Accessible Blood Glucose Monitor Interface

Team 2
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Owner’s Manual
Important Safety Information

Accurate glucose measurements from the gPod can be safely and reliably obtained when done properly. Please read the appropriate sections of the gPod Owner’s Manual thoroughly before performing any function with the meter.

The gPod glucose meter will only reliably work with One Touch Ultra Test Strips that are **Batch 15**. It is imperative that only these specific test strips be used with the meter for proper function and measurement. Other batches of OneTouch Ultra test strips can be used; however this requires some simple recalibration.

When performing a glucose test, the unit of measure for the results will **always** be in **mg/dL**. Please do not confuse this with any other unit of measure. A mistake in the unit of measure could lead to improper diagnosis.

Testing your own glucose requires exposing blood to the surface of your skin, please wash your hands with warm water and soap before performing a test. This will greatly reduce any chance of infection.

Do not reuse lancets. Once a lancet has been used, properly dispose it.

Do not leave test strip vials open. Humidity and other environmental factors can lead to inaccurate results.

Do not open or tamper with the meter. Any tampering with the contents of the meter can potentially damage the meter.

Only use **9 volt** batteries with the gPod meter. Also, do not attempt to recharge batteries while they are still in the meter.

Do not use any other AC adapter with the barcode scanner. Doing so may cause damage to the scanner, and possibly the meter as well.
Parts and Accessories

The following parts and accessories are included with the gPod Blood Glucose Monitoring System:

- Carrying Case
- gPod Meter
- Daily Log Book
- Owner’s Manual
- OneTouch Ultra Test Strips
- OneTouch Ultra Normal Control Solution
- OneTouch Ultra High Control Solution
- OneTouch UltraSoft Sampler
- OneTouch UltraClear Cap
- OneTouch UltraSoft Lancets
- Insulin Vials (optional)
- Barcode Scanner
- Barcode Scanner AC Adapter
- Extra 9V Batteries
Features

The gPod Blood Glucose Meter offers a variety of helpful features for the user. It is designed to accommodate individuals that have a wide range of disabilities.

Such features include:

- Easy user-interface
- Ergonomically sized
- Two button operation
- Compatible with commercially available test strips
- Accurate blood glucose measurements
- Highly visible glucose test strip port
- Clear, audible voice instructions and results
- Attachable barcode scanner for insulin vial identification
- Carrying case for easy portability of all your diabetes supplies
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About gPod

The gPod Glucose Monitoring system uses the latest in glucose measurement technology as well as innovative designs to enhance performance. The glucose concentration of a sample is measured by an electro-chemical test strip that produces a current based on the amount. It is this current that then can be measured by the meter for an accurate assessment of the sample. The gPod meter is designed for testing fresh capillary whole blood samples (for example, blood from your fingertip or forearm.) However, due to the type of test strip being used, the test results are “plasma calibrated”. This is different from some other meters which return whole blood results. If you have been using such a meter, you may notice that your gPod results are slightly higher.

The gPod also incorporates a talking feature. This allows for audible communication from the meter to the user. For persons with diabetes that also have trouble seeing, the meter can audibly speak the results to ensure that the user has a correct understanding of their glucose level. Other features on the gPod include attachable insulin vial scanner. This feature allows the user to scan an insulin vial and have the meter display and speak the type of insulin.

The meter is for outside the body (in vitro) use. It should not be used to diagnose diabetes.

The gPod Blood Glucose Monitoring System consists of the gPod Glucose Meter, OneTouch Ultra-Batch 15 Test Strips, and the OneTouch Ultra Control Solution. The gPod Meter has been designed specifically with these products to provide repeatable, accurate results. Do not use any other test strips or control solutions with this meter.

CAUTION: Before using or any product to test your blood, read all instructions thoroughly and practice the test. Do all quality control checks as directed and consult with a diabetes healthcare professional. These recommendations apply to all blood glucose monitoring systems and are supported by the American Association of Diabetes Educators, the American Diabetes Association, the U.S. Food and Drug Administration, the Advanced Medical Technology Association.
Health Related Information
- This information is taken from OneTouch Ultra Owner’s Booklet. Due to the specific test strips that can be used, the health information with them strictly applies.

**Dehydration:**
Severe dehydration resulting from excessive water loss may cause false low results. If you believe you are suffering from severe dehydration, consult a healthcare professional immediately.

**Low Glucose Results:**
If your test result is lower than 70mg/dL, it may mean hypoglycemia (low blood glucose). **This may require immediate treatment according to your healthcare professional’s recommendations.** Although this result could be due to a test error, it is safer to treat first, and then do another test.

**High Glucose Results:**
If your test result is greater than 180 mg/dL, it may mean hyperglycemia (high blood glucose). If you do not have symptoms, first repeat the test. Your healthcare professional can work with you to decide what actions, if any, you should take if you continue to get results higher than 180 mg/dL or if you have symptoms.

**Repeated Unexpected Results:**
If you continue to get unexpected results, check you system with control solution. See control solution testing on page 15.

If you are experiencing symptoms that are not consistent with your blood glucose results and you have followed all instructions in this manual, call your healthcare professional. Never ignore symptoms or make significant changes to your diabetes control program without speaking to your healthcare professional.

