- Keep device away from extreme cold
- Make sure to turn power off when not in use
Parts and Accessories

The following parts are included with the Accessible Home Vital Signs Monitor:

- Life Fitness Blood Pressure Cuff

- Thermocouple

- Thermometer

- Homedics Digital Scale

- Fingertip Pulse Oximeter Unit.
• Accessible Home Vital Signs Monitor Carrying Case.

• CVS Probe Covers
Features

The accessible home vital signs monitor has the capability to provide the patient with the following features:

- Non-invasively obtain a patient's weight, body temperature, blood oxygen level, respiratory rate, blood pressure, and pulse

- Displays the corresponding vital signs for those audibly impaired

- Speaks the corresponding vital signs for those visually impaired

- Send resulting vital signs to a computer

- Upload these vital signs to a secure, password protected website

- It’s compact and lightweight design allows the vital signs monitor to be put anywhere

- Colorful carrying case allows the vital signs monitor to blend in to the surrounding area, as well as an easy way to hold the transducers
Table of Contents

1 INTRODUCTION ........................................................................................................... 7-24
   1.1 General Overview of Device ........................................................................... 7-9
   1.2 Step by Step Instructions .............................................................................. 10-24
2 MAINTENANCE ......................................................................................................... 25-27
3 TECHNICAL DESCRIPTION ..................................................................................... 28-52
4 TROUBLE SHOOTING ............................................................................................. 53-68
5 APPENDIX ............................................................................................................... 69-70
1 INTRODUCTION

1.1

The objective of the Accessible Home Vital Signs Monitor is to provide patients with a broad range of illnesses a way to remotely monitor their health in the comfort of their own home. This vital signs monitor will have the capability to non-invasively gather a patient’s heart rate, blood pressure, blood oxygen level, body temperature, weight, and respiratory rate, and send this information to the appropriate healthcare provider via Bluetooth technology. In assuring that this information is confidential, this information could be uploaded onto a password protected website through the Biomedical Engineering Department. This accessible home vital signs monitoring system is an accurate and consistent way to obtain a patient’s vital signs, regardless of the caregiver’s skill level. To accommodate all users, the monitoring system was designed as simple and user friendly as possible.

This section will provide the user with a top-down description of the various components of the monitor. Pictures as well as descriptions are provided to make the user as comfortable as possible when first learning how to operate the device. In the next section (1.2), step by step instructions on how to use each probe are provided which will allow the patient to manually obtain their own vital signs.
The Accessible Home Vital Signs Monitoring System

**Figure 1:** Accessible Home Vital Signs Monitor Front View

- Carrying Case
- Blood Pressure Button
- Blood Pressure Cuff Jack
- Thermocouple Jack
- Thermometer Jack
- Scale Jack
- LCD Screen
- Bluetooth Button
- Thermometer
- Speaker
- Thermocouple
As shown by figure 1, the right side of the monitor houses the input jacks for the blood pressure cuff, thermocouple, and scale. To disconnect any probe, simply pull the plug out of the jack, and push back in to reconnect. Note the pulse oximeter is unable to be disconnected.

The Accessible Home Vital Signs Monitoring System (cont’d)

Figure 2: Accessible Home Vital Signs Monitor Top View

Figure 2 shows a top view of the monitor which contains the input to the pulse oximeter unit. Operation of all these probes will be described later in this manual.
1.2

To begin obtaining vital signs, the power button found on the left side of the monitor will have to be first on.

**Figure 3:** Power On

After power is applied to the monitor, the device is ready to begin obtaining vital signs, and the message “Welcome to UConn BME” will be displayed on the LCD screen and “Welcome to the Accessible Home Vital Signs Monitoring System” will be spoken by the text-to-speech module. Once this message has been displayed on the screen and spoken by the text to speech module, the monitor is ready for use. The welcome message which appears on the LCD screen is shown in the following figure.
The order in which the vital signs must be obtained does not matter. The monitor is programmed to continuously check the result from the analog to digital converter. This enables the microprocessor to know when a voltage is applied to any one of the respective pins on the microchip. This allows the patient to choose any transducer they desire, and the internal microprocessor will know which vital sign to calculate at that time. When the patient is finished with the first vital sign acquisition, they have to then simply pick up the next probe and repeat.

The rest of this section will explain in detail how to acquire each vital sign using the probes provided.
**Body Temperature**

To obtain a patient's temperature, the thermometer has to be retrieved from the monitor's carrying case. The pocket for the vital signs monitor can be found on the rear of the monitor, as shown below.

**Figure 5: Thermometer in Case**

When the patient is ready to take their temperature, a thermometer cover must first be applied to the thermometer tip to ensure maximum sanitation to the probe. To do this, remove one probe cover from the package, lift up the plastic flap, then insert the tip of the thermometer into the respective slot designed for the tip. Figure 6 shows proper insertion of the thermometer probe into the cover.
**Figure 6: Probe Cover on Thermometer**

It must be sure that the cover completely covers the tip and is fully wrapped around the thermometer prior to inserting it into the patient’s mouth. Once the thermometer is properly covered, it is ready to be used. To use the thermometer, it must be placed under the tongue of the patient. As the thermometer is inserted into the patient’s mouth under the tongue, the LCD will display “Acquiring temp…” to show that the microchip began to process the temperature. CVS Probe Covers will be provided with the device.
Figure 7: CVS Probe Covers
The thermometer must remain in the patient’s mouth for 30 seconds to wait for the voltage to stabilize. Once the 30 seconds are up, the LCD will display the resulting temperature and the text-to-speech module will speak the corresponding results. After the patient is satisfied with the result, the probe cover can be removed and thrown away, and the thermometer can be replaced into the carrying case. If the patient is not satisfied with the way they carried out the process, the previous steps can be repeated. Figure 9 shows a complete body temperature reading.
Figure 9: Body Temperature Result
**Pulse Oximetry**

The pulse oximeter unit can be found embedded into the enclosure on the top of the monitor shown in figure 10.

