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Final Design Review

W.I.L.P.S Wireless Interfacing Linear Positioning Syringe

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Table of Contents

Section

1.0	Table of Contents
2.0	System Specifications
3.0	System Design
	Block Diagram, Figure 3.1
	Flow Diagram, Figure 3.2
4.0	Product Technologies
5.0	Subsystem Tests
6.0	Final Acceptance Test
7.0	Gantt Chart
8.0	Schedule of Deliverables
9.0	Cost Analysis
10.0	Unresolved and Resolved Issues
11.0	System Manual

2.0 System Specifications

As requested by Customer, the system in review here is one that makes use of wireless transmission methods to measure, calculate and display values of fluids dispensed from drug-specific syringes.

Given an instruction to deliver a prescribed dose, the system shall transmit the prescription dosage wirelessly to the test station. When the prescribed dosage is displayed at the test station, an operator shall manually deliver that dose. Dosage data shall be transmitted (via RF) to the computer and the delivered dose shall be displayed at the test station. An image of the syringe shall be displayed before and after each dosage.

2.1 Requirements:

- Test Station consisting of a CCD camera, a horizontal line selector/ sampler module, camera-mounting tower, a base-plate, syringe and RF transmitter-receiver pair.
- Interface Station (DAS16 interface panel and horizontal line selector)
- Computer Display (image will be scaled as required, and shall include the image, time of delivery before and after dosage, patient number, prescribed dosage, delivered dosage, syringe ID and computed dosage.
- Operation will be as follows:
 1. Manual computer entry of patient number, prescribed dosage and syringe ID.
 2. Next keystroke shall cause prescription and syringe ID to be sent to the test station
 3. Prescribed dosage shall be manually administered
 4. Delivered dosage will be determined by the chosen sensing technology, and appear on the test station display. Total time for this operation does not exceed 90 seconds, and accuracy provided will be ± 0.1 ml, with a range of 0.00 to 10.00 ml
- Interfacing and Power Supply: The interface system should be able to be connected to the computer via serial, parallel or mouse ports. The DAS16 panel will provide A/D, D/A conversion and digital inputs/ outputs. All communication with the computer shall be wireless at 1.7 m, with the exception of video composite signals. Wireless transmission shall be encoded and decoded at the

proper terminals as to avoid problems with interference. In any case, audio signaling shall confirm the receipt of 'bad data' versus 'good data', or vice versa. Apart from the camera, every device shall be battery-powered.

- System cost shall be not more than \$50.00

3.0 System Design

3.1 System Operation and Theory

This proposed system requires primary user *input* (e.g. a doctor entering a prescription) at the base-station and secondary user *action* (e.g. a nurse administering the requested amount) at the test-station.

Data input by the primary user is not encoded for output, and is sent through the DAS16 at the interfacing station to an infrared (IR) transmitter (an infrared LED). The test station is situated 2.0 meters away, and this step requires line-of-sight operation between the IR transmitter and receiver. Any errors in transmission will result in the LED display at the test station not displaying anything. This also serves as a sign for the user to resend data.

Once syringe and prescription data is displayed properly at the test station, the secondary user will dispense the requested amount with the modified dispenser. The modified dispenser acts as an adaptor for different syringes; the sensing mechanism (linear potentiometer) is present on the adaptor, thus allows for different syringes to be used. In this prototype, capacity for two syringes containing two different types of drug is provided. (See fig. 4-1)

The linear potentiometer, dividing between 0.0 and 5.0 volts, measures the change in voltage with the linear displacement of the syringe plunger. The output voltage of the potentiometer is sent to a serial-in/ parallel out A/D converter, responsible for digitizing the result with 8 bits of resolution. These bits are then 'padded' with 8 more bits consisting of syringe ID and encoding bits, then transmitted via an RF link at 300 MHz. Once these bits arrive at the RF receiver they are shifted into the computer through the DAS16 interfacing panel, and the clock for the whole RF transmission is actually generated by the computer.