**Hematocrit:**
A hematocrit (percentage of your blood that is red blood cells) that is either very high (above 55%) or very low (below 30%) can cause false results.
gPod Glucose Management System

Carrying Case

OneTouch Test Strips (Batch 15)

OneTouch Control Solutions

Spare 9 Volt Batteries

gPod Glucose Meter

OnTouch Ultrasoft Sampler

Insulin Vials

OneTouch Ultrasoft Lancets

Barcode Scanner

Barcode Scanner AC Adapter

Figure 1, gPod Glucose Management System carrying case layout
gPod Glucose Meter

Figure 2, gPod Glucose Meter
OneTouch Ultra Test Strips

The gPod Glucose Measurement System measures the amount of glucose in whole blood. A whole blood sample is applied to the top edge of the OneTouch Ultra Test Strip. The blood will then be automatically drawn into the reaction cell of the test strip.

- **TOP EDGE**
  - Apply a drop of blood to the reaction cell here in the top of the test strip

- **CONFIRMATION WINDOW**
  - Check here to confirm if enough blood has been applied.

- **CONTACT BARS**
  - Insert this end of the test strip, contacts facing up, into the meter. Push it all the way in.

Figure 3, OneTouch Ultra Test Strip
**Important Test Strip Information**

This information is taken from OneTouch Ultra Owner’s Booklet.

- Store test strip vials in a cool, dry place below 86°F (30°C). Keep away from direct sunlight and heat. Do not refrigerate.

- Store test strips in their original vial only. To avoid damage or contamination, do not transfer test strips to any other place.

- Do not use test strips beyond the expiration date printed on the package since they may give inaccurate results.

- After removing a test strip from the vial, replace the vial cap immediately and close it tightly.

- Do not use test strips from any vial that has been damaged or left open to air.

- With clean, dry hands, you may touch the test strip anywhere on its surface.

- Use each test strip immediately after removing it from the vial.

- Count three months from the date you first open a new vial of test strips and write this discard date on the vial label. Throw test strips and vial away after this discard date.

- Apply only OneTouch Ultra Control Solution or a blood sample to the test strip.

- Do not bend, cut, or modify the test strips in any way.

- OneTouch Ultra Test Strips are for single use only. **Never reuse a test strip that has either blood or control solution applied to it.**

- Refer to additional information in the OneTouch Ultra Test Strip package.

**WARNING:** Do not swallow test strips. The test strip vial may contain drying agents that are harmful if inhaled or swallowed and may cause skin or eye irritation.
Important Control Solution Information

- Check the expiration date on the control solution vial. Record the discard date (three months after date opened) on the vial label. Do not use after expiration or discard date, whichever comes first.

- Control solution, meter, and test strips should be at room temperature (68-77°F) before testing with control solution.

- Shake the vial, discard the first drop of control solution, and wipe off the tip to ensure a good sample and an accurate result.

- Store control solution tightly closed at temperatures below 86°F (30°C). Do not refrigerate.

CAUTION: The control solution range printed on the test strip vial is for OneTouch Ultra Control Solution Only. It is not a recommended range for your blood glucose level.

When to do a control solution test:

- Once a week.

- When you open a new vial of test strips.

- Whenever you suspect that the meter or test strips are not working properly.

- If you have had repeated unexpected blood glucose results.

- After dropping the meter.
Using the Control Solution

The OneTouch Ultra Control Solution is used to check that the meter and the test strips are working properly together. Additionally, it can be used to verify that you are performing the test correctly.

OneTouch Ultra Control Solution contains a measured amount of glucose that reacts with OneTouch Ultra Test Strips. Compare your control solution test results with the range printed on the test strip vial label. It is very important that this simple check is performed routinely to make sure you get an accurate result.

Before you use the gPod meter to test your blood for the first time, practice the testing procedure using control solution. When you can do three tests in a row that are within the range, you are ready to test your blood.

Figure 4, OneTouch Ultra Control Solution

WARNING: Do not swallow the control solution.
Control Solution Test Procedure

Step 1:

While the meter is off, insert a test strip into the slot on the top of the meter as shown. Be sure that the test strip is inserted with the contact bars facing up and going in first. Push the test strip all the way in until it can go no further.

The gPod meter is calibrated to work with Batch 15, OneTouch Ultra Test Strips. Please verify that these are the strips being used.

Step 2:

With the test strip inserted, turn the meter on by pressing the switch located on the right side of the meter. Once turned on, the meter will display several opening screens along with synchronized speech.
Step 3:

Apply Control Solution

Once the meter displays ‘Ready’ on the screen and says “Ready”, you may apply the control solution.

To ensure an accurate result:
- Shake the vial well
- Discard the first drop
- Wipe the dispenser tip

Squeeze a drop of solution to the tip of the bottle. Hold this drop to the narrow channel in the top edge of the test strip. If the solution is applied correctly, the meter will count 2 seconds and display a result.
Step 4:

Once a measurement is displayed on the screen, and announced by the meter, compare this test result with the range that is printed on the test strip vial.

The result should fall within this range.

Note: All measurements with the gPod have mg/dL units.

If the control solution test results fall outside of the range printed on the test strip vial, repeat the test.

According to LifeScan resources, out-of-range results may be caused by one of more of the following:

- Error in performing the test
- Failure to shake the control solution vial well
- Expired or contaminated control solution
- The meter, test strips, or control solution are too warm or too cold
- Failure to discard the first drop of control solution and wipe the dispenser tip clean
- Test strip deterioration
- Meter malfunction

WARNING: If you continue to get control solution test results that fall outside of the range printed on the vial, the system may not be working properly. Do not use the meter.
Testing Your Glucose

- Read this whole section carefully before attempting the test. Verify that you have all of the following items that will be needed for the test.