**Figure 10:** Embedded Pulse Oximeter Unit

To begin obtaining a patients blood oxygen level, the patient must insert their index finger directly into the pulse oximeter device. The correct way to do this is shown in figure 11.
Once the device has obtained the result, it will be displayed onto the LCD screen.
Figure 11: Blood Oxygen Result
Weight

To obtain a patient's body weight, the Homedics Digital Scale will be used. To obtain a weight reading, the patient must first step on the scale. As the patient steps on the scale, “Acquiring weight…” will be seen on the LCD screen. This is due to the fact that the scale takes about 4 seconds to acquire a weight reading. Once the weight has been obtained, the result will be displayed on the LCD screen.
Respiratory Rate

To obtain the patients respiratory rate, a thermocouple was purchased which is shown below. To increase the accessibility of this probe, a retractable cable was attached to the thermocouple. To obtain a temperature reading, simply grab the end of the retractable cable a hold the end up to the patients’ nose. Like the previous vital signs, as soon as the microchip detects a voltage, it will begin to take the reading. After one minute, the result will be displayed onto the LCD screen in breaths per minute.

**Figure 12:** Thermocouple with Retractable Cable
Blood Pressure

Life Fitness Blood Pressure Cuff is used to obtain a patients’ blood pressure. To obtain this reading, the patient must simply wrap the blood pressure cuff around their upper arm, making sure not to wrap too tight. Once the cuff is secure, the green button on the front panel must be pushed to begin inflation of the cuff. The microprocessor will continue to inflate until the appropriate reading has been gathered, at which point the cuff will automatically deflate. The patients pulse will also be obtained from the blood pressure cuff. By setting a threshold value, the peaks from the pressure sensor will be counted. Each peak is denoted as a heart beat, so by counting these pulses, beats per minute will be obtained.

⚠️ If the patient notices the cuff becoming unusually tight, power down the unit immediately by pressing the “On/Off” switch on the left side of the monitor.

Figure 13: Operation of the Blood Pressure Cuff
Bluetooth

The results from the vital sign measurements will be sent to the computer via Bluetooth technology and be displayed on the computer screen using HyperTerminal. Setting up Bluetooth can be found in the appendix of this manual.

First, the serial connector must be attached to the rear of the computer. To set up HyperTerminal, go to Start → All Programs → Accessories → Communications → HyperTerminal. You will be asked if you would like to make HyperTerminal your default program. Click “No”. You should then see the following window.

Figure 14: HyperTerminal Window

To enable the Bluetooth connection, go to File → Properties, then select the correct Com port. This is determined when you setup Bluetooth found in the appendix.
Figure 15: HyperTerminal Connection Properties

The Bluetooth should now be ready to send information to the HyperTerminal.

**NOTE:** To upload vital signs to the secure password protected website, visit:  
http://www.bme.uconn.edu/sendes/Spring07/Team3/index.htm

Click on “Secure Upload Site”.
2 MAINTENANCE

Safety plays a crucial role when designing a product, so it is important to provide the user with a description of the maintenance that needs to be performed to minimize any potential safety hazards. To begin, the power on the device must be turned off prior to any cleaning/maintenance of the monitor.

Cleaning

To clean the Accessible Home Vital Signs Monitor, a 100% pure cotton rag damp with water must be used to minimize scratches to the LCD screen. A regular wipe down of the exterior case and screen is suitable for cleaning the outside monitor. To access the internal circuit board (if needed), the cover on the back of the monitor must be carefully removed with a Philips screwdriver.

Figure 16: Removal of Back
NOTE:

It is important to keep the monitor in a dust free environment, to minimize damage to the internal circuitry. Failure to do this could result in malfunction to the monitor as well as injury to the patient.

Any technical malfunctions must be returned to the manufacturer!

**Electrical**

- If any loose wires are showing, do not attempt to fix yourself, please return to the manufacturer to minimize any injuries

- If you smell any burning of any sort immediately turn the power off and unplug from the wall. Then proceed to contact the manufacturer

- If any smoke can be seen immediately power off and unplug the device from the wall. Contact the manufacturer

**Serial Connection**

- Do not bend the pins on the male serial connector. Bending pins will result in the serial connection to no longer fit properly.

- Refrain from placing foreign objects into the female serial connector. This will cause the connector to malfunction or even cause damage.
Environmental

a) Water
   i  The monitor and its probes must be kept away from all moisture to eliminate the risk of damage to the device and injury to the patient.

b) Heat
   ii Exposure to extreme heat or cold could result in damage to the monitor. It is advised to keep it at 23°F

c) Humidity
   iii Exposure to high humidity could result in damage to the monitor.
3 TECHNICAL DESCRIPTION

The Accessible Home Vital Signs Monitor allows a patient to obtain their blood pressure temperature, blood oxygen level, weight, pulse, and respiratory rate. The following section will describe in detail the specifics of how this was made possible.

Microprocessor

The main component of this system is Microchips PIC16F877 microprocessor shown below.