A CCD camera is mounted on the test station, and image capture through it begins once the syringe is replaced. The signal to start image capture is the same that initiates A/D conversion and RF transmission. The image data, however, is transferred back to the interfacing station through wires connected between the camera and the line selector unit that serves the purpose of separating the individual video lines for capture

and storage. Once the video signal has been separated it is stored in memory one line at a time and sent through the DAS16 where it is collected by the computer and displayed on the screen. The computer will ultimately run the entire product. The operations associated with the computer are outlined in the Flow Diagram in Figure 3.2. The syringe apparatus itself will not be wireless; the cord is over six feet long and allows for flexibility.

Results and data produced by the computer shall be output to the test station display by means of two infra-red (IR) channels. These will allow 3 seven-segment LEDs to display either dosage prescribed or dosage delivered, and the test station will also display whether the data displayed concerns syringe A or syringe B using two different LEDs.

3.2 Hardware System

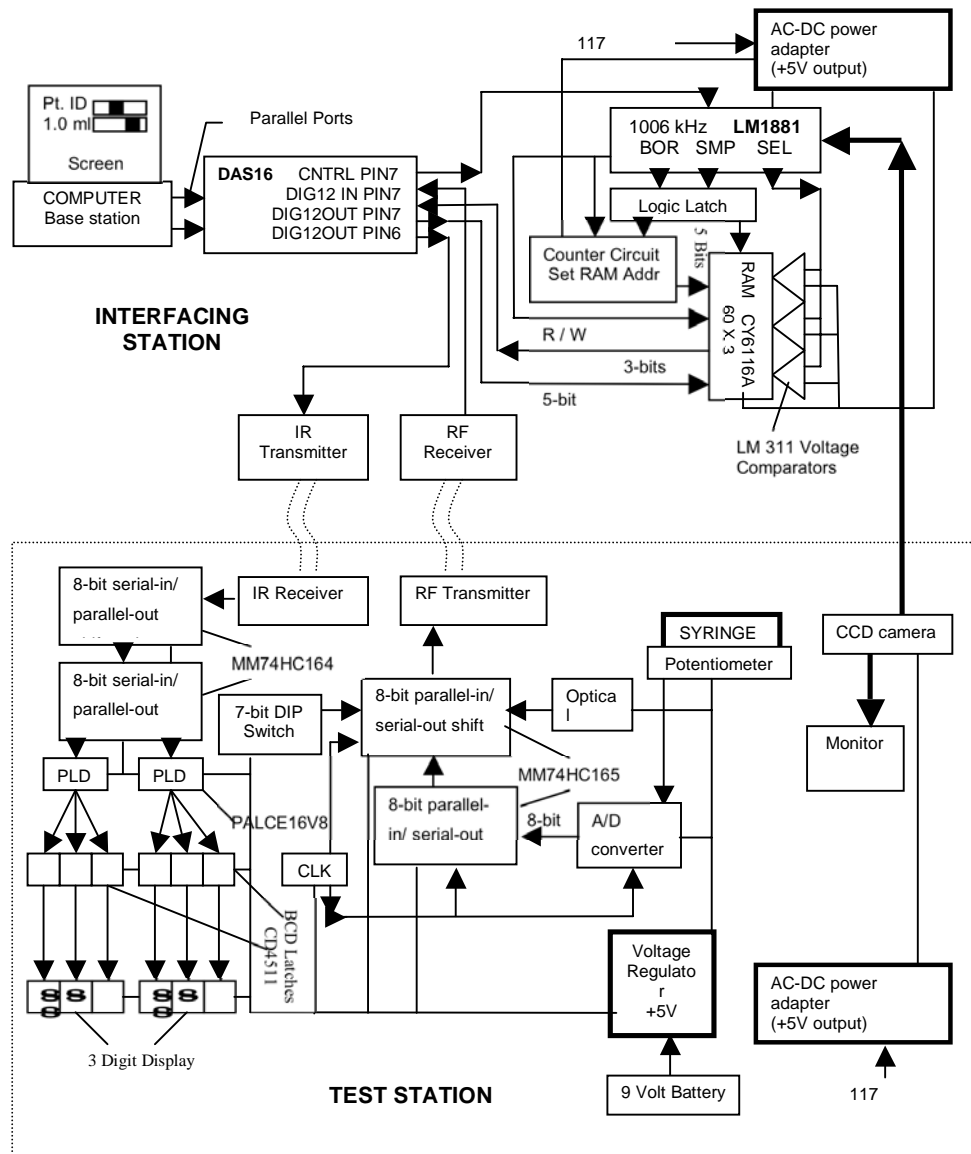


Fig. 3.1 Hardware System Block Diagram

3.3 Software System

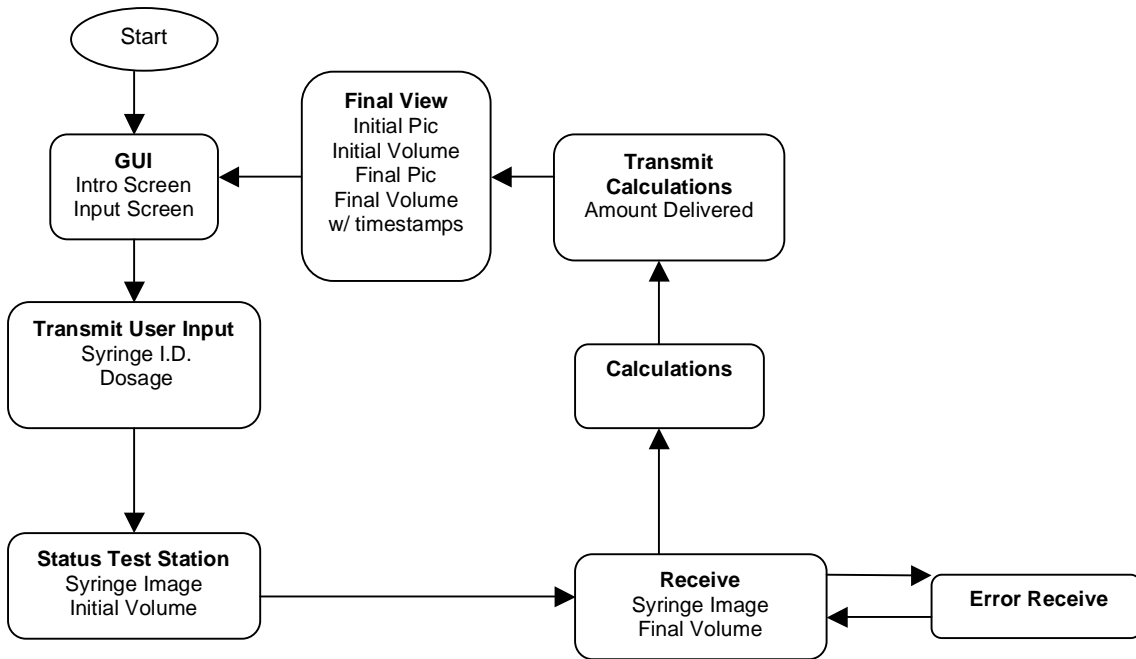


Fig. 3.2 Flow Diagram for the Software System

Start – The user runs the software and it will initialize all of the variables and perform routine system checks.

GUI - Graphical User Interface - This is where the user will be greeted by an introduction screen. After the introduction screen the user will then input a 7 digit patient ID number, the syringe I.D., and the dosage to be administered. All of these values will be checked for errors and the user will not be able to continue until the errors are resolved.

Transmit User Input– Sends the user input to the test station via infrared (IR) communication. The computer will send this signal through the Dig12 Out on The

DAS16 board to the IR transmitter. This signal will contain the data of which syringe is to be used and how much is to be dispensed. This data will then be received by the IR receiver at the test station. Once it is decoded the LED for which syringe to be used will be illuminated, and the 4 digit LED display for Prescribed Dosage will contain the amount to be dispensed. If there are any errors in the IR transmission the Prescribed Dosage display will be blank, and the user will required pressing the “R” button on the keyboard to resend the data.

If the transmission completed successfully the user will then press the Enter key to continue.

Status Test Station – Check to see if the syringe is placed properly in the test station and ready using the optical sensor. Once the computer senses that the syringe is ready it will obtain the voltage across the potentiometer and capture an image of the syringe and display it on the screen. The computer will then wait for the syringe to be removed from the test station and used and then placed back in the test station.

Receive – Once the syringe is placed back in the test station and the optical sensor senses it. The computer will obtain the new voltage across the potentiometer and a new image of the syringe. The new voltage that was acquired will be sent via RF transmission to the base station. This signal will be sent a total of three times and then all three signals will be compared for uniformity. If any one of the signals is different the system will go into Error Receive mode.

