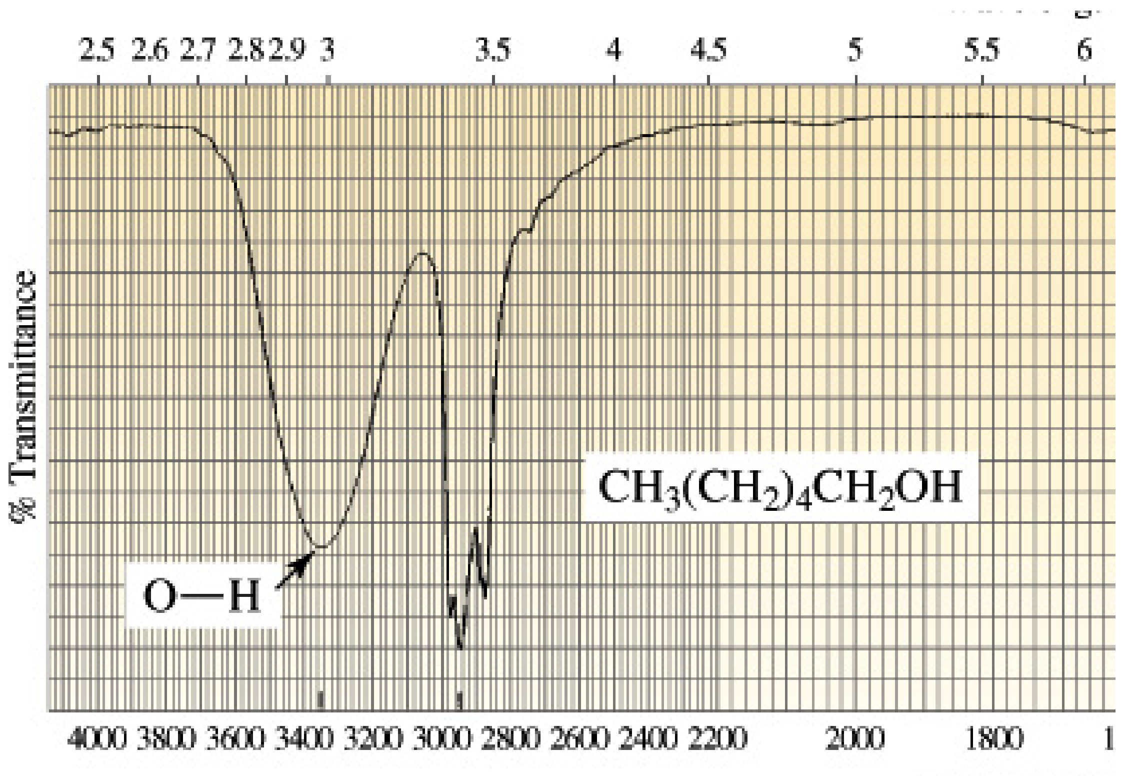
Electronic Tongue based on IR Absorption

SUMMARY:

The purpose of our project is to identify liquids based on infrared absorption, determined by a thermopile detector array and compared to a database of sampled liquid compositions.



	Rebecca Moehring	becca@themoehrings.com
	James Smith	James_smith@tamu.edu
	Chris Freytag	cfreytag@neo.tamu.edu

Texas A & M University
Computer Science Department
Ricardo Gutierrez-Osuna

TABLE OF CONTENTS

1 OVERVIEW

The purpose of our project is to identify liquids based on infrared absorption, determined by a thermopile detector array and compared to a database of sampled liquid compositions.

1.1 Goal and objectives

☑ - Completed
☐ - Not completed / not possible

Goal:

- Develop a low-cost alternative to modern FTIR spectrometers that can identify common liquids

Objectives:

- Identify alcohols accurately
  - ☑ Pure
  - ☑ Concentrations / Mixtures
- ☑ Design should minimize outside interference
- ☑ Stay within budget ($500)
- ☑ Minimize manufacturing cost
- ☑ Safe and simple
- ☑ Produces a result in an acceptable amount of time

1.2 Literature and technical survey

Dexter Research is the company we have been in contact with since the beginning of the project. Their main product is thermopile detectors. Our proposed design uses their 2M detector that contains four sensors. Three of the sensors will monitor frequencies of interest, and the fourth will be used as a base/reference filter.

International Crystals is a provider of the window panes and they provide a kit for $142 that includes 6 Silver Chloride plates, a slide holder, and a sample holder. We are very excited about this kit because it saves us money on our budget and also provides more windows than we would have been able to purchase separately. The only drawback to Sliver Chloride when compared to Barium fluoride is that it will darken with prolonged exposure to ultraviolet radiation. Normal use should not be a problem as long as we store the plates in a dark container.

Hawkeye Technologies is the provider of our infrared source. We are purchasing the most powerful one they offer at a price of $90, this emitter can be set to be pulse-able or constant, but we will use it in constant mode and turn it on and off with a button in LabVIEW.

National Instruments carries a wide range of instrumentation devices. We are purchasing a USB 6009 Data Acquisition Card from them.

*The following are companies who have products that apply to our project but that we did not purchase from***:**

EOC Inc. has conducted various experiments on liquid determination with their most recent product (a linear variable filter). We contacted EOC to find if they would be willing to sell their Linear Variable Filters and they said that we could purchase the whole unit, sensor included with software for $4,000. Of course this is very expensive and is the purpose of our project. However, they did say because we were building our project for educational purposes, they would be will to give us a faulty linear variable filter for roughly $800, if they had one available. They will have a tuneable filter that will be available for sale in the next 6 months, which is not in the timing scope of our project. The tuneable filter will be sold as a package with a pyro-electric detector for under $500.

OCLI had some very interesting products that we would be interested in purchasing. After reviewing their products we found that they did have variable filters in the frequency range which our project needed. But the price was very far out of our range. According to their sample prices, it would roughly be $600 for a variable filter that would only be able to absorb infrared in a bandwidth of 2 micro-meters which is a rough estimate of the frequency range that we could build with a thermopile detector with four different frequency filters from Dexter Research.

Acroname is the United States vendor for Robot Electronics in the United Kingdom. We contacted Robot Electronics and they gave us a rough estimate for their Devantech Thermal Array Sensor. The sensor is only $96 and has 8 sensors on it that can monitor between 2 micro-meters and 22 micro-meters which is perfect for our project purposes. They also provide in depth data sheets and software that connects to the Devantech Thermal Array Sensor to a computer through a CM2 port. Unfortunately, we would still need to buy a linear variable filter which makes this solution too costly.

McCarthy is the provider of the Barium fluoride window panes we were going to use for our project. Originally we were going to use Sodium Chloride plates, but we would not be able to test concentrations that contain water. From the catalog of McCarthy products we found that we could purchase a Barium Fluoride window pane for $40.

Ocean Optics has linear variable filters but all of their filters are in the nano-meter range which is in ambient light range and not the infrared range. Since our project uses infrared, all of their products are useless to us.