Figure 17: PIC16F877

The PIC16F877 is a 40 pin 8-bit microcontroller that was chosen due to the fact that it is capable of processing every aspect of the monitor. This chip is required to make every part of the monitor function. Needing only 5V to power up, the microprocessor was used to read the voltages sent to it by the probes, convert this reading to digital data, and send
this result to the LCD display. The analog pins used for analog inputs were AN0, AN1, AN2, AN3, and AN5. After the voltage was read into the analog pins, the corresponding digital number was used in calculating the correct number to be sent to the LCD screen. The internal A/D converter does this using the following equation:

\[
\frac{Vin}{5V} \times 1024
\]

Where:

- \(Vin\) = Voltage input to analog pin
- \(5V\) = Reference voltage of 5V
- 1024 = number of bits in A/D

The key features of this popular processor are listed below. Note the abundance of analog input channels as well as I/O ports which were needed for the 5 analog pins for our probes.

**Figure 18: PIC16F877 Features**

<table>
<thead>
<tr>
<th>Key Features</th>
<th>PIC16F873</th>
<th>PIC16F874</th>
<th>PIC16F876</th>
<th>PIC16F877</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>DC - 20 MHz</td>
<td>DC - 20 MHz</td>
<td>DC - 20 MHz</td>
<td>DC - 20 MHz</td>
</tr>
<tr>
<td>RESETS (and Delays)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
</tr>
<tr>
<td>FLASH Program Memory (14-bit words)</td>
<td>4K</td>
<td>4K</td>
<td>8K</td>
<td>8K</td>
</tr>
<tr>
<td>Data Memory (bytes)</td>
<td>192</td>
<td>192</td>
<td>368</td>
<td>368</td>
</tr>
<tr>
<td>EEPROM Data Memory</td>
<td>128</td>
<td>128</td>
<td>256</td>
<td>256</td>
</tr>
<tr>
<td>Interrupts</td>
<td>13</td>
<td>14</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Timers</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Capture/Compare/PWM Modules</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Serial Communications</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
</tr>
<tr>
<td>Parallel Communications</td>
<td>—</td>
<td>P8P</td>
<td>—</td>
<td>P8P</td>
</tr>
<tr>
<td>10-bit Analog-to-Digital Module</td>
<td>5 input channels</td>
<td>8 input channels</td>
<td>5 input channels</td>
<td>8 input channels</td>
</tr>
<tr>
<td>Instruction Set</td>
<td>35 instructions</td>
<td>35 instructions</td>
<td>35 instructions</td>
<td>35 instructions</td>
</tr>
</tbody>
</table>
To configure the analog to digital converter, the ADCON0 and ADCON1 registers were used. The ACON0 register shown below is control the operation of the A/D converter. Each vital sign required its own A/D conversion. This was done by changing bits 5-3 as needed, to select the appropriate input channel. Also, FOSC/32 was selected for the conversion clock.

Figure 19: ADCON0 Register

<table>
<thead>
<tr>
<th>REGISTER 11-1: ADCON0 REGISTER (ADDRESS: 1Fh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/W-0</td>
</tr>
<tr>
<td>ADS1</td>
</tr>
<tr>
<td>bit 7</td>
</tr>
</tbody>
</table>

- **bit 7-6 ADS1:ADS0**: A/D Conversion Clock Select bits
  - 00 = FOSC/2
  - 01 = FOSC/8
  - 10 = FOSC/32
  - 11 = FRC (clock derived from the internal A/D module RC oscillator)

- **bit 5-3 CHS2:CHS0**: Analog Channel Select bits
  - 000 = channel 0, (RA0/AN0)
  - 001 = channel 1, (RA1/AN1)
  - 010 = channel 2, (RA2/AN2)
  - 011 = channel 3, (RA3/AN3)
  - 100 = channel 4, (RA4/AN4)
  - 101 = channel 5, (RE0/AN5)(f)
  - 110 = channel 6, (RE1/AN6)(f)
  - 111 = channel 7, (RE2/AN7)(f)

- **bit 2 GO/DONE**: A/D Conversion Status bit
  - If ADON = 1:
    - 1 = A/D conversion in progress (setting this bit starts the A/D conversion)
    - 0 = A/D conversion not in progress (this bit is automatically cleared by hardware when the A/D conversion is complete)

- **bit 1 Unimplemented**: Read as '0'

- **bit 0 ADON**: A/D On bit
  - 1 = A/D converter module is operating
  - 0 = A/D converter module is shut-off and consumes no operating current

**Note**: These channels are not available on PIC16F673/676 devices.

**Legend:**
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as '0'
- n = Value at POR
- '1' = Bit is set
- '0' = Bit is cleared
- x = Bit is unknown
The ADCON1 register (shown below) controls the function of the port pins. Since all of our inputs were analog, bits 3-0 were configured as "0000", allowing for all analog inputs. Also, the result of the A/D conversion was right justified (bit 7).

**Figure 20: ADCON1 Register**

**REGISTER 11-2: ADCON1 REGISTER (ADDRESS 9Fh)**

<table>
<thead>
<tr>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADFM</td>
<td>—</td>
<td>—</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
<td></td>
</tr>
</tbody>
</table>

- **bit 7**  
  - **ADFM**: A/D Result Format Select bit  
  - 1 = Right justified, 0 Most Significant bits of ADRESH are read as '0'.  
  - 0 = Left justified, 0 Least Significant bits of ADRESL are read as '0'.