- gPod Meter
- Test Strips
- Sterile Lancet

Preparing a Blood Sample:

![OneTouch UltraSoft Sampler Diagram](image)

Figure 5, OneTouch UltraSoft Sampler

**CAUTION:** To reduce the risk of infection:

- Never share a lancet or the OneTouch Ultrasoft Sampler with anyone.
- Always use a new, sterile lancet. Lancets are for **single use only**.
- Keep the gPod meter and UltraSoft Sampler clean.
- Make sure to wash puncture site with soap and water before testing.
This information is taken from OneTouch Ultra Owner’s Booklet.

Step 1:

**Insert a Lancet**

Turn the cap counterclockwise to remove it.

Insert the lancet into the lancet holder and push down firmly until it is fully seated. Do not twist the lancet. Twist the protective disk until it separates from the lancet. Replace the OneTouch UltraSoft Cap. Turn it clockwise until it is snug.

Adjust the puncture depth setting if necessary. Twist the depth adjustment knob toward the smaller bumps for a shallower puncture or toward the larger bumps for a deeper puncture.
Step 2:

Cock the Sampler

Slide the ejection/cocking control back until it clicks. If it does not click, the sampler may have been cocked when then lancet was inserted. The sampler is now ready for use.

Step 3:

Wash your hands and the Puncture Site

To reduce the chance of infection, use warm, soapy water. Rinse and dry thoroughly.
Fingertip Blood Sampling

The gPod Glucose Meter uses OneTouch Ultra test strips for its glucose measurement. This type of test strip requires a very small blood drop to perform a test. This drop of blood may be obtained from a **fingertip** or **forearm**. (See page 22 for information on obtaining a blood sample from the forearm.) Choose a different puncture site each time you test. Repeated punctures in the same spot may cause soreness and calluses.

This information is taken from OneTouch Ultra Owner’s Booklet.

**Step 1:**

**Position the Sampler**

Hold the OneTouch UltraSoft Sampler firmly against the side of your finger. Press the release button.

**Step 2:**

**Massage the Fingertip**

Massaging the fingertip gently will help you obtain a round drop of blood. **Do not** squeeze excessively on the puncture site. The blood sample must be at least one microliter (1.0 μL) in volume, or the test will not work properly. Do not smear the blood sample. Proceed with the blood glucose test.
Forearm Blood Sampling

The forearm has fewer nerve endings than the fingertip so you may find that obtaining a blood sample from the forearm may be much less painful than using the fingertip. The technique for forearm sampling is different from fingertip sampling. Also, there are differences between forearm samples and fingertip samples that you should understand. Please read the important information on page 24 carefully.

This information is taken from OneTouch Ultra Owner’s Booklet.

Step 1:

Install the UltraClear Cap

To aid in obtaining a blood sample from the forearm, replace the regular sampler cap with the UltraClear cap. If necessary, set the sampler for a deeper puncture.

Step 2:

Choose the Puncture Site

Select a soft, fleshy area on your forearm that is clean and dry, away from bone, and free of visible veins and hair.
Step 3:

Massage the Area

To increase blood flow to the puncture site, massage the area gently. For individuals who experience difficulty in getting sufficient blood for a test, rubbing the area more vigorously or applying heat briefly may be helpful.

Step 4:

Position the Sampler

Press and hold the sampler against the forearm for a few seconds. Press the release button.

Step 5:

Allow Blood Drop to Form

Continue holding the sampler against the skin for a few seconds until a blood drop forms. Allow enough blood to form under the cap until you have a blood sample that is sufficient to fill the confirmation window of the test strip. If you must massage the area to obtain more blood, do not squeeze the site excessively.
If bruising occurs, or you are having difficulty obtaining blood from the forearm, you may choose to lance a fingertip instead.

**Important Information about Forearm Testing:**
This information is taken from OneTouch Ultra Owner’s Booklet.

- Under certain conditions, blood glucose test results obtained using samples taken from your forearm may differ significantly from fingertip samples.

- The conditions in which these differences are more likely to occur are when your blood glucose is changing rapidly such as following a meal, an insulin dose, or physical exercise.

- When blood glucose is changing rapidly, fingertip samples show these changes more quickly than forearm samples.

- When your blood glucose is falling, testing with a fingertip sample may identify a hypoglycemic (low blood sugar) level sooner than a test with a forearm sample.

- Use forearm samples only for testing prior to or more than two hours after meals, insulin doses, or physical exercise.

- Testing performed within two hours after meals, insulin doses, physical exercise, or whenever you feel that your glucose levels may be changing rapidly, should be done with a fingertip sample.

- You should also use fingertip testing whenever you have a concern about hypoglycemia (insulin reactions) such as when driving a car, particularly if you suffer from hypoglycemic unawareness (lack of symptoms to indicate an insulin reaction), as forearm testing may fail to detect hypoglycemia.

**What you should do:**

- Use forearm or fingertip samples for testing prior to, or more than two hours after meals, insulin doses, or physical exercise.

- Routine testing before meals can be done either at the fingertip or the forearm.

- Consult your healthcare professional before you begin using the forearm for testing.
Self Testing Procedure

Step 1:

While the meter is off, insert a test strip into the slot on the top of the meter as shown. Be sure that the test strip is inserted with the contact bars facing up and going in first. Push the test strip all the way in until it can go no further.

The gPod meter is calibrated to Work with Batch 15, OneTouch Ultra Test Strips. Please verify that these are the strips being used.