Error Receive – This function will only be executed if there was any error in the Receiving mode. Once in this mode the computer will send a signal via IR to the test station telling it to send the receive data signal again. Once this has been done the computer will go back into Receive mode.

Calculations – Computes the actual amount of drugs that are dispensed using a formula that is calibrated for that particular type of sensor. The formula will use the initial and final values of the voltage that are obtained through Status Test Station and Receive.

Transmit Calculations – The computer will send this signal through the Dig12 Out on The DAS16 board to the IR transmitter. This signal will change the LED display of the

Amount Delivered. If there are any errors in the IR transmission the Amount Delivered display will be blank, and the user will be required to press the “R” button on the keyboard to resend the data. If the transmission completed successfully the user will then press the Enter key to continue.

Final View – The user will see a before and after picture of the syringe with the volumes and the time the picture was taken below it. At this point the user can press “Q” to exit the program or “Enter” to continue using the program. If they choose to continue the user will be returned to the GUI Intro Screen and can enter new data.

This software was developed to be easy to use for the user and provide error checking for common mistakes that could be made by the user. The software will also check for errors in the RF transmission of data. The software will continue executing in this loop until the user decides to quit.

4.0 Product Technologies

4.1 Syringe Sensor

The sensing technology for the system makes use of a potentiometer slide moving linearly with the plunger of the syringe. A change in linear position of the plunger corresponds directly to change in voltage. The potentiometer is mounted on an aluminum jacket, and different syringes can be slid into the jacket. Connection between the plunger and the potentiometer slide are made through a control arm. A prototype of the syringe-sensor apparatus is shown below in figure 4.1. The potentiometer is powered by a 9.0V battery supply, regulated to 5.0V using a National Semiconductor voltage dropout-regulator (specific part not chosen yet), and long wires leading to the test station allow flexibility of movement.

Calibration and measurement of the syringe will be as follows:

1. The syringe is filled slightly over the 10 ml mark with distilled and de-ionized water.
2. Using the value of 0.932g/ml for density of pure water, 10.0 ml of dispensed water should weigh 9.32 g. This weight can be measured using a digital weighing scale.
3. The apparatus is connected as shown in the figure, and powered.
4. Water is dispensed by pushing down on the plunger, and collected in a plastic cup of known weight (able to hold at least 10ml of fluid), until a change in weight of 9.32 g is measured. While dispensing water, the distance moved by the plunger is also recorded with a digital caliper.
5. Once this distance is measured it is recorded, and the total potential drop across it (5.0 V) divided by it to produce a value in V/mm.
6. This value is then used as a multiplier. Every time a change in voltage is measured, the linear displacement can be calculated as well. Since radius of the syringe is constant throughout, total change in volume can be determined this way. The accuracy of this calibration method will be verified using the subsystem system test described in 6.11



Fig. 4.1 Syringe-Sensor Apparatus

The analog voltage from the potentiometer is input to an ADC0804 A/D converter, which outputs an 8-bit wide digital value (input impedance is sufficient to not require the use of a voltage follower). This value is input to an MM74HC165 8-bit parallel-in/ serial-out shift register, which is in turn cascaded with the first input of another MM74HC165 shift register. Of the remaining 7 inputs, 6 are hardwired to a DIP switch, through which a selected sequence of bits are input as a 'preamble', in order to encode the signal. The remaining input comes from the optical transistor/ switch at the test station, indicating whether a syringe is present or not, thereby aiding us with the generation of a 'ready' signal. Bits from the second shift register are moved into a voltage-to-frequency converter (details of this component and frequency have not been resolved yet), which is connected to the input of the RF transmitter. All components are clocked simultaneously, using the same clock signal coming out of Control pin 6, generated by the computer. Connections are shown in figure 4.2.