- **bit 6-4**  
  - **Unimplemented**: Read as '0'

- **bit 3-0**  
  - **PCFG3:PCFG0**: A/D Port Configuration Control bits:

<table>
<thead>
<tr>
<th>PCFG3</th>
<th>PCFG0</th>
<th>AN7(1)</th>
<th>AN6(1)</th>
<th>AN5(1)</th>
<th>AN4</th>
<th>AN3</th>
<th>AN2</th>
<th>AN1</th>
<th>AN0</th>
<th>VREF+</th>
<th>VREF-</th>
<th>Chan/Res(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>8/0</td>
</tr>
<tr>
<td>0001</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VREF+</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>7/1</td>
</tr>
<tr>
<td>0010</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>5/0</td>
</tr>
<tr>
<td>0011</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>VREF+</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>4/1</td>
</tr>
<tr>
<td>0100</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>3/0</td>
</tr>
<tr>
<td>0101</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VREF+</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>2/1</td>
</tr>
<tr>
<td>011x</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VDD</td>
<td>VSS</td>
<td>VSS</td>
<td>1/0</td>
</tr>
<tr>
<td>1000</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VREF+</td>
<td>VREF-</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>RA3</td>
<td>RA3</td>
<td>6/2</td>
</tr>
<tr>
<td>1001</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>VDD</td>
<td>VSS</td>
<td>VSS</td>
<td>5/0</td>
</tr>
<tr>
<td>1010</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>VREF+</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>RA3</td>
<td>VSS</td>
<td>VSS</td>
<td>5/1</td>
</tr>
<tr>
<td>1011</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>VREF+</td>
<td>VREF-</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>RA3</td>
<td>RA3</td>
<td>4/2</td>
</tr>
<tr>
<td>1100</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VREF+</td>
<td>VREF-</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>RA3</td>
<td>RA2</td>
<td>3/2</td>
</tr>
<tr>
<td>1101</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VREF+</td>
<td>VREF-</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>RA3</td>
<td>RA3</td>
<td>RA2</td>
<td>2/2</td>
</tr>
<tr>
<td>1110</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VDD</td>
<td>VSS</td>
<td>VSS</td>
<td>1/0</td>
</tr>
<tr>
<td>1111</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>VREF+</td>
<td>VREF-</td>
<td>D</td>
<td>A</td>
<td>RA3</td>
<td>RA3</td>
<td>RA2</td>
<td>1/2</td>
</tr>
</tbody>
</table>

A = Analog input  
D = Digital I/O

**Note 1:** These channels are not available on PIC16F873/875 devices.
**Note 2:** This column indicates the number of analog channels available as I/O inputs and the number of analog channels used as voltage reference inputs.

**Legend:**
- **R** = Readable bit  
- **W** = Writable bit  
- **U** = Unimplemented bit, read as '0'  
- **-n** = Value at POR  
- **'1'** = Bit is set  
- **'0'** = Bit is cleared  
- **x** = Bit is unknown

---

31
Shown below is a sample of how the AN0 pin was initialized for the body temperature.

```c
void init_a2dtemp(void)
{
    ADCON0=129; // select Fosc/32, AN0, A/D on
    ADCON1=128; // select right justify result.
    ADON=1; // turn on the A2D conversion module
    DelayMs(50);
}
```
**LCD Screen**

The results of these vital sign acquisitions are sent to our Crystalfontz CFAH1602L-GGH-JP character LCD screen.

**Figure 21:** Crystalfontz LCD

Operation of this screen was controlled by pins RD0-RD7 for the data bits, as well as RB7-RB5 for the control bits.
Figure 22: LCD Screen Configuration

Port A
- AN0
- AN1
- AN2
- AN3
- AN5

Port E
- RB7
- RB6
- RB5

Port D
- RD0/PSP0
- RD1/PSP1
- RD2/PSP2
- RD3/PSP3
- RD4/PSP4
- RD5/PSP5
- RD6/PSP6
- RD7/PSP7

Output
- Pulse Oximeter
- Weight
- Respiratory Rate
- Blood Pressure

LCD Screen
- Vss
- Vdd
- VO
- RS
- RW
- E

Data Bus
- DB0
- DB1
- DB2
- DB3
- DB4
- DB5
- DB6
- DB7
Text to Speech

As well as being displayed onto the LCD screen, the vital signs are also spoken. This was made possible by utilizing the SP03 text-to-speech module, which takes strings of ASCII text and produces the resulting speech.

Figure 23: Sp03 Text-to-Speech Module
This was made possible by the use of RS232 serial communication. The only pins that needed to be used on the SP03 was the Rx, Tx, ground, and 5V pins. To accomplish this, the SP232ACP 16 pin chip was needed. The SP232ACP is the industrial standard IC for converting TTL/CMOS level signals to RS232 level signals.

**Figure 24: SP232ACP**

The Rx and Tx pins from the SP03 were connected to the corresponding pins 13 and 14 on the SP232ACP, then sent to pins 25 and 26 on the PIC16F877. This connection is shown in figure 25.
Figure 25: SC232ACP to SP03
To communicate between the SP03 and microchip, USART (Universal Synchronous/Asynchronous Receiver/Transmitter) was used. This communication allows the SP03 to speak a line of text, by sending it a sequence of commands. These commands are shown in figure 26.