1.3 Alternative solutions considered

Linear Variable Filter – Use of a linear variable filter will remove the need to buy multiple filters because we would only need one sensor and one filter. It would add the need to slide the sensor from one end of the filter to the other so that the whole spectrum range can be analysed. A linear variable filter has a large range of frequencies at which infrared will be absorbed at. Unfortunately, the linear variable filters are very expensive and completely out of range of the budget that we are required to follow. We actually found a thermopile array sensor for roughly $96 and also included software to evaluate the given results, but the linear variable filter is the controlling factor of this design. After reviewing all of our prices and feasibility we have concluded that we will not be able to do this design. Instead we will try a thermopile detector with multiple filters installed in it. This will be purchased and built by Dexter Research.

Rotary/Film strip Filter – Another option for filtering would be to use one sensor and change the filter by use of a rotary wheel or a film strip type design. This would save the need to buy a lot of sensors, but could also be very difficult due to the size of the filters. This solution will be too difficult to create with the filters because they are very small and this would also require us to do a lot more mechanical design.

NaCl/$BaFl_2$ and other various Salt Plates – An issue that we have had to deal with when trying to purchase salt plates is the substance they are made of. Each substance transmits different ranges of infrared light (some will not work for our purpose). Each substance also is either water insoluble or water soluble. We wanted to be able to identify concentrations with water so we needed to purchase plates that are insoluble, for this reason, NaCl is not possible as part of our design.

1.4 Societal, safety and environmental analysis

1.4.1 Safety and Environmental

We determined the health and safety ratings of the chemicals we worked with from chemfinder.com and stored and handled them appropriately. The safety ratings of the compounds we have chosen can be found in our appendix.

Another safety factor introduced in our product is the temperature of the infrared source. At the source, the specs say that it could get up to 750° C. This could potentially be very dangerous, thus we have chosen to totally enclose the infrared source in our box.

1.4.2 Societal Impact

The following is a list of some of the main areas in which infrared spectroscopy has been used and could be potential uses for our product:

- Pollution Monitoring
- Agriculture: determining compounds in soils, plant material, fertilizers and foodstuffs
- Food Processing: determining compounds in meat preservatives
- Salt content of meat, fish, dairy products, fruit juices, brewing solutions
- F in drinking water and other drinks
- Ca in dairy products and beer
- K in fruit juices and wine making
- Corrosive effect of NO3 in canned foods
- Detergent Manufacture: Ca, Ba, F for studying effects on water quality
- Paper Manufacture: S and Cl in pulping and recovery-cycle liquors
- Explosives: F, Cl, NO3 in explosive materials and combustion products
- Electroplating: F and Cl in etching baths; S in anodising baths
- Biomedical Laboratories: Ca, K, Cl in body fluids (blood, plasma, serum, sweat).
- F in skeletal and dental studies

2 DESIGN

First, we will be sending an Infrared signal through a liquid set on a Silver Chloride plate, which allows IR to pass from 2.5 to 25 microns. We purchased a quad-thermopile detector which will be able to monitor three different bands/functional groups. We narrowed these down to O-H, and 2 bands of C-H bonds. These functional groups are predominant in alcohols, thus we will be focusing on identifying different alcohols.

We will be monitoring the temperature inside our box by using a thermistor because the sensors work by determining temperature changes. The sensors require a warm up time to allow the temperature to stabilize. An aluminium heat sink will be used to help stabilize its temperature.

The second part of the design involves interpreting and cataloguing the data received from the thermopile detector. Using the USB-6009 from National Instruments and LabVIEW software, we will take voltage signals from the thermopile detector, amplify them with instrumentation amplifiers from TI, and interpret them into digital signals which will be catalogued and compared to a functional database (Microsoft Access) that we will create for our known liquids (alcohols). Because all liquids have different molecular compounds, they absorb IR at different wavelengths. By comparing these values to the values captured in our database we will be able to accurately describe and identify an unknown liquid.

Due to the limited number of bands that we will be monitoring, we focused on alcohols and determine their identity based on amount of asorbption instead of identifying liquids based solely on the presence of different functional groups.

2.1 Design constraints and feasibility

Since we are using Silver Chloride plates, we need to be aware of how we store the plates so that they will not darken. However, normal use of the plate still has darkened them during the course of our testing. We also have to handle them with gloves so we do not leave fingerprints.

The operating temperature of our device needs to be in the range between freezing and boiling of the substances we are trying to identify.

We will be limited by the number of frequencies – number of functional groups – we can effectively monitor at the same time. Since we would like to buy the quad sensor, we will only be able to monitor three functional groups, thus limiting us to O-H and 2 types of C-H bonds, which are prevalent in alcohol compounds.

2.2 Implementation Notes

This section is designed to allow an engineer the ability to reproduce our product.

Please read this final report in its entirety before trying to build our product so that you understand the goals and objectives fully.

Parts needed: (refer to page 4 or the appendices for the specific parts we ordered)

- NI LabVIEW
- NI 6009 – Daq Card
- An infrared source
- A quad-sensor thermopile with filters in the O-H and C-H bands
- Salt plates and a holder to stabilize them
- Various alcohol samples
- Two 9-Volt batteries
- Miscellaneous circuit parts (please see pg 14, circuit design)

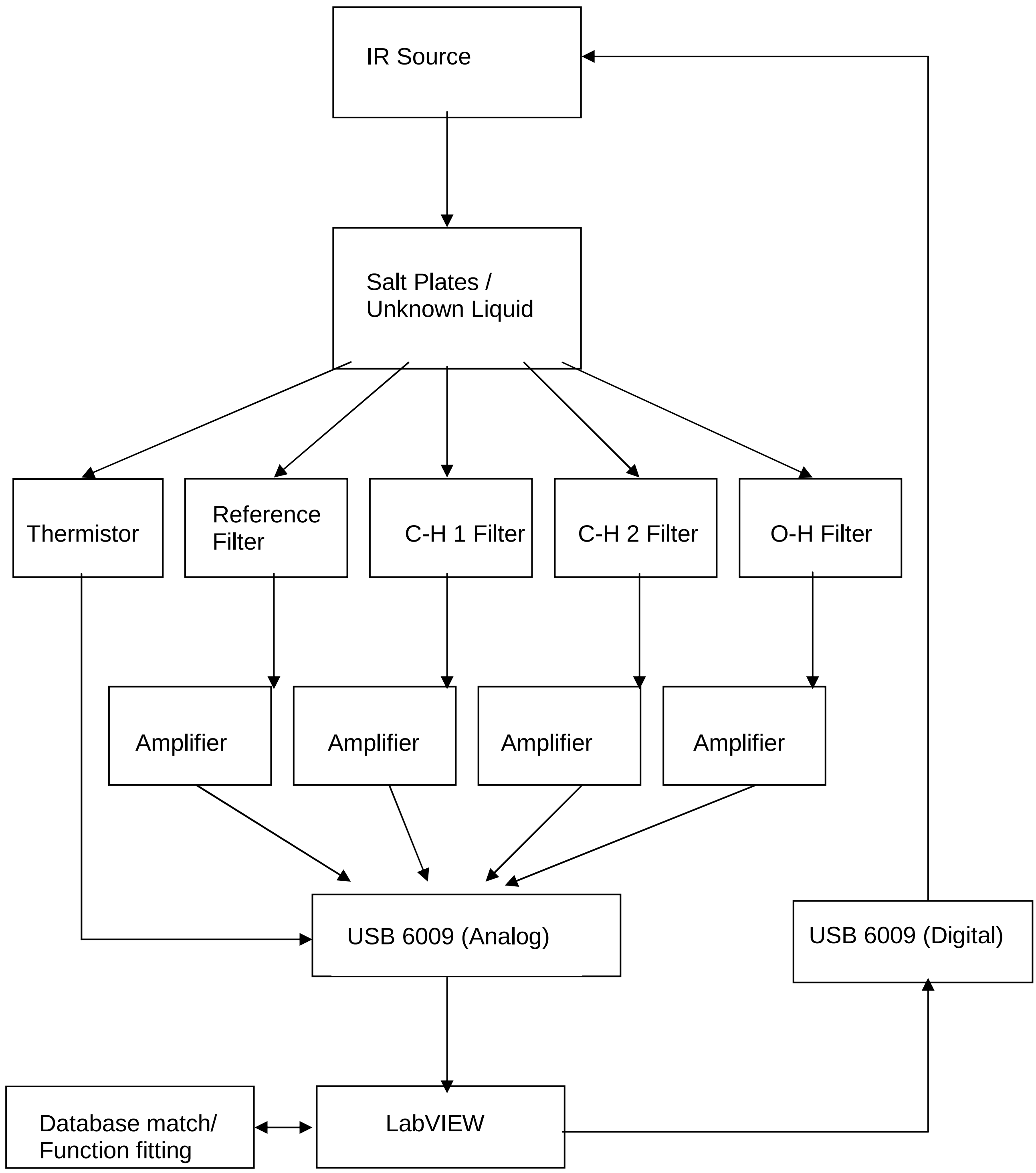
Build:

- Circuit (pg 14)
- Aluminum or other material box (pg 23)

Procedure:

- Install NI LabVIEW
- Install the specific drivers needed by the 6009 card
- Install the ElectronicTongue Virtual Instrument (.vi)
- Use the pin out page (pg 15) to hook up the wires from the circuit board and box
- Run the program and debug any loose wires

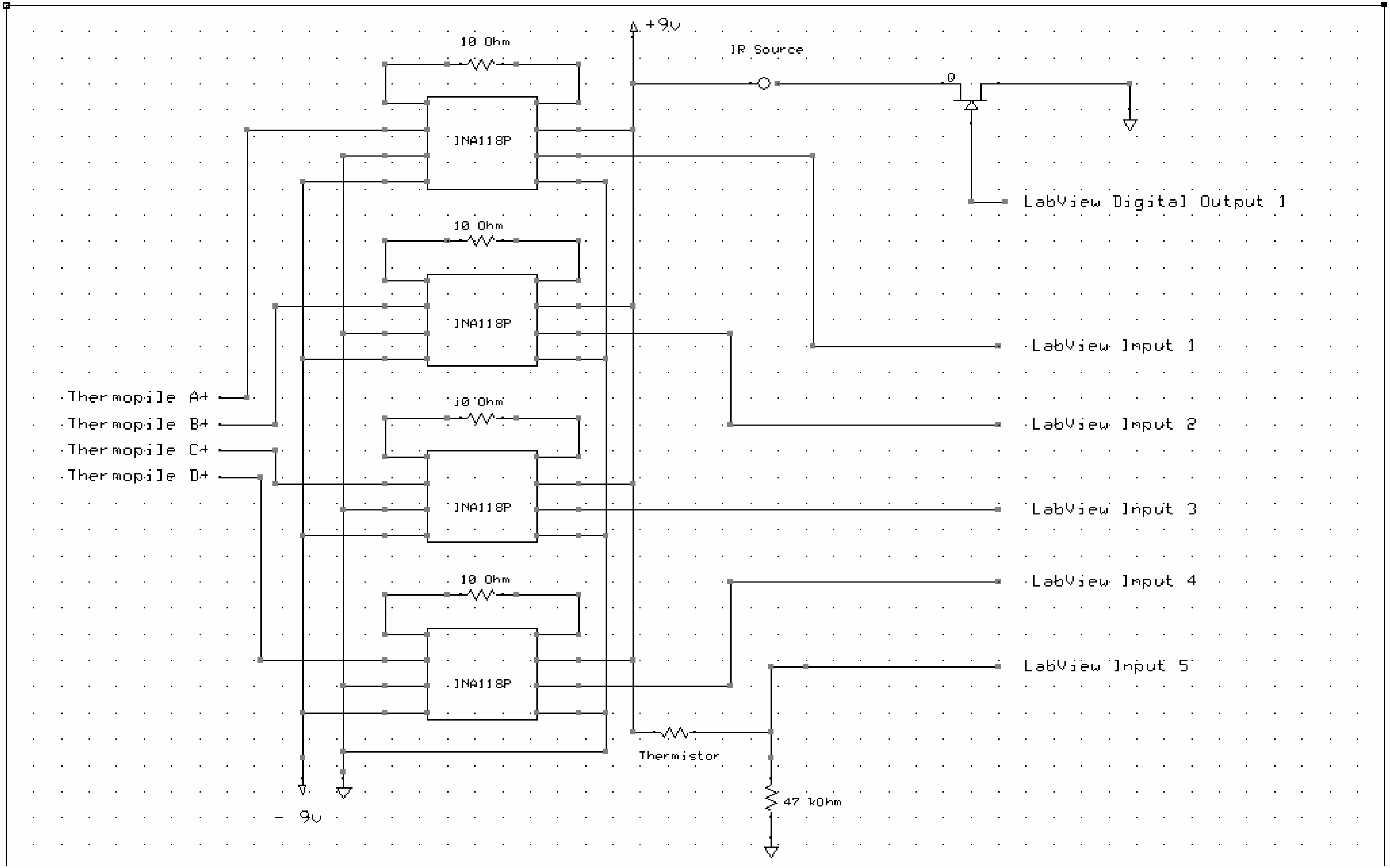
2.3 System block diagram



2.4 Specifications

2.4.1 Circuit and logic diagrams

See next page.


+9v
10 Ohm
IR Source
INA118P
LabView Digital Output 1
10 Ohm
INA118P
LabView Input 1
Thermopile A+
Thermopile B+
Thermopile C+
Thermopile D+
10 Ohm
LabView Input 2
INA118P
LabView Input 3
10 Ohm
LabView Input 4
INA118P
LabView Input 5
Thermistor
47 kOhm
- 9v

2.4.2 Interfaces and pin-outs

National Instruments USB DAQ Card:

Analog Terminal Assignments

Terminal	Signal, Single-Ended Mode	Output from Amplification Design
1	GND	GND
2	AI0	Output C-H
3	AI4	Output Thermister
4	GND	GND
5	AI 1	Output O-H
6	AI 5	
7	GND	GND
8	AI 2	Output C-H
9	AI 6	Battery +
10	GND	GND
11	AI 3	Output Base Filter
12	AI 7	Battery -
13	GND	GND
14	AO 0	
15	AO 1	
16	GND	GND

Digital Terminal Assignments

Terminal	Signal	Input for Power Switch
17	P0.0	IR Switch Control
18	P0.1	
19	P0.2	
20	P0.3	
21	P0.4	
22	P0.5	
23	P0.6	
24	P0.7	
25	P1.0	
26	P1.1	
27	P1.2	
28	P1.3	
29	PFI 0	
30	2.5 V	
31	5 V	
32	GND	GND

2.4.3 Timing diagrams and waveforms

Due to our design (see block diagram pg 12), we do not have any timing constraints. All of our logic is sequential and dependent on the block above it. The only time consideration is set up time, when we allow our sensors to stabilize prior to taking measurements of our sample.