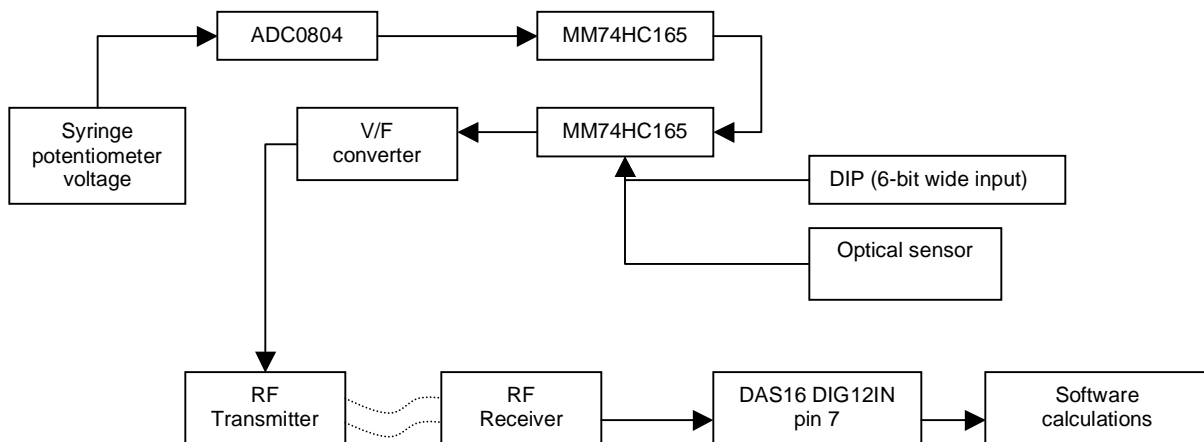


Fig. 4.2 Voltage conversion and result transmission from Test Station (power connections not shown)

4.2 RF Transmission

The RF transmitter provided by the client operates at 300 MHz. The signal at the receiving end is put into pin 7 of DIG12IN, and then used by the computer to perform calculations to determine volume change. The specific strategy of RF transmission and error checking involves the conversion result itself to be sent three times, and having the computer compare each of these three streams of data with each other. Any discrepancy found will be treated as an error, and the user will be prompted to 'resend' data from the test station by cutting the optical sensor beam once more.

Once this is done the results are output through the IR system for display at the test station. The RF subsystem has already been tested, as described in section 6.12.

The A/D conversion, shifting, V/F conversion and RF transmission can all be coordinated using the same clock signal coming from the computer, fed into a PLD. The PLD will not let the clock through to all the other components of the system until it receives the input signal to do so from the test station. Once it does, the clock signal is 'latched' through to all components requiring it. It also serves as the 'initiate' signal for the A/D.