**Figure 26: SP03 Commands**

<table>
<thead>
<tr>
<th>Command byte Transmitted to SP03 Module</th>
<th>Acknowledge byte returned from SP03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command 0x80</td>
<td>0x01</td>
</tr>
<tr>
<td>Full Volume 0x00</td>
<td>0x00</td>
</tr>
<tr>
<td>Speech Pitch 0x04</td>
<td>0x04</td>
</tr>
<tr>
<td>Speech Speed 0x02</td>
<td>0x02</td>
</tr>
<tr>
<td>Text 'H'</td>
<td>'H'</td>
</tr>
<tr>
<td>Text 'e'</td>
<td>'e'</td>
</tr>
<tr>
<td>Text 't'</td>
<td>'t'</td>
</tr>
<tr>
<td>Text 'o'</td>
<td>'o'</td>
</tr>
<tr>
<td>NULL 0x00</td>
<td>0x00</td>
</tr>
<tr>
<td>SP03 will now speak the text</td>
<td>0x00 indicates text loading is complete</td>
</tr>
</tbody>
</table>

To send the SP03 a line of text, a small subroutine had to written. This subroutine, programmed in C, allows the microchip to send the SP03 text one character at a time.

```c
void speech(char c)
{
    int cnum;
    cnum=c;
    printf("%c", cnum);
    DelayMs(1);;
}

void Writespeech(const char* s)
{
    while(*s)
        speech(*s++);
}
```
Temperature Measurements

To measure body temperature, a thermistor circuit was used. The probe we have chosen for this is a digital thermometer purchased from CVS. The thermistor within the probe will convert changes in temperature to changes in voltage. Unfortunately, thermistors are inherently non-linear. The Steinhart-Hart equation describes the resistance-temperature curve of a thermistor:

\[
\frac{1}{T} = a + b \ln(R) + c \ln^3(R)
\]

where \( T \) is the temperature in kelvins, \( R \) is the resistance in ohms, and \( a, b, \) and \( c \) are constants called the Steinhart-Hart parameters. This output can be linearized through the use of a Wheatstone bridge (Fig. 27).

**Figure 27:** Temperature Linearization

Thus, the resistance of the thermistor, \( RT1 \), can be modeled by the first order equation:
\[ R(T_1) \approx R \left[ 1 + \alpha \Delta T \right] , \]

where \( R \) is the resistance of the other resistance in the Wheatstone bridge, \( \alpha \) is the temperature coefficient, and \( \Delta T \) is the change in temperature from the reference temperature (\( \Delta T = T - T_0 \)) in degrees Kelvin. The temperature coefficient, \( \alpha \), was calculated from the following equation:

\[
\alpha = \frac{d(R(T_1))}{dT} = -\frac{\beta}{T^2},
\]

where \( \beta \) is a temperature constant, typically around 4000°K. For our use as an oral temperature probe, the thermistor needed to be linearized (calibrated) around 98.6° F (37°C), for a temperature range of at least 90-104° F (32-40°C). When linearizing the thermistor, we were careful to keep the accuracy of the thermometer high (± .1°C) so as to be able to take appropriate measurements.

After being linearized, the signal is sent to a 3rd order butterworth filter to remove any noise. The cutoff frequency for the filter should be less than 40Hz to remove any noise from room lights and other sources (\( f_c = \frac{1}{2\pi R C} \)). The signal is then sent to a non-inverting amplifier to be amplified and then passed to the microprocessor where it is analyzed and sent to the LCD screen to be displayed. Our full thermometer circuit is shown below.
Values for R3 and R4 were determined from gain equation for non-inverting amplifiers:

\[
\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}}.
\]

The target gain for the amplifier was based on the input current for the microprocessor.

The thermometer was tested by placing the probe in a beaker of water heated to a certain temperature and comparing the resulting temperature given by the thermometer to the actual temperature of the water. This was done over a range of temperatures to determine the thermometer’s actual operating range and to assure that it is within the appropriate range to measure body temperature.

Because we did not have the manufacturers thermistor coefficient data, we had to determine our temperature versus resistance curve experimentally to calibrate the thermometer. The thermometer was calibrated by calculating a curve that relates
thermistor resistance to temperature in degrees Fahrenheit. Using only two points in the
temperature region of interest (Table), I found the line on which those points lie,

<table>
<thead>
<tr>
<th>Points</th>
<th>Temperature (°F)</th>
<th>Thermistor Resistance (kΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91.9</td>
<td></td>
<td>35.4</td>
</tr>
<tr>
<td>96.8</td>
<td></td>
<td>31.2</td>
</tr>
</tbody>
</table>

\[ R_T = -857.143 \cdot T_F + 114171. \]

The equation for the voltage out of the thermometer circuit (Wheatstone bridge and
differential amplifier) is

\[ V_0 = \frac{R_2}{R_1} \left( \frac{V_s}{R} \frac{1}{1 + \frac{R}{R_T}} - \frac{V_s}{2} \right), \]

where \( R \) is the resistance of the 3 resistors in the Wheatstone bridge, \( V_s \) is the source
voltage, \( R_T \) is the thermistor voltage (variable), and \( R_1 \) and \( R_2 \) are the resistances from the
resistors of the differential amplifier. Solving this for \( R_T \), plugging into the resistance
curve, and solving for \( T_F \) yields the equation for temperature based on the change in
thermistor resistance:

\[ T_F = \frac{1}{m V_s} \frac{1}{R} \left( \frac{R_1 - V_s}{R_2} + \frac{V_s}{2} \right) - \frac{b}{m}, \]

where \( m \) and \( b \) are the constants from the resistance curve. Using the following part and
calculated values, this equation becomes:

\[ R = 1000\Omega \]
\[ V_s = 3.3V \]
\[ R_2 = 470\Omega \]
\[ R_1 = 470\Omega \]
\[ m = -857.143 \]
\[ b = 114171 \]

\[ T_F = \frac{1}{-2.82857 V_0 + 1.65 + .857143} + 133.199. \]
Final testing done by taking group members’ temperature with the thermometer and comparing the reading with that taken by a commercial digital thermometer, showed that the thermometer was accurate to within .5°F.
Pulse Oximeter