Caution: Using Batch 15 Test Strips is essential to obtaining accurate results. Each time you test, check to make sure the batch number on the test strip vial is 15. Also, the gPod meter measures exclusively in mg/dL. No other units of glucose measurement exist with this meter. Use of the wrong unit of measure may cause you to misinterpret your blood glucose level, and may lead to incorrect treatment.
Step 2:

With the test strip inserted, turn the meter on by pressing the switch located on the right side of the meter. Once turned on, the meter will display several opening screens along with synchronized speech.

Step 3:

Apply Sample

Obtain a round drop of blood using the OneTouch Ultrasoft Adjustable Blood Sampler. The blood sample must be at least 1.0 μL in volume to fill the confirmation window.
When a large enough drop of blood has formed on your fingertip or forearm, touch and hold the drop of blood to the narrow channel in the top edge of the test strip.

- **Do not** apply sample to front or back of the test strip.

- **Do not** push your finger against the test strip.

- **Do not** apply a smeared sample.

Hold the blood drop to the top edge of the test strip until the confirmation window is full. Upon a successful application of blood, the meter will count 2 seconds and compute your glucose level.

If the confirmation window does not fill completely before the meter begins to count down, **do not** add more blood to the strip. Discard the strip and repeat the test again.
Step 4:

Accurate Results

Your blood glucose level will appear on the screen about 2 seconds after a successful blood application. This glucose result will also be spoken through a speaker located on the back of the meter. This allows for a verbal verification of the result.

The gPod meter does not store the test results in memory, so you may want to record them in the log book provided with the system.

Once the test is complete, the test strip can be removed from the meter, and the meter can be turned off.

To repeat the test, be sure that the previous test strip has been removed, and the meter has been turned off. Then, you can repeat the procedure as instructed.
**Disposal of Test Strips and Lancet**

It is important to discard the used test strip and lancet to avoid reuse or other possible errors. Due to blood contact, these used items may be considered biohazardous waste. Please follow any local regulations for proper disposal.

This information is taken from OneTouch Ultra Owner’s Booklet

**Removal of Lancet from Sampler**

**Step 1:**

Remove the OneTouch UltraSoft Cap from the Sampler

Twist the OneTouch UltraSoft Cap counterclockwise.

**Step 2:**

Eject the Lancet

Point the Sampler down and away. Push the release button to ensure that the Sampler is not cocked. Push forward on the ejection/cocking control and eject the lancet directly into a container for sharp objects. Return the ejection/cocking control to the middle position. Replace the OneTouch UltraSoft Cap.
Barcode Scanner

Another advanced feature of the gPod Glucose Meter is an attachable barcode scanner. This scanner attaches to the bottom of the meter via a RS232 serial port. Whenever an insulin dose is needed, this scanner can be attached to the meter, and the insulin vial can be scanned and verified. All insulin vials have a specific National Drug Code (NDC) that has been administered by the FDA. This NDC number provides specific information about the type, manufacturer, and concentration of the insulin it is labeled on. The gPod barcode scanner allows the user to scan a vial of insulin and have the meter display and speak the brand and type of insulin. Any person who uses multiple types of insulin should use this feature to always verify the correct insulin is being used.

Scanning Procedure

Step 1:

Plug In the Scanner

To attach the barcode scanner to the meter, connect the scanner cable to the serial plug located at the base of the meter. Be sure that the scanner plug is pushed in until it will go no further.

Step 2:

Scan Mode

When the meter display says “gPod Ready”, press the black button located on the left side of the meter. This will switch the meter into the scanning mode. Once this button has been pressed, the meter will display and speak the phrase “Scan Vial”.
Step 3:

Scan the Vial

Hold the vial in one hand, and the scanner in the other. Orientate the two objects so that the scanner will scan the length of the barcode, with the beam of the scanner traveling across each bar.

Press the trigger button on the scanner to scan the barcode. The scanner will emit a beep upon a successful scan.

Step 4:

Insulin Verification

When the vial has been scanned, the meter will display the type and concentration of that insulin. This information will also be spoken by the meter.
Summary of Voice Prompts

“University of Connecticut Biomedical Engineering.”
  - Requires no operation.

“gPod ready for test.”
  - Informs user that the meter is ready for testing operation

“Testing.”
  - Informs the user that the meter is performing a glucose test.

“Blood glucose level is …”
  - Informs the user of their results.

“Scan Vial.”
  - Instructs the user to scan a vial of insulin.

“Humulin ‘x’, 100 units per millileter.”
  - Informs the user that they have scanned a Humulin brand insulin.

“Novolin ‘x’, 100 units per millileter.”
  - Informs the user that they have scanned a Novolin brand insulin.
Maintenance

Battery Replacement

1. Turn the meter off.

2. Open the battery compartment on the back of the case.
3. Pull on the ribbons located within the battery case to easily lift the batteries out.

4. Remove the batteries from their respective 9V leads.

5. Connect new batteries in correct orientation to the 9V leads. Place the attached ribbons underneath the batteries and insert them back into the case. Slide the battery cover back on.
**Static**

Do not expose the meter to static electricity. The electrical components within the meter are very sensitive and could possibly be damaged in the event of a shock.

**Cleaning**

a. Cleaning of Screen
   i. Turn the meter off
   ii. Using a piece of soft cloth, gently wipe the screen panel

b. Cleaning of Case
   i. Turn the meter off
   ii. Using a damp soft cloth and surface cleaner, gently wipe the dirty area of the gPod case
   iii. Dry the previously cleaned area with a piece of dry cloth

c. Keep electrical leads clean

d. Keep the meter free of dust. This can be done by keeping the gPod in a relatively dust free environment and by frequently cleaning the case.