2.4.4 Software processes

All of our functions are embodied in our LabVIEW VIs (virtual instruments).

- **Monitor Temperature:** LabVIEW will have a graphical thermometer which will take the data from the thermistor and allow us to monitor the temperature inside our box at all times.
  - ☑ **This has been implemented and tested.**
- **Graph Sensor Data:** LabVIEW will log the outputs from the sensors via the USB card, in bar form to show the concentrations of C-H and O-H bonds in the current liquid sample.
  - ☑ **This has been implemented and tested.**
- **Sampling Function:** During our experimental analysis of the compounds, we will take known liquids and record their values in a database.
  - ☑ **This has been implemented and tested.**
- **Compare Data with Known (Sampled) Values:** It will then take these values and compare with our known sample data using a least squares approximation to determine what compound(s) are present in the sample.
  - ☑ **This has been implemented and tested.**

2.5 Economic Analysis

Economical viability:

Our product is extremely marketable to low-cost users because there is already a similar product on the market that is high cost.

According to our budget, we should be able to prototype a design for roughly $1000.00, and if we were mass producing this design we estimate it to cost $500.00 per unit.

Sustainability:

All of our parts are manufactured by multiple vendors except for the thermopile, causing them to compete for pricing. Our product will require care and cleaning. We would need to provide on going support and additions to the database as more and more liquids would be identifiable.

Manufacturability:

The thermopile requires a heat sink due to temperature tolerances.

The performance can be affected by the amount of water in the ambient air, but we will be trying to calibrate the readings previous to each measurement.

2.5.1 Budget

Item	Quantity	Amount ($)
Infrared Source	1	$90.00
2M QUAD - 4 Channel Thermopile	1	$229.00
Filters		
F3000 – 3 micron	1	
FHC1 - 3.43 micron	1	
FREF – 4.862 micron	1	
- 9.6 micron	1	
Silver Chloride Plate Kit	1	$142.00
Compound samples	5	Free
9 Volt Battery	4	$13.00
Aluminium box	1	$25.00
USB Data Acquisition Card	1	$220.00
Total (does not include USB card)		$499.00

2.6 Approach for design validation

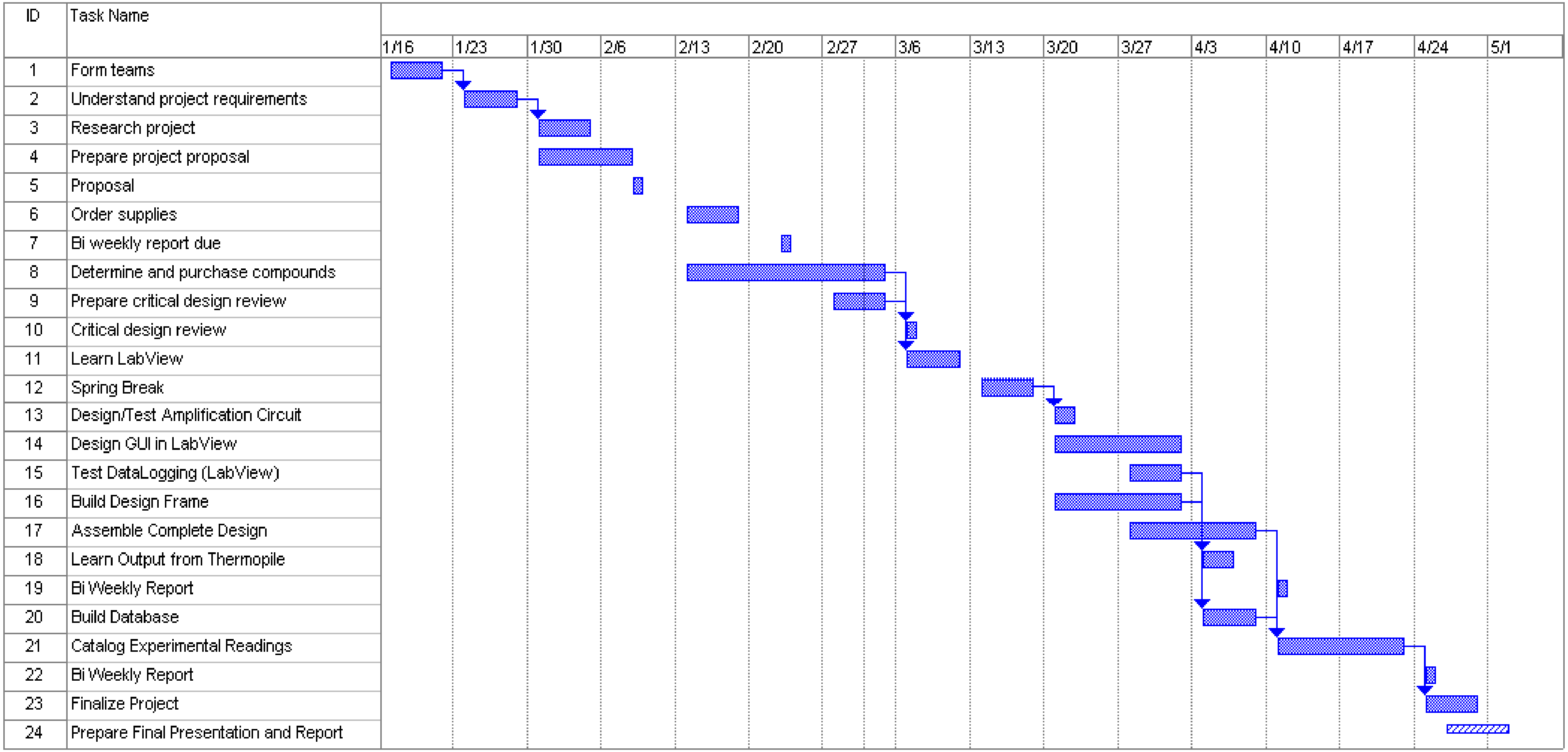
We will test our design by providing the device with samples of known compounds and determining if the device identifies the liquid correctly in an acceptable amount of time. This procedure will be broken into three (sequential) parts:

1. ☑ Pure Compounds
2. ☑ Varied concentrations of a specific known compound in water
3. ☐ Mixtures of compounds

We will also allow inexperienced users to try to operate our device to see if the interface is simple and easy to use.