To gather the patients’ blood oxygen level, a commercially purchased pulse oximeter unit was purchased. Since we did not have the blood oxygen saturation lookup tables for this pulse oximeter, it made it impossible to calibrate the unit. By opening up this pulse oximeter, unit we were able to obtain the signal which came from across the photodiodes. This output of the pulse oximeter probe was then scoped to observe changes in voltage as the patient’s finger was inserted into the probe. Through experimental testing, it was observed that a subject with 98% blood oxygen level reached 300mV on the voltmeter. It was then concluded that any voltage above 250mV was used as 98% blood oxygen. This signal was then through the A/D converter of our microprocessor. The microprocessor was then coded to send data to the LCD screen and speech module when the A/D converter reached above 51 ($\frac{250V}{5V} \times 1024$).
**Weight**

To obtain the patients weight, the Homedics Digital Scale was used. Like the pulse oximeter, the output from this scale was taken before it reached the internal microprocessor of the scale, then filtered and amplified, and sent to our microprocessor. Here, the voltage was run through the A/D converter and inserted into the equation:

\[
\text{Weight} = 9000 \times \frac{5 \times \text{ADC value}}{1024} - 32374
\]

This equation was obtained by having test subjects step on the scale, then compare the voltage read on the voltmeter to the weight produced by the scale’s LCD. The circuit diagram for the scale is shown below.

**Figure 31: Weight Circuit Diagram**
Thermocouple

To obtain the patients respiratory rate, a thermocouple was used to generate breathing patterns. Thermocouples are a widely used type of temperature sensor and can also be used as a means to convert thermal potential difference into electric potential difference. The voltage from the thermocouple is linear over range (approx. 65°F to 98°F) so the signal from the thermocouple only needs to be filtered and amplified before being A/D converted and processed by the microprocessor. As the patient breathes in and out, the hot air being released from their nose causes a voltage change, which can be used to determine the rate at which breathing occurs in a minute. Figure 32 is the circuit diagram of the hardware used to process the incoming voltage.

**Figure 32:** Thermocouple Circuit
Blood Pressure

In obtaining blood pressure measurements we used the MPX2050 pressure transducer from Motorola to sense the pressure from the arm cuff. The pressure transducer produces the output voltage proportional to the applied differential input pressure. Blood pressure will be automatically measured through the oscillometric method. This is done by wrapping a blood pressure cuff around the upper arm and inflating it until the pressure around the arm due to the cuff collapses (or occludes) the brachial artery. The cuff is then slowly deflated. As the cuff deflates, blood starts pumping through the brachial artery causing minute vibrations of .5 to 1 mmHg in the cuff. The pressure at which these vibrations start is the systolic pressure, and the pressure at which they stop is the diastolic pressure. The block diagram in Fig. ** illustrates how this method will be used to measure blood pressure in the accessible vital signs monitoring system. Each system in the flow chart is described in more detail in the following paragraphs.

When the blood pressure “Start” button on the vital signs monitor is pressed (green button), the blood pressure cuff will be inflated to about 40mmHg above normal (160mmHg). The cuff is inflated by a Hargrave Fluidics Series Micro Air Pump. The microprocessor controls the inflation of the cuff. As previously stated, the sensor used to sense cuff pressure is the MPX2050 pressure transducer. Once the pressure sensor determines that the cuff has been inflated to 160mmHg, the cuff deflates slowly at a rate of 2-3mmHg/sec. Deflation occurs through a release valve.

As blood begins flowing through the brachial artery again, it will cause small pulsations that will be picked up by the pressure sensor in the cuff (Fig. **). This waveform is analyzed by the microprocessor to determine the systolic and diastolic pressures.
Figure 33. Blood Pressure Waveform Picked Up by Pressure Sensor[17]

Where: MAP = Maximum Arterial Pressure
       SBP = Systolic Blood Pressure
       DBP = Diastolic Blood Pressure

A threshold voltage level is set. This was be done by experimentally comparing blood pressure readings from a sphygmometer or other commercial device to those detected by our pressure sensor. Once 4 pulsations peak above the threshold level, the voltage was recorded and from that value the systolic pressure determined. The microprocessor continues to monitor the blood pressure readings and diastolic pressure will be taken when the voltage drops below the threshold voltage for 2 pulsations. After the diastolic pressure is determined, a command from the microprocessor deflates the cuff quickly and completely.
Due to the safety issues that arise with automatic blood pressure systems, we have incorporated a “kill switch” into our design. If at any time during the blood pressure measurement the user wants to stop the inflation of the cuff and rapidly deflate it, they just need to press the vital signs monitor “On/Off” button. This will cut power to the whole device and open the pressure release valve. This method bypasses the
microprocessor, avoiding any software bugs that an emergency stop button might encounter. Figure 35 shows our blood pressure circuit.

**Figure 35:** Blood Pressure Circuit
A full circuit diagram for the Accessible Home Vital Signs Monitor can be found below. This schematic was used to generate our PCB using Express PCB.

**Figure 36: Full Circuit Diagram**
Our PCB Diagram is shown below.

Figure 37:
4 TROUBLESHOOTING

In general, most software problems can be solved by turning the device off, waiting a few minutes, then turning it back on and repeating the procedure to acquire a vital sign. Other problems that may occur can be solved by the tips listed in the Troubleshooting Tables (Tables.)