**Serial Connection**

a. Do not bend the pins on the male serial connector. Bending the pins will result in the connector no longer fitting with the female connector.

b. Do not place foreign objects into the female serial connector. Placing foreign objects into the female serial connector may cause damage to the connector.
Environmental

a. Water
   Do not expose the gPod, or any of its accessories to water. This device is not water proof. If exposed to water the gPod may become damaged and should not be turned on for safety reasons.

b. Temperature
   i. The gPod should not be exposed to extreme heat
      1. This may result in damage to the gPod
   ii. The gPod should not be exposed to extreme cold
        1. This may result in damage to the gPod
   iii. Do not artificially heat up or cool down the gPod
     1. This may result in damage to the gPod
   iv. Avoid rooms such as kitchen, bathrooms, and laundry areas.

c. Humidity
   i. Should not be exposed to high humidity
      1. This may result in damage to the gPod

Packing

The gPod Glucose Measurement System comes equipped with a carrying case. After use, repack travel case as suggested on page 9 of manual. Please keep the travel case clean and organized. This will help you keep good management of your supplies.

General Care

a. Handle meter with care
   - If meter is dropped, perform a quality test. Refer to page 15.

b. Check to make sure you have enough testing supplies periodically
   - Check the expiration dates of your testing supplies weekly
Technical Description

The gPod Blood Glucose meter is a portable, battery powered unit. The meter is controlled by a PIC16F874 microprocessor. The power for the components is delivered from two 9 volt batteries connected to two voltage regulators, one for +5 volts, and the other for -5 volts. The glucose measurement and filtering circuit includes two LM358 op amps, a TL072CP op amp, and a 7486 XOR gate. The speech capabilities of the gPod are handled through a Sipex 232 chip and the SP03 text-to-speech module. The instructions and measurements are displayed on a 16x2 character LCD.

Microprocessor

The microprocessor is connected to each component of the meter. The processor is responsible for the analog-to-digital conversion, LCD control, speech control, user interface, and communication with a serial device. The microprocessor uses a 5 MHz clock. Figure 6 is a schematic of the connections to the microprocessor.

Figure 6, Connection Diagram of PIC Microprocessor.
Analog-to-digital converters

The connections to the glucose circuit are made through Pin 2 and Pin 4. The input to the analog-to-digital is Pin 2 and the input from the glucose trigger is Pin 4. The microprocessor is capable of 10-bit analog-to-digital conversion. Analog-to-digital conversion is the process of converting an analog voltage into a discrete digital count. The resolution is controlled by the number of bits of the converter. Equation 1 shows the function to calculate the resolution.

\[
\text{Resolution} = 2^{\text{bits}} \quad \text{Equation 1}
\]

\[
\text{bits} = 10
\]

\[
\text{Resolution} = 2^{10}
\]

\[
\text{Resolution} = 1024
\]

The digital counts are related to the input voltage through the use of a reference voltage. The reference voltage \((V_{\text{ref}})\) used in the meter is equal to \(V_{\text{DD}}\) (5 V). Equation 2 shows the function to convert a digital count to the actual voltage.

\[
\text{Voltage} = \frac{\text{Count} \times V_{\text{ref}}}{\text{resolution}} \quad \text{Equation 2}
\]

\[
\text{Voltage} = \frac{\text{Count} \times 5}{1024}
\]

The analog-to-digital converter is configured with two control registers, ADCON0 and ADCON1. ADCON0 is used to configure the conversion clock, the input channel, and to power on the module. The analog-to-digital converter is set up to use an \(F_{\text{osc}}/8\) conversion clock, read channel 0, and turn the module on. The \(F_{\text{osc}}/8\) conversion clock is selected according to the maximum device frequency. The maximum device frequency is 5 MHz. Table 1 shows the A/D acquisition time vs. the maximum device frequency.

<table>
<thead>
<tr>
<th>AD Clock Source (T(_{\text{AD}}))</th>
<th>Maximum Device Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (T_{\text{OSC}})</td>
<td>1.25 MHz</td>
</tr>
<tr>
<td>4 (T_{\text{OSC}})</td>
<td>2.5 MHz</td>
</tr>
<tr>
<td>8 (T_{\text{OSC}})</td>
<td>5 MHz</td>
</tr>
<tr>
<td>16 (T_{\text{OSC}})</td>
<td>10 MHz</td>
</tr>
<tr>
<td>32 (T_{\text{OSC}})</td>
<td>20 MHz</td>
</tr>
<tr>
<td>64 (T_{\text{OSC}})</td>
<td>20 MHz</td>
</tr>
<tr>
<td>(R_{\text{C}(2,3)})</td>
<td>20 MHz</td>
</tr>
<tr>
<td>(x11)</td>
<td>(Note 1)</td>
</tr>
</tbody>
</table>

Table 1, \(T_{\text{AD}}\) vs. Maximum Device Frequency.
**Glucose Trigger**

The glucose trigger is used to start the analog-to-digital conversion. The trigger is made using a LM358 op amp as a comparator. The outputs of the comparator are input to an XOR gate. A schematic representation of the trigger is shown in Figure 7.

![Glucose Trigger Schematic](image)

Figure 7, Glucose Trigger Schematic.