4.3 IR Transmission and Test Station Display

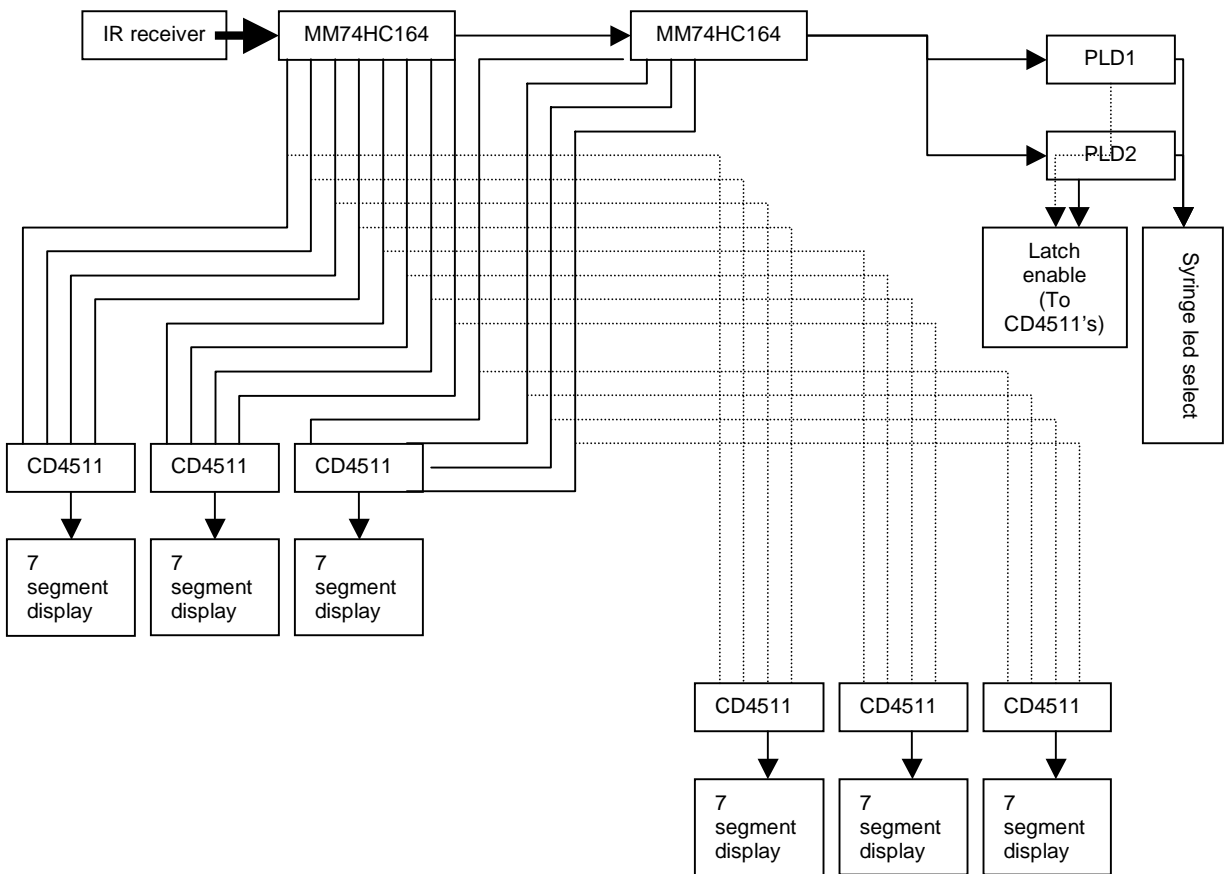
IR transmission will be making use of two channels (i.e. two separate IR transmitter-receiver pairs). An inverted clock signal having a frequency between 50 and 150Hz (exact frequency remains unresolved, depending on what frequency cutout will be observed at) is output through DIG12OUT pin 7 from the DAS16, and data will be sent as a series of pulses at the same frequency as the clock but pulse width equal to time period of the clock out of DIG12OUT pin 6. A minimum spacing of 14cm has been calculated to be required between IR transmitters to prevent overlap of their transmission envelope at the test station. Distance between the test station and base station is 2.0m.

The output from the computer is in the form of a 16-bit stream:

$X_0 X_1 X_2 X_3 Y_0 Y_1 Y_2 Y_3 Z_0 Z_1 Z_2 Z_3 ABCD$

X, Y and Z bits are in sets of four, each making up one BCD (binary coded decimal) digit. A and B form the syringe identifier, while C and D form the display identifier (more details below)

Data received at the IR receiver is sent into an MM74HC164 serial-in/parallel-out shift register, cascaded with another one. Once data has been shifted in, outputs corresponding to the BCD digits are latched into hardwired CD4511 BCD decoders/latches. The latches do not output their values to the LEDs unless output enabled by PLDs, which make use of C and D bits for display selection. See figure 4.3.



Hardwired inputs to the CD4511 latches are intended to show 4-bit wide wiring for BCD digits. The first two digits to be displayed come from the first shift register, and the last digit comes from the first 4 bits of the second register. The remaining four bits make up A, B, C and D bits (selector bits).

Fig. 4.3 Display System (power supplies not shown)

The PLDs used are PALCE16V8 type, and both will be programmed using ABEL code that differentiates between the C and D bits of the code once it has been shifted into the shift registers. CD=00 selects the “prescribed dosage” display, while CD=01 selects the “delivered dosage” display. Whichever display is selected, only *that* one is sent an enable signal by the PLD.

Similarly, bits A and B are responsible for selecting the proper syringe LED.

Test station displays are of the format

N.NN

N is a BCD digit (0-9). The decimal point will be illuminated constantly (direct power). This way, we can display values up to 9.99ml, which the client mentioned as being acceptable at the preliminary design review.