3 PROJECT MANAGEMENT

3.1 Schedule of tasks, Pert and Gantt charts



3.2 Project Management and Teamwork

All team mates have a general understanding and expertise in most applications and computer programming.

Chris Freytag has exposure to infrared sources and has completed a prior project in lasers. He is currently taking a course in organic chemistry and has used an IR spectrometer in some of his prior semesters in chemistry. Because of his exposure to the IR spectrum he will be responsible for sensors and data interpretation.

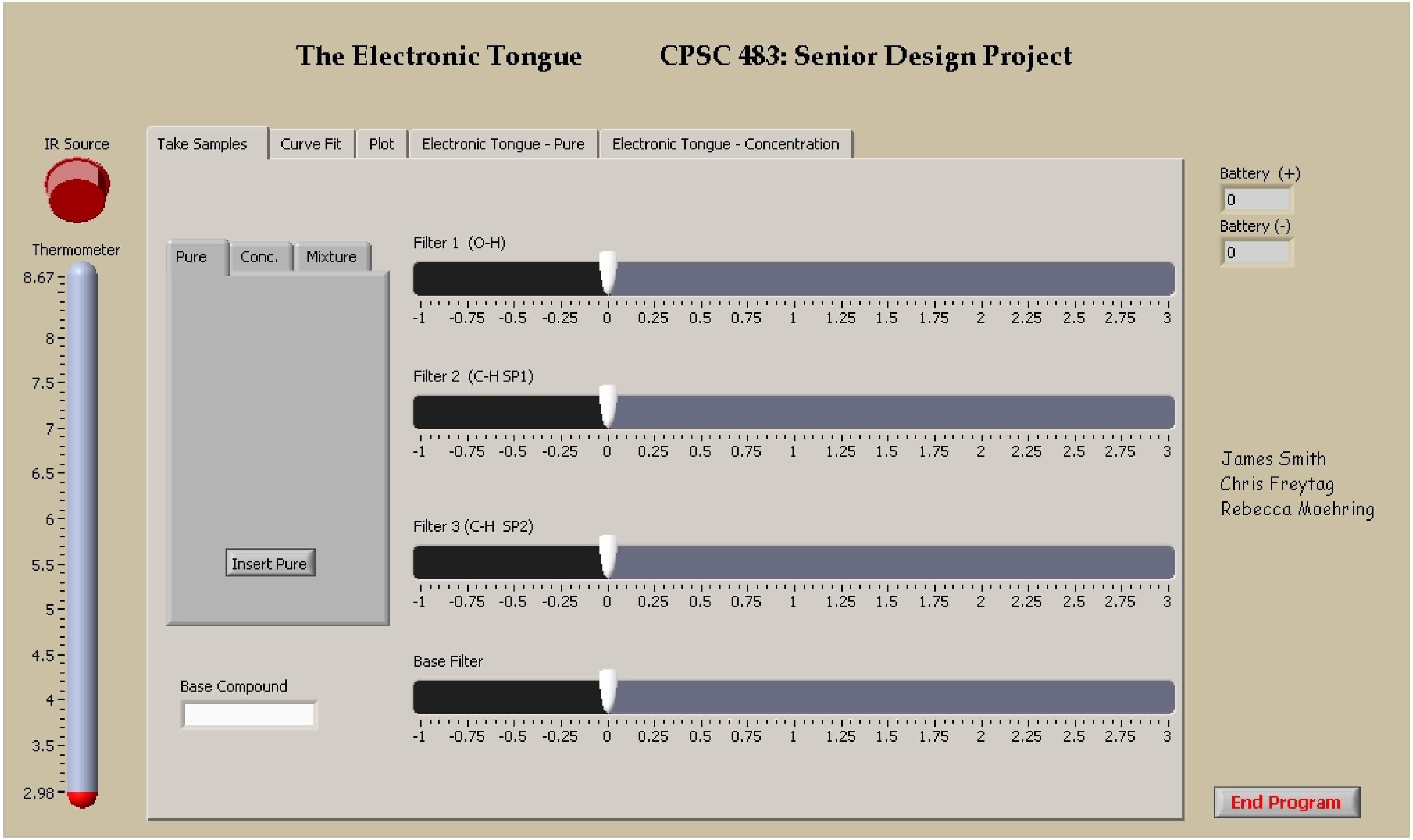
Rebecca Moehring has used National Instrument's LabVIEW software and is familiar with National Instruments DAQ Card, which is vital in signal processing and interpretation in our project. She will be in charge of signal processing and data cataloguing.

James Smith has taken courses in system design and is familiar with most hardware aspects of the project therefore he will be responsible for device communication. We will also closely be working together to develop the database of known liquids to identify the unknown liquids tested by our product.

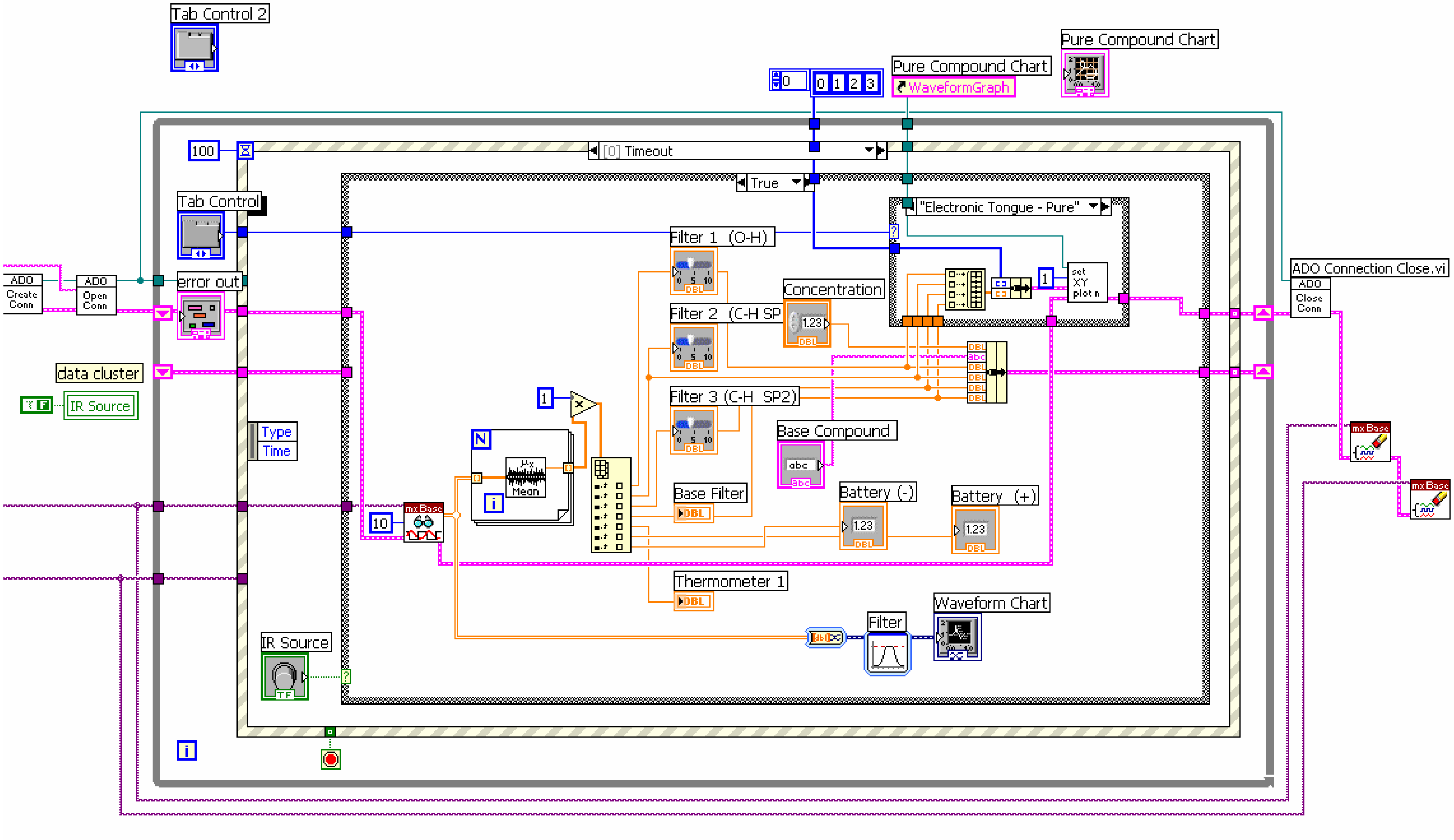
We have been having brainstorming meetings twice a week and working on the project or separate parts of the project during those times as well. All team members keep log books that describe our findings and discussions from each session. Considering all three of us have worked with each other previously, we do not anticipate any complications during the completion of our project. However, the purpose of having a GANTT chart is to stay reminded of desired completion dates so that we are able to produce a successful project. We will follow this chart as closely as possible.