Comparator 1 is set up with a reference voltage of 0.05 V. Comparator 2 is set up with a reference voltage of 0.10 V. These voltages were picked because they are very near the start of the glucose signal. When the glucose voltage level reaches 0.05 V the output of Comparator 1 goes HIGH. Once the glucose voltage level goes above 0.10 V the output of Comparator 2 goes HIGH. The outputs of the comparators are input into the XOR gate. When one of the comparators is HIGH, the output of the XOR gate is HIGH. If both of the outputs of the comparators are either HIGH or LOW the output of the XOR gate is LOW. Table 2 shows a truth table for the glucose trigger.

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>Comparator 1 Out</th>
<th>Comparator 2 Out</th>
<th>XOR Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
<tr>
<td>0.05</td>
<td>HIGH</td>
<td>LOW</td>
<td>LOW</td>
</tr>
<tr>
<td>0.07</td>
<td>HIGH</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>0.10</td>
<td>HIGH</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>0.15</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>

Table 2, Glucose Trigger Truth Table.

The microprocessor detects the falling edge of the trigger pulse. This signal is then used in the programming of the microprocessor to start the delay and acquisition sequence in the code. Two seconds after the trigger pulse occurs, the analog-to-digital converter takes a single measurement. Figure 8 shows the voltage curve (orange) and the trigger pulse (blue).
The connection diagram for the glucose trigger circuit is shown in Figure 9. The only difference between the theoretical schematic in Figure 7 and the actual circuit is the 1k pull-up resistors on the inputs and outputs of the 7486 XOR gate. The pull-up resistors ensure that the input and output voltages do not drop below 5 volts. Without the pull-up resistors the input and output voltages were only reaching approximately 4 volts and could be lower than the digital threshold required for a HIGH input on the microprocessor.

Figure 9, Glucose trigger connection diagram.
Glucose Filter

The glucose voltage curve shown above in Figure 8 is filtered with a low pass filter. The filter uses a TL072 dual op amp and is configured as a 100 Hz Sallen-Key Low Pass Butterworth filter. Figure 10 shows the filter schematic created using Filter Pro.

![Figure 10, 100 Hz Low Pass Butterworth Filter.](image)

The glucose measurement originates as a small current generated by the chemical reaction occurring in the test strip. The test strip contains glucose oxidase, a chemical that binds to D-glucose to start a redox reaction. The redox reaction breaks down the glucose and releases electrons. The flow of electrons is known as current and is collected by electrodes built-in to the test strip. The current is converted to voltage through the use of a current-to-voltage converter.

A current-to-voltage converter is simply an op amp with a feedback resistor. The op amp is used as a high impedance source that forces all of the current to flow through the resistor. Figure 11 shows the theoretical schematic for a current-to-voltage converter.

![Figure 11, Current-to-Voltage Converter Schematic.](image)

Show in **Equation 3** is Ohm’s Law which is used to calculate the value of the resistor. Experimental data shows that an average current produced by the glucose test strip is 20μA.

\[ V = I \times R \]  \hspace{1cm} \textbf{Equation 3}
Because an average value is being used, $V$ is chosen to be 2 volts so that it is about half the maximum voltage that can be used by the analog-to-digital converter.

\[ 2 = 20 \times 10^{-6} \times R \]
\[ R = 100,000 \text{ Ohms} \]

_Glucose Detection Circuit_

The circuits described above are all connected to produce the glucose detection circuit. The glucose detection circuit includes the current-to-voltage converter and the 100 Hz low pass Butterworth filter. Figure 12 shows the glucose detection circuit connection diagram.

![Glucose Circuit Connection Diagram](image)

Figure 12, Glucose detection circuit connection diagram.
**Glucose Test Strip**

The glucose test strip is connected to the circuit at the component labeled S1. A potential of -400 mV is applied between the first and third pins. This voltage difference is required to initiate the redox reaction on the test strip. The current produced from the test strip comes from pin 3 of S1 and connects to the inverting input of the LM358. The current is converted to a voltage in the LM358 and output at pin 1 where it goes to the filter.

The test strip is shown in Figure 13.

![Test strip illustration](image)

**Figure 13, Test strip illustration.**

**Glucose Voltage Measurement**

The glucose measurement is taken from a single acquisition from the analog-to-digital converter. When a sample is applied to the test strip the voltage jumps to a peak value and then begins to decay linearly between 1 and 5 seconds. The voltage reading is taken 2 seconds after the sample is applied. Figure 14 shows a typical voltage curve for glucose.

![Glucose voltage curve](image)

**Figure 14, Glucose voltage curve.**
The voltage level is then converted to a glucose concentration. This equation was determined experimentally. To determine the glucose-voltage characteristic measurements were taken at 2 seconds over a range of glucose concentrations (20-400 mg/dL). The glucose concentration was plotted as a function of voltage and is shown in Figure 15. A linear trend line was applied to the curve to determine the slope and intercept of the line. This trend line is the glucose-voltage equation shown in Equation 4.

\[ \text{concentration} = (\text{voltage}) \times 922.23 - 22.9 \]  \hspace{1cm} \text{Equation 4}
**LCD Screen**

The glucose measurements are displayed on a 16 x 2 character LCD screen. The LCD connects to the microprocessor using 14 pins. There are eight parallel pins used for data transfer, one pin for the enable clock, one for the instruction/register select, and one for the read/write control. The LCD is controlled by a Hitachi 44780 LCD driver. Figure 16 shows the connection diagram for the LCD screen.