5.0 Subsystem Tests

5.1 Test Station Subsystem Tests

5.11 Syringe Sensor

Status: Performance remaining

The final sensor assembly is as shown in fig. 4.1. The potentiometer will be dividing voltage between a range of 0.0 and 5.0 Volts. Power will be provided by a 9.0 volt Duracell battery. There are three primary subsystem tests:

i) Linearity Test

The purpose of this test is to determine whether the sensor/ potentiometer does in fact show a change in voltage with displacement that is linear. The total distance the plunger moves with dispensing is divided into ten points, and a potential difference of 5.0 volts is placed across the syringe. Measurements of voltage are to be taken at each division, in order to generate a plot of voltage versus distance. A linear 'best-fit' curve shall indicate satisfaction of the linearity requirement.

ii) Resolution Test

This test verifies that our sensor meets minimum resolution requirements; i.e. the ability to measure changes as small as ± 0.1 ml. The method of sensor calibration has been discussed in section 4.0 and this test is its verification. First, a syringe is filled with 10 ml of distilled, de-ionized water, so that its density is as close as possible to the exact value of 0.932 g/ml. Next, the syringe plunger is moved in by the exact distance corresponding to 1.0 ml of volume (0.176 inches, monitored with a digital caliper), and the water dispensed is collected in a plastic cup, of prior determined weight. The cup is then placed on a digital scale, and the weight of water in it is determined, recorded and denoted 'A'. Next, 5.0 ml of volume are dispensed, and the same procedure is repeated. The result is then divided by five, and the resolution requirement will only be satisfied if this value and the value 'A' are equal.

5.12 RF Transmission

Status: Performance remaining

i) Transmission Distortion Status

The use of a voltage-to-frequency (V/F) converter introduces pulses, and to observe the accuracy of reproduction (or lack of, thereby equaling distortion) of these pulses an Agilent 33120A function generator and series 54600 oscilloscope are used. The output of the signal generator is connected to the input pin of the RF transmitter. A probe from the oscilloscope is connected to the input pin of the RF receiver, and results displayed. Results obtained showed output waveforms to be exactly the same as input, with the same frequency and peak-to-peak voltage. Thus there is no need for a threshold detector.

5.13 IR Transmission

Status: Performance remaining

i) Transmission Distortion

A clock signal is generated by using an Agilent 33120A function generator. A square wave of known frequency, with a dc offset equal to amplitude is put in to the IR transmitter. Another similar function generator is used to provide the clock. Once the shift registers are full, transmission is stopped. Shift registers' outputs are then observed using a multimeter, where a TTL high value will indicate a '1' and TTL low value a '0' bit.

5.2 Software Subsystem Tests

5.21 GUI Test

Status: Performance remaining

i) The GUI test will consist of executing the GUI and gathering user input valid or invalid. If the data is invalid it will prompt the user for correct input, until the user is correct. Invalid data will be used to try and make the program crash.

5.22 IR Test

Status: Performance remaining

i) This will consist of hard coding values into the program and transmitting them via an IR transmitter to an IR receiver. On the other end of the IR receiver will be an oscilloscope to check and make the expected values are being obtained.

5.23 RF Test

Status: Performance remaining

i) This will consist of using a signal generator to create a signal and transmitting it with an RF transmitter to a RF receiver connected to the computer. The computer will then be checking to see if it received its expected values.

5.24 Imaging Test

Status: Performance remaining

i) The computer will have known values of an image stored in a file on the computer. The computer will then be expected to go to that file and display the image stored in it. If this test is completed successfully then it will be verified to be operational after test ii is completed successfully.

ii) The computer will read known values from a RAM chip, and store this data in the computer. Once this data is gathered it will then output the expected image on the screen.

5.3 Imaging Subsystem Tests

5.31 Image Capture

Status: Performance remaining

In order to properly ensure the capture of the syringe image, each component must work according to their design. To test the capture system, the outputs of the selector/sampler unit must be tested. By using the 54600 oscilloscope, the SEL, BOR, and SMP signals are checked to see if their outputs are correct. Next, the output of the Logic Latch is checked to ensure that its output will properly work as the clock for the RAM and the binary up counter. Then using LEDs and the generated clock signal, the output of the counter will be checked. The LM311's must be tested as well. This is done by checking its output with the 54600 oscilloscope. After these two parts are working the RAM is to be checked. This is done by using a dip switch for the address and data inputs of the RAM. If all tests work accordingly, then the hardware will function properly.