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Cause</th>
<th>How To Fix It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device does not turn on.</td>
<td>Dead batteries.</td>
<td>Turn the device off. Recharge the batteries for at least 4 hours. Turn the device on. If the device does not turn on, it may be damaged.</td>
</tr>
<tr>
<td>Screen does not turn on when the device is turned on.</td>
<td>Software problem.</td>
<td>Turn the device off, then turn it back on.</td>
</tr>
<tr>
<td>No sound is heard from the speaker.</td>
<td>Software/Hardware problem.</td>
<td>Turn the device off, then turn it back on. If this does not work, the issue maybe in the hardware, such as a disconnect between the text-to-speech module and the speaker. Return the device to the manufacturer.</td>
</tr>
<tr>
<td>Something burning can be smelled coming from the monitor.</td>
<td>Hardware failure.</td>
<td>A piece of the hardware has failed. Turn the device off. Do not turn it back on. Return device to the manufacturer.</td>
</tr>
<tr>
<td>The two push buttons on the front of the</td>
<td>Debris has been</td>
<td>Turn the device</td>
</tr>
<tr>
<td>Debris has been</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue</td>
<td>Cause</td>
<td>Solution</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Case can no longer be depressed.</td>
<td>Caught in the button casing.</td>
<td>Off. Open the case. Carefully check debris around the buttons (dust, food, loose parts, etc.). Remove the debris, and close the case.</td>
</tr>
<tr>
<td>One or more of the probes will not plug into their jack(s).</td>
<td>Debris in the jack, or the plug has been deformed.</td>
<td>Look to see if there is any debris in the jack. Gently blow on the jack to remove debris. Check the plug for deformities. If the plug has been deformed (stripped, bent, etc.), it will need to be replaced.</td>
</tr>
<tr>
<td>The device LCD screen displays the improper function. For example, when taking blood oxygen saturation levels, the LCD screen displays, “Acquiring temp.”</td>
<td>Software problem.</td>
<td>Turn the device off, then turn it back on.</td>
</tr>
<tr>
<td>A significant amount of water/liquid has spilled on the device.</td>
<td>--</td>
<td>Immediately turn the device off. Towel dry or wait for the device to dry. Try turning the device on. If the device starts up and operates correctly, no water has entered the casing. If there is any doubt to the device’s functionality, return to the manufacturer.</td>
</tr>
</tbody>
</table>

**Table 1**: Device (monitor) Troubleshooting Tips
<table>
<thead>
<tr>
<th>Issue</th>
<th>Problem Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>The blood pressure cuff does not inflate.</td>
<td>The inflate button hasn’t been pushed.</td>
<td>The blood pressure cuff does not inflate upon power-up of the device. Press the green “Inflate” button to inflate the cuff.</td>
</tr>
<tr>
<td>The blood pressure cuff inflates without warning.</td>
<td>The “Inflate” button may have accidentally been pushed.</td>
<td>Turn the device off to immediately deflate the cuff.</td>
</tr>
<tr>
<td>The pulse oximeter will not produce a blood oxygen saturation reading.</td>
<td>Poor circulation/sensor obstruction.</td>
<td>Try sticking another finger in the pulse oximeter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poor circulation (or cold) can interfere with blood flow and prevent a proper reading. Nail polish, fake nails, marker, or paint can also interfere with readings.</td>
</tr>
<tr>
<td>The thermometer will not produce a temperature reading.</td>
<td>The temperature probe is not plugged into the device.</td>
<td>Make sure the probe is plugged into the appropriate socket on the side of the device.</td>
</tr>
<tr>
<td>The respiratory rate measurement probe does not produce a respiratory rate reading.</td>
<td>The respiratory nasal probe is not plugged into the device.</td>
<td>Make sure the probe is plugged into the appropriate socket on the side of the device.</td>
</tr>
<tr>
<td>The scale LCD screen shows a weight reading, but the device LCD screen does not</td>
<td>The scale is not plugged into the device.</td>
<td>Make sure the scale is plugged</td>
</tr>
<tr>
<td>Issue</td>
<td>Cause</td>
<td>Solution</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>When stepped on, the scale LCD screen shows “Err”</td>
<td>There has been an error in the scale measurement.</td>
<td>Step off the scale until its LCD screen blanks. Step back on the scale.</td>
</tr>
<tr>
<td>When stepped on, the scale LCD screen shows “-- --“</td>
<td>The scale is self-calibrating.</td>
<td>Step off the scale until its LCD screen blanks. The scale is now calibrated. Step back on the scale.</td>
</tr>
<tr>
<td>After a weight is displayed, the scale LCD screen shows “C”</td>
<td>A less accurate weight has been acquired.</td>
<td>To obtain a more accurate weight reading, step off the scale, let the screen clear, then step back on the scale. The scale cannot take an accurate reading if the person on the scale is moving around.</td>
</tr>
<tr>
<td>The scale will not turn on.</td>
<td>The scale battery is dead.</td>
<td>Change or recharge the battery in the back of the scale. Step on the scale again to automatically turn it on.</td>
</tr>
<tr>
<td>The reading shown on the scale LCD screen differs from that on the device LCD screen.</td>
<td>Software problem.</td>
<td>Step off the scale. Turn the device off, then turn it back on again.</td>
</tr>
</tbody>
</table>
The weight read by the scale is off by more than five pounds.

Scale is on an uneven surface.

Step back on the scale.