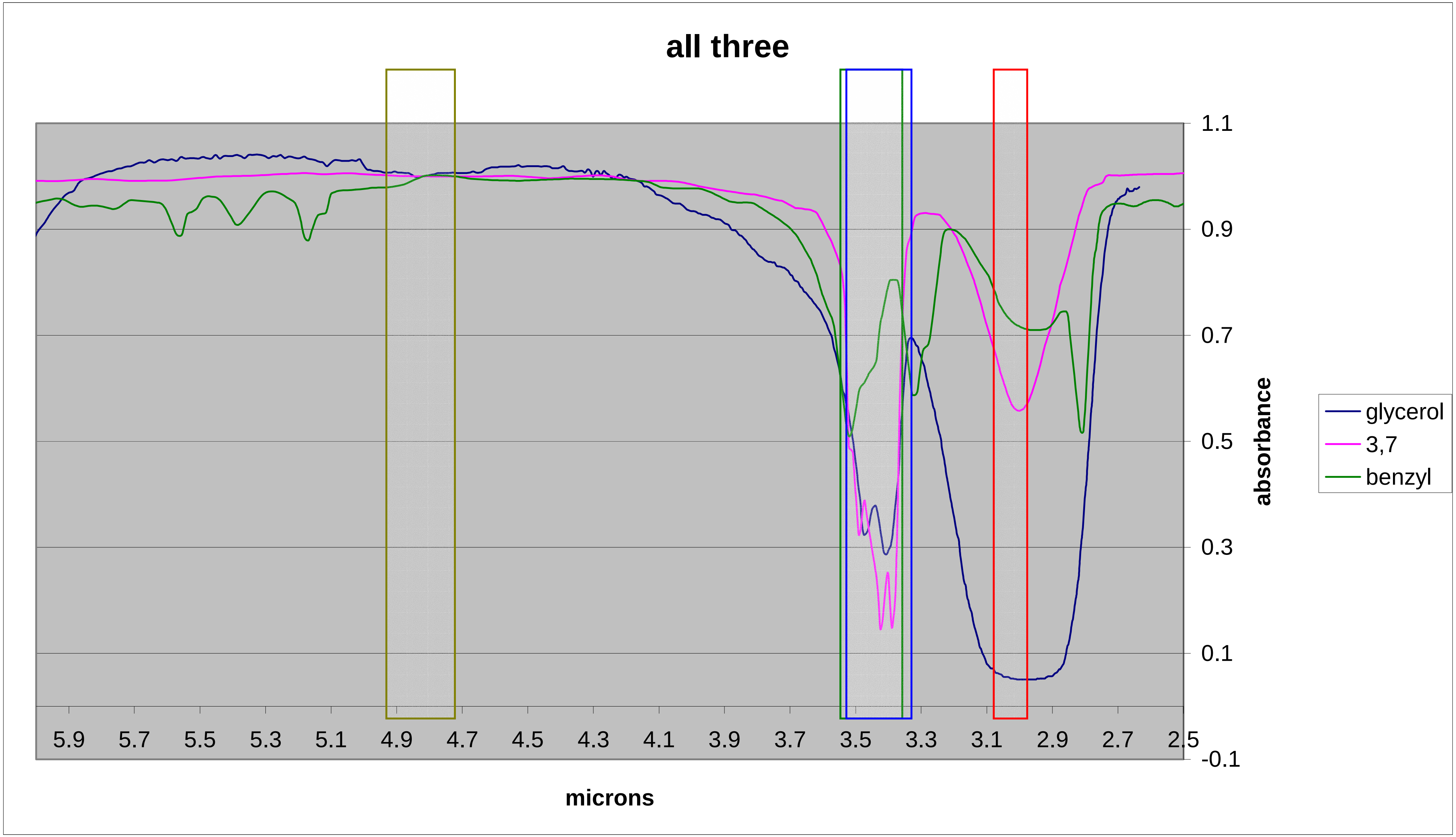
4 PRELIMINARY RESULTS

4.1 National Instruments Screen Shot of Front Panel



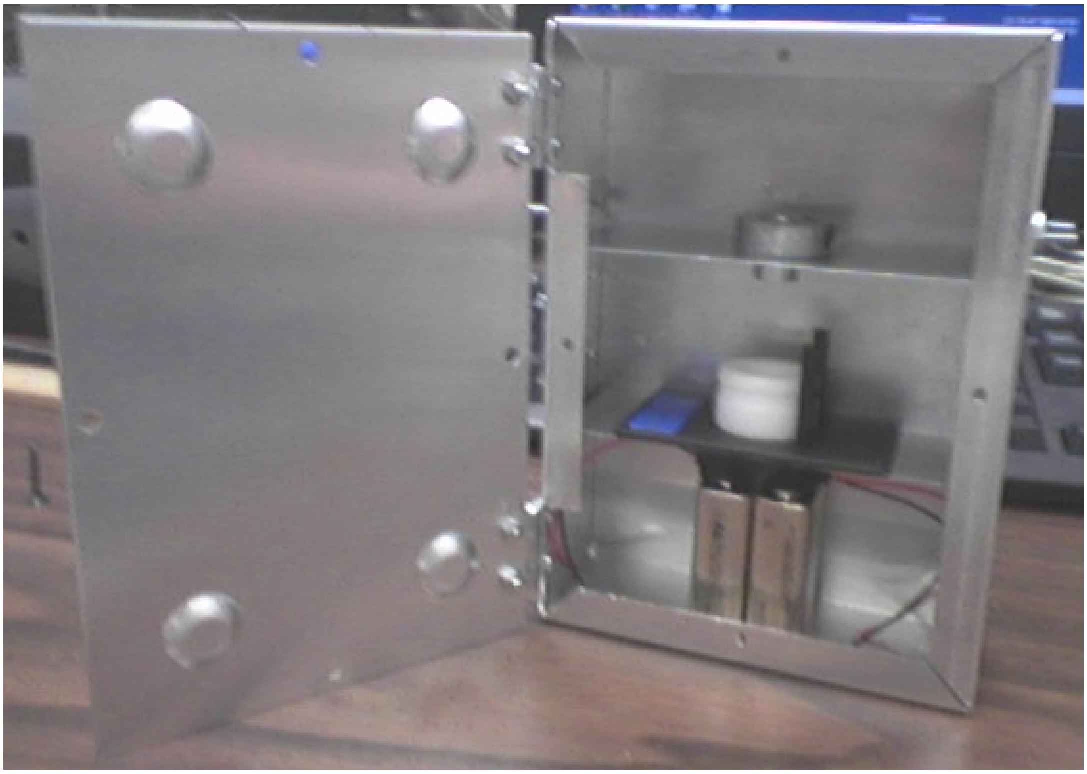
4.2 LabVIEW Block Diagram





The boxes represent our 4 filters and their bandwidths.

4.3 Product Box Design



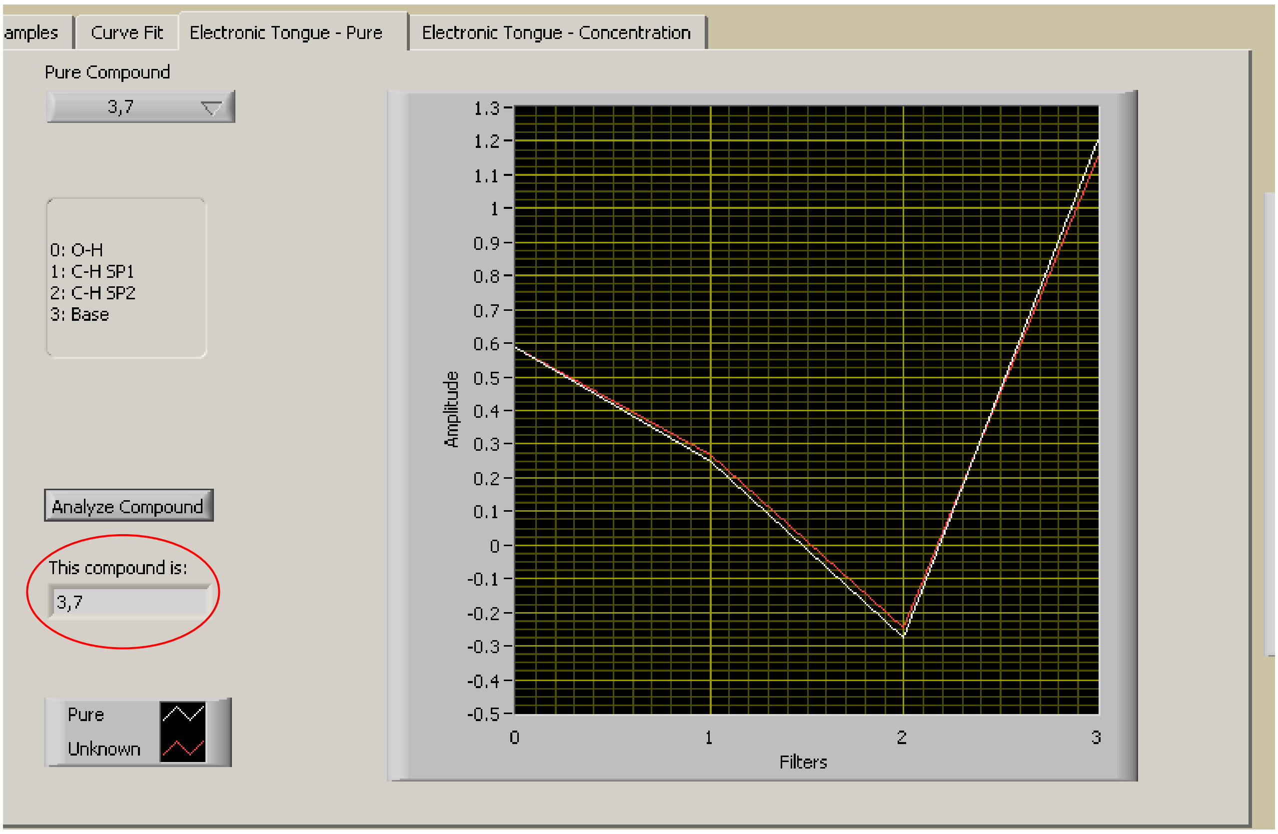
Top Rack: Infrared Emitter

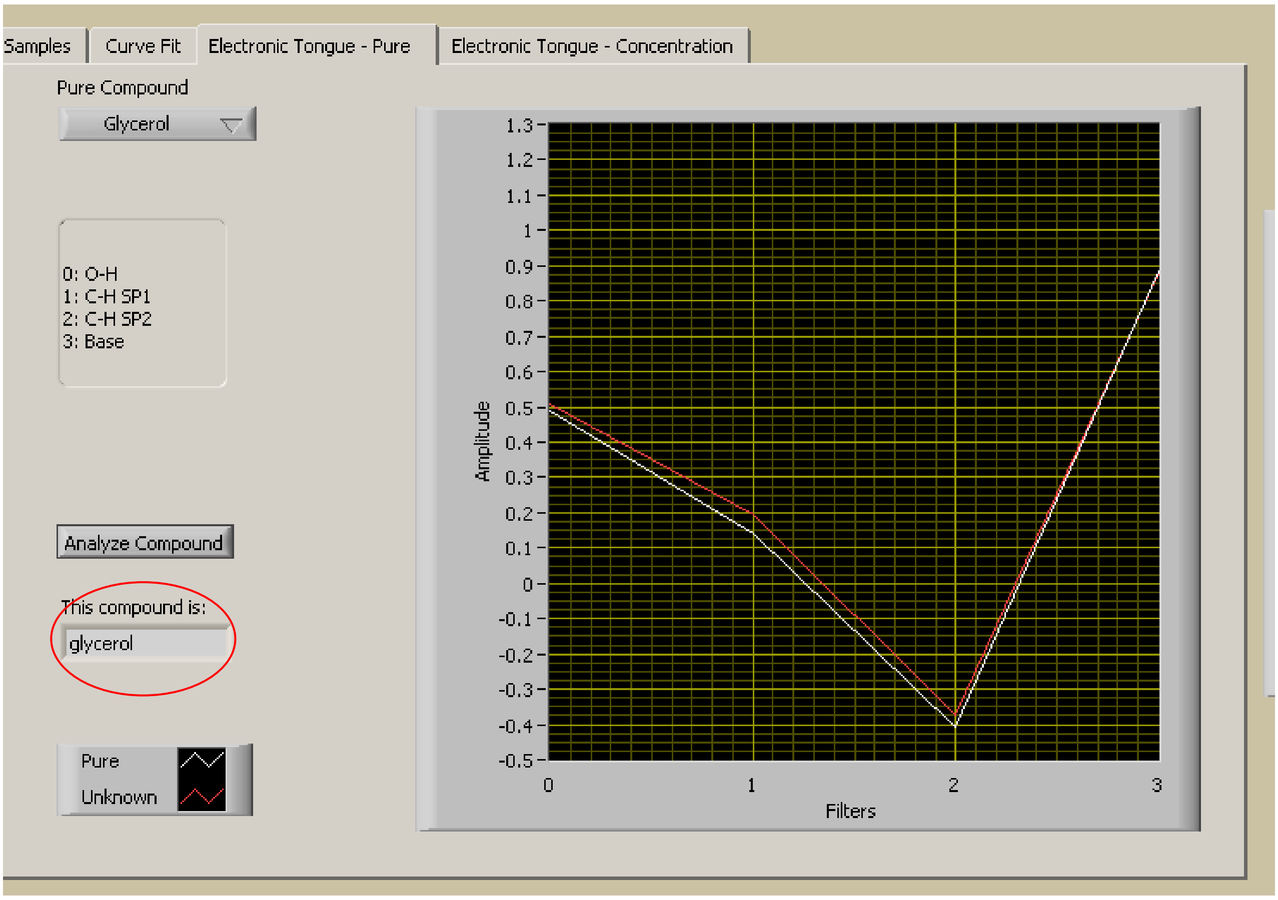
Middle Rack: Unknown Liquid and Thermopile Detector

Floor: Batteries and Protoboard

5 EXPERIMENTAL RESULTS

5.1 Images of Electronic Tongue Working

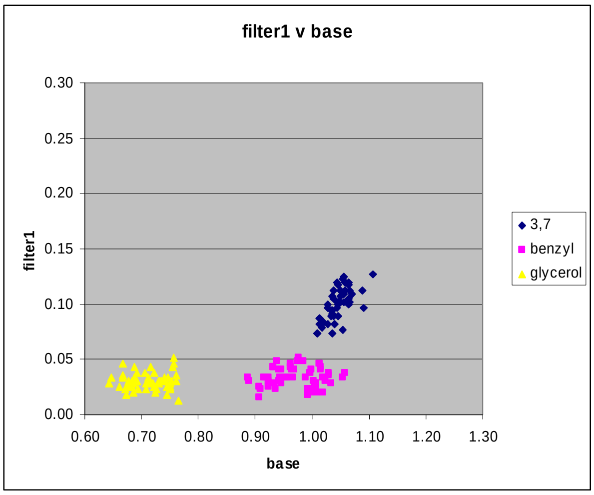


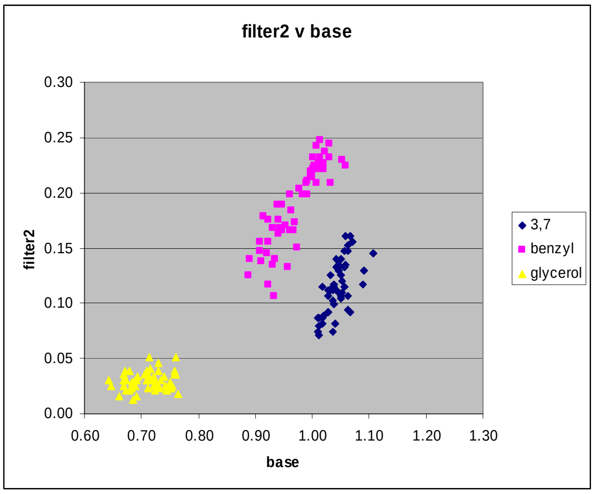


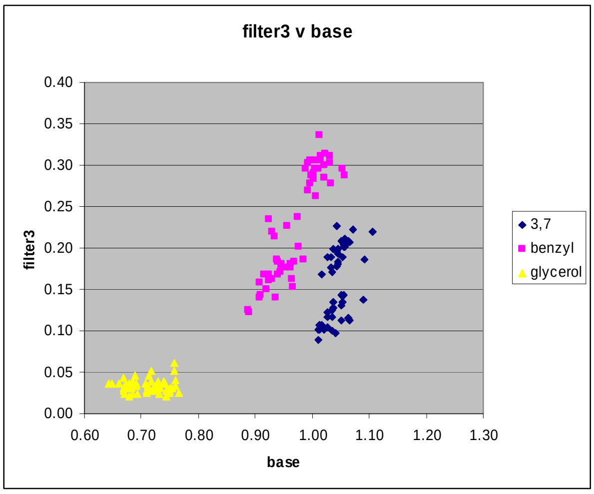
5.2 Filters Versus Base Data

The following charts are the raw data of each filter compared to the base filter.

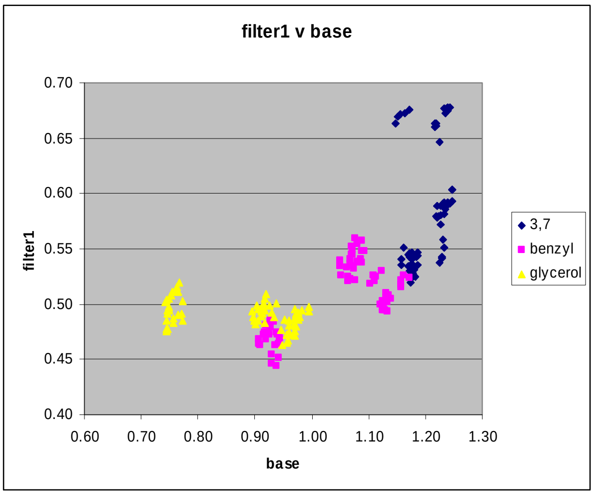
Pulsed Data

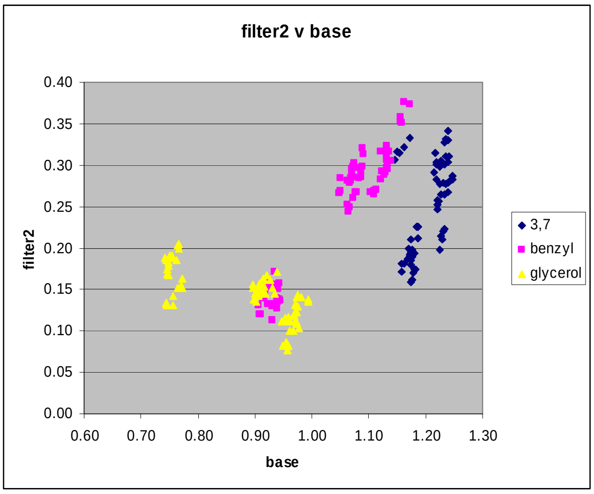