![LCD Connection Diagram](image)

The text and instruction data are sent across pins 7-14 on the LCD screen. The instruction/register select commands are sent across pin 4. Pin 5 is used to receive the read/write commands from the microprocessor. Pin 6 is the enable clock and is used to latch in the data on pins 7-14. Pin 3 is used to set the contrast on the LCD. Pin 2 and Pin 1 are 5 volts and ground respectively.

The instruction/register select command is used to tell the LCD if data or a control instruction is being written. The instructions available to the LCD are shown in Table 3.

<table>
<thead>
<tr>
<th>R/S</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Clear Display</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Cursor Home</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>Enable Display / Cursor</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>DL</td>
<td>N</td>
<td>F</td>
<td>-</td>
<td>-</td>
<td>Interface Length</td>
</tr>
<tr>
<td>1</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>Write a Character</td>
</tr>
</tbody>
</table>

Table 3, LCD instructions.
Table 4 defines the modes that can be set using the structure set up in Table 3. The bold instructions are the settings used for the LCD.

<table>
<thead>
<tr>
<th>Enable Display/Cursor</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td><strong>Display On</strong></td>
<td>Display Off</td>
</tr>
<tr>
<td>C</td>
<td>Cursor On</td>
<td><strong>Cursor Off</strong></td>
</tr>
<tr>
<td>B</td>
<td>Cursor Blink On</td>
<td><strong>Cursor Blink Off</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interface Length</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td><strong>8 data lines</strong></td>
<td>4 data lines</td>
</tr>
<tr>
<td>N</td>
<td><strong>2 display lines</strong></td>
<td>1 display line</td>
</tr>
<tr>
<td>F</td>
<td>5x10 font</td>
<td><strong>5x7 font</strong></td>
</tr>
</tbody>
</table>

Table 4, LCD instruction definitions.

Text is written to the LCD screen by setting the R/S bit to 1 and writing the ASCII text to the eight pin data bus. The LCD screen will read in the data on the data bus when the enable clock is set high and then low. The text information is read on the falling edge of the data clock.

When the LCD is initialized properly the screen should be blank. If the first row of characters is filled with dark boxes turn the power off and back on. The instructions for the meter should be displayed correctly after doing this.

**Speech Module**

The measurements and instructions of the gPod glucose meter are not only displayed on a LCD screen but are spoken as well. The speech module is used to output the measurements and instructions in a voice output for users who are blind or have diminished eyesight. The module is capable of taking an ASCII string of text and converting it to sentences or words. A photo of the module is shown in Figure 17.

![Figure 17, SP03 text-to-speech module.](image)
The speech module is connected to the microprocessor’s UART (Universal Asynchronous Receiver Transmitter). The speech module communicates with the microprocessor through RS232 protocols. The connection diagram for the speech module is shown in Figure 18.

![Speech module connection diagram](image)

Figure 18, Speech module connection diagram.

The Max232 chip shown in the diagram is used to convert the 3 volt logic produced by the speech module to the 10 volt logic required by RS232 communication. The Max232 chip is then connected to the microprocessor where the speech routines are implemented. The command sequence for the speech module is shown in Table 5.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x80</td>
<td>Start command</td>
</tr>
<tr>
<td>0x00</td>
<td>Speech Volume (Full)</td>
</tr>
<tr>
<td>0x05</td>
<td>Speech Pitch (Level 5)</td>
</tr>
<tr>
<td>0x00</td>
<td>Speech Speed (Level 0)</td>
</tr>
<tr>
<td>ASCII text</td>
<td>Text phrase sent as a string of characters</td>
</tr>
<tr>
<td>0x1A</td>
<td>Stop command</td>
</tr>
<tr>
<td>0x00</td>
<td>Speak phrase</td>
</tr>
</tbody>
</table>

Table 5, Speech module command sequence.

The speech module will start filling its input text buffer when it receives the 0x80 command. The next three commands sent tell the speech module what volume, pitch, and speed to speak the text. Following the volume, pitch, and speed commands the phrase is read by the speech module. Each character of the phrase must be read individually. The 0x1A command tells the speech module the phrase is finished and to wait for the 0x00 command to speak the phrase. Table 6 shows an example of the speech module speaking the phrase “Hello World.”
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x80</td>
<td>Start command</td>
</tr>
<tr>
<td>0x00</td>
<td>Speech Volume (Full)</td>
</tr>
<tr>
<td>0x05</td>
<td>Speech Pitch (Level 5)</td>
</tr>
<tr>
<td>0x00</td>
<td>Speech Speed (Level 0)</td>
</tr>
<tr>
<td>0x48</td>
<td>H</td>
</tr>
<tr>
<td>0x65</td>
<td>e</td>
</tr>
<tr>
<td>0x6C</td>
<td>l</td>
</tr>
<tr>
<td>0x6C</td>
<td>l</td>
</tr>
<tr>
<td>0x6F</td>
<td>o</td>
</tr>
<tr>
<td>0x20</td>
<td></td>
</tr>
<tr>
<td>0x57</td>
<td>W</td>
</tr>
<tr>
<td>0x6F</td>
<td>o</td>
</tr>
<tr>
<td>0x72</td>
<td>r</td>
</tr>
<tr>
<td>0x6C</td>
<td>l</td>
</tr>
<tr>
<td>0x64</td>
<td>d</td>
</tr>
<tr>
<td>0x1A</td>
<td>Stop command</td>
</tr>
<tr>
<td>0x00</td>
<td>Speak phrase</td>
</tr>
</tbody>
</table>

Table 6, Speech module “Hello World” example.

Each command in the sequence is separated by a 1 ms delay to ensure that the speech module receives the data correctly. The speech module may not function correctly if the batteries are running low. If the speech is choppy, broken up or inaudible replace the batteries.

**Barcode Scanner**

The barcode scanner is connected through a DB9 connector located at the bottom of the meter. The barcode scanner is used to scan the National Drug Code printed on bottles of insulin. A patient who uses insulin and is unable to read the label can scan the barcode and the meter will output the type of insulin.

The barcode scanner communicates using RS232 protocol. Programming the settings for the barcode scanner requires the user to simply scan the corresponding code. The scanner must be configured for RS232 communication, 38400 baud, 8 bits no parity, 1 stop bit, no handshaking. The barcodes to set these parameters are shown below in Figure 19.
Scan the following codes to configure the barcode scanner to work with the gPod Blood Glucose Meter.

**Set scanner to RS232 communication.**

- \texttt{CO02}$

  RS232

**Set scanner for 38400 baud rate.**

- \texttt{EO22}$

  38400

**Set scanner for 8 Bits, No Parity.**

- \texttt{EO08}$

  8 Bits None

**Set scanner for 1 Stop Bit**

- \texttt{EO16}$

  1 STOP BITS

**Set scanner for No Handshaking.**

- \texttt{EO18}$

  NONE

Figure 19, Required barcode scanner settings.
The meter should be powered off when connecting the barcode scanner. The power cable must be connected in order for the barcode scanner to work. Once connected to the meter the user can power on the meter and wait for the command to insert a test strip or scan vial. When ready the user should press the black button located to the left side of the meter. If the button is pressed, the meter will wait until a barcode is scanned. If more barcodes are desired to be scanned press the button again. Turn off the meter when finished. Scanning barcodes must be done as a separate activity from glucose testing. The user will be unable to scan a barcode if a glucose test has already been run on the meter.

The insulin vial should be held flush to the surface of the barcode scanner. Rotate the vial until an audible beep is heard from the scanner and the meter speaks the insulin type. Figure 20 illustrates the function of the barcode scanner.

![Barcode scanner and insulin vial](image)

**Figure 20, Barcode scanner and insulin vial.**

**Batteries**

The positive power is supplied from a 9 volt battery and a 7805 positive voltage regulator. The 7805 produces +5 volts when the input voltage is above 7.5 volts. The power required to supply the speech module may cause battery life to be significantly shortened. The negative power for the glucose circuit is supplied for a 9 volt battery and a 7905 negative voltage regulator.

The batteries are expected to last 4 hours if the meter is run continuously.
**Electrical Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Battery Voltage</td>
<td>7.5</td>
<td>Volts</td>
</tr>
<tr>
<td>Microprocessor Operating Voltage</td>
<td>5.0</td>
<td>Volts</td>
</tr>
<tr>
<td>LCD Operating Voltage</td>
<td>5.0</td>
<td>Volts</td>
</tr>
<tr>
<td>Speech Module Minimum Operating Voltage</td>
<td>5.0</td>
<td>Volts</td>
</tr>
<tr>
<td>Barcode Scanner Operating Voltage</td>
<td>120</td>
<td>Volts AC</td>
</tr>
<tr>
<td>Speech Module Operating Current</td>
<td>100</td>
<td>mA</td>
</tr>
<tr>
<td>Meter Operating Current</td>
<td>140</td>
<td>mA</td>
</tr>
<tr>
<td>Peak Operating Current</td>
<td>220</td>
<td>mA</td>
</tr>
</tbody>
</table>

Table 7, Electrical Specifications
# Troubleshooting/Technical Support

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Cause</th>
<th>How To Fix It</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter does not turn on.</td>
<td>Dead batteries.</td>
<td>Turn the meter off. Replace both batteries. Turn meter back on. If meter still will not turn on, it may be damaged.</td>
</tr>
<tr>
<td>Screen does not initialize when you turn the meter on.</td>
<td>Software issue.</td>
<td>Turn the meter off, then turn it back on.</td>
</tr>
<tr>
<td>Meter did not count down and display a result after a blood sample was applied.</td>
<td>There was not enough blood applied to the test strip.</td>
<td>Remove the used test strip from the meter and dispose of it. Retest.</td>
</tr>
<tr>
<td>Meter has no audio output.</td>
<td>Low battery power.</td>
<td>Turn meter off. Switch the batteries from one lead to another. Retry.</td>
</tr>
<tr>
<td>The meter is displaying “Scan Vial” but you want to perform a glucose test.</td>
<td>The scan button on the side of the meter may have accidentally been pressed.</td>
<td>Turn the meter off. Follow the procedure on pages 30 to properly perform a test.</td>
</tr>
<tr>
<td>Meter does not say “Scan Vial” after the button has been pressed.</td>
<td>Software issue.</td>
<td>Turn the meter off, then turn it back on. Retry the scanning procedure.</td>
</tr>
<tr>
<td>Scanner will not scan.</td>
<td>Scanner is not plugged in correctly.</td>
<td>Unplug scanner from the meter, and plug it back in. Follow the scanning procedure on page 30 to ensure proper handling.</td>
</tr>
<tr>
<td>Scanner will not turn on.</td>
<td>Scanner is not powered.</td>
<td>Verify that the scanner has been plugged into a power outlet. If so, verify that the power cable has been properly connected to the scanner.</td>
</tr>
<tr>
<td>Meter did not return to ready status after a vial was scanned.</td>
<td>Software issue.</td>
<td>Turn the meter off, then turn it back on.</td>
</tr>
</tbody>
</table>

Table 8, Troubleshooting.