5.32 Software for Image Capture

Status: Performance remaining

The software is tested by using LEDs to test the outputs of the DAS16. Those are the DIG12 OUT, DIG12 IN, and CONTROL parallel outputs. The CONTROL parallel out

must properly output the correct line video line number. The DIG12 OUT must properly output the correct addresses and clock speed to run the RAM. If these are working accordingly, then the computer and DAS16 can be connected to the Interfacing Station to test them together. This is work by running a test program on the computer, to ensure that each video line is captured by the RAM and then stored in an array in the computer's memory. By running all of these tests on the hardware and software it can be ensured that the Imaging Capture System will work according to their design and theory.

6.0 Final Acceptance Test

The customer will be asked to make a 'test run' of the system, and will be asked to follow instructions in the System Manual. The RF system is to be demonstrated under two settings, simulating different 'operating theater' conditions. In one, data will be sent with no other systems in operation (no other RF systems at the same frequency will be operating in the same room.)

In the second, data shall be transmitted in the presence of possible interference from other systems.

When the customer has completed using the W.I.L.P.S. system correct final assembly shall then be confirmed by the customer.

7.0 Gantt Chart

Please see attached sheets overleaf.

8.0 Schedule of Deliverables

<u>Item Deliverable</u>	<u>Person Responsible</u>	<u>Due Date</u>
Imaging Hardware	Andy Witmeier	10/16/02
GUI	Ryan Tiruchelvam	10/25/02
Software RF Communications	Ryan Tiruchelvam	10/30/02
Image Acquisition	Andy Witmeier	10/30/02
RF Communications	Khurram Siddiqi	11/19/02
Software Image Acquisition	Ryan Tiruchelvam	11/01/02
Building Test Station	Andy Witmeier	11/16/02
IR Communications	Khurram Siddiqi	11/06/02
Software IR Communications	Ryan Tiruchelvam	11/6/02
Sensor Calibration	Khurram Siddiqi	11/12/02
Test Station Display	Khurram Siddiqi	11/14/02
Power supplies	Andy Witmeier	11/16/02

9.0 Cost Analysis

The project budget has been set at \$50.00 by the client. The product outlined in this proposal will cost less than \$50.00, provided that the product stays within the stated requirements in this document. Several components have been supplied: one test station stand, one RF transmitter and receiver pair, one line selector/sampler, one DAS16 Computer Interface Panel, and common sub-connectors of varying lengths. Other components that will be used as are listed in the table below.

<u>Item</u>	<u>Quantity</u>	<u>Unit Cost (\$)</u>	<u>Total Cost</u>
Linear Potentiometer	1	0.00	\$0.00
IR receiver and transmitter	1	0.52	\$0.52
Seven-segment displays	6	0.40	\$2.40
Common LEDs	4	0.35	\$1.40
Common Transistors	2	0.35	\$0.70
Bypass capacitors	20	0.05	\$1.00
Shift Registers	4	0.40	\$1.60
BCD Latches	6	0.40	\$2.40
A/D Converter	1	0.40	\$0.40
Test Station conversion switch	1	N/A	N/A
LM 311 Voltage Comparators	4	0.40	\$1.60
CY6116A RAM	1	1.35	\$1.35
Binary up Counter	2	0.35	\$0.70
9 Volt Batteries	5	1.00	\$5.00
5 Volt DC Power Supply	1	5.00	\$5.00
Total Projected System Cost*			\$24.07

Fig. 8.1 Cost Analysis Chart

10.0 Resolved and unresolved issues

There have been many issues that were not completely developed or understood when the Preliminary Design Review was written. Those issues have now been resolved. The types of power supplies have been determined. The syringe and potentiometer are now mounted so measurement can take place. The different pins from the computer have been assigned different functions. At the time of preparation of this final design report, the chief outstanding issues remaining are:

- Selection of clock frequency for RF and IR transmission
- Selection and integration of BJT amplifiers into IR transmission

- Selection, design with and implementation of a V/F (voltage to frequency) converter.

It can be expected of the customer to find some issues still unresolved or new issues altogether. Such discrepancies shall be attended to with the highest attention and resolved before moving into production phase.

11. System Manual

Please see attached manual overleaf