Step off the scale, and turn the device off. Make sure the scale is on a clean, even surface. A hard floor (wood, linoleum, etc.) is recommended. Even a carpeted floor can produce an inaccurate weight reading.

Table 2: Transducer/probe Troubleshooting Tips
<table>
<thead>
<tr>
<th>The computer does not receive vital signs when the “Send” button on the device is pushed.</th>
<th>Bluetooth module is not installed on the computer.</th>
<th>Make sure that your Bluetooth dongle is plugged into a USB port on the computer, and the computer is turned on. Follow the Bluetooth module installation steps below.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The secure website won’t load.</td>
<td>Server is busy/down.</td>
<td>Reload the webpage (Click , or similar icon for your web browser). If the secure website still will not load, wait 30 minutes, the server may be busy. If the site still will not load, it may be down. Call the webmaster or consider e-mailing your vital signs data.</td>
</tr>
</tbody>
</table>

**Table 3:** Communication/Bluetooth/Website Troubleshooting Tips
To repair hardware issues or open the casing to remove debris

If you encounter any hardware issues with your accessible home vital signs monitor, it is recommended that you send the device back to the manufacturer for maintenance. However, if you feel you have the knowledge and ability to repair the device yourself, use the following instructions to open the casing.

1. Make sure the device is not charging and is off (the on/off switch is in the “off” position).

Remove charger plug from wall socket.
2. Remove all probes from the device.

Pull the probes by the plug from the socket to remove.

3. Remove the outer cloth casing.

Undo the snaps on the side, back, and bottom of the casing to remove the cloth cover.
Gently pull the cloth cover at the snaps to undo.

4. Lay the casing on its front to access the screws.
5. Remove the 4 screws from each of the corners with a standard Philips Head screwdriver.

Remove the screws and place them aside.
6. Now you can carefully lift the back panel from the front. Do not pull too hard or fast, as the LCD screen is inserted in the front panel and connected to the back panel by wiring.

You will not be able to completely take apart the two halves of the casing, as the LCD screen connects the front and back panels. However, with care you should be able to open the case enough to be able to access whatever parts you need.
Bluetooth Dongle Installation

The Bluetooth module should connect immediately to the computer upon device power-up. However, if it does not, follow these easy steps to install the module.

1. Right click on the [Bluetooth] symbol in the time tool bar.

2. Select “Add a Bluetooth Device”
3. Follow the directions on the screen that pops up and click “Next”.

4. Highlight (click) on eb505, then click “Next”.
5. Click the circle that says “Choose a Passkey” and enter your passkey. Choose a number that you can easily remember, but no one else can guess. This will secure your vital signs monitor’s connection to your computer.
6. Once connected, a screen will show up indicating which COM ports the Bluetooth module will connect with. Use these COM ports to set up a Hyperterminal link. The incoming COM port is the one which Hyperterminal is assigned.
5 APPENDIX

Updated Specifications

**Mechanical**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (unit without peripheries)</td>
<td>&lt;6 pounds</td>
</tr>
<tr>
<td>Size</td>
<td>9.87” x 7.10” x 3.99”</td>
</tr>
<tr>
<td>Button size</td>
<td>0.75” x 0.75”</td>
</tr>
<tr>
<td>Durability</td>
<td>Able to transported and withstand minor bumps and disturbances</td>
</tr>
<tr>
<td>Water Resistance</td>
<td>Recommend avoid water and spills</td>
</tr>
<tr>
<td>Anchoring/Mounting</td>
<td>Rubber treads on bottom of device</td>
</tr>
</tbody>
</table>

**Electrical**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Source</td>
<td>11.4V Rechargeable Li-Ion battery with charger</td>
</tr>
<tr>
<td>Display</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>1.35”</td>
</tr>
<tr>
<td>Width</td>
<td>4.20’</td>
</tr>
<tr>
<td>Illumination</td>
<td>Back-lit LCDs</td>
</tr>
<tr>
<td>Data Output</td>
<td>Bluetooth Wireless Transmission</td>
</tr>
<tr>
<td>Temperature Measurements</td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td>°Fahrenheit (F)</td>
</tr>
<tr>
<td>Range</td>
<td>94-105°F</td>
</tr>
<tr>
<td>Accuracy</td>
<td>± .2°F</td>
</tr>
<tr>
<td>Response Time</td>
<td>30 seconds (oral)</td>
</tr>
<tr>
<td>Pulse Oximetry</td>
<td></td>
</tr>
<tr>
<td>Saturation Range</td>
<td>98%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>-- --</td>
</tr>
<tr>
<td>Non-invasive blood pressure (NIBP)</td>
<td></td>
</tr>
<tr>
<td>Cuff Pressure Range</td>
<td>0-160mmHg</td>
</tr>
<tr>
<td>Measurement Time</td>
<td>&lt;60 seconds</td>
</tr>
<tr>
<td>Heart Rate</td>
<td></td>
</tr>
<tr>
<td>Beats per Min Range</td>
<td>0-220 bpm</td>
</tr>
<tr>
<td>Accuracy</td>
<td>± 3 bpm</td>
</tr>
</tbody>
</table>
Respiratory Rate
Range 0-60 breathes per min.
Measurement Time 30 seconds

Weight
Scale Type Digital
Range 0-300 pounds

**Hardware and Software Parameters**

Microprocessor PIC16F877
Programming Language C

**Environmental**

Location Home (indoors)
Dust Recommend preventing large amounts of dust from settling on the device
Operating Temperature 40-105°F
Storage Temperature 40-110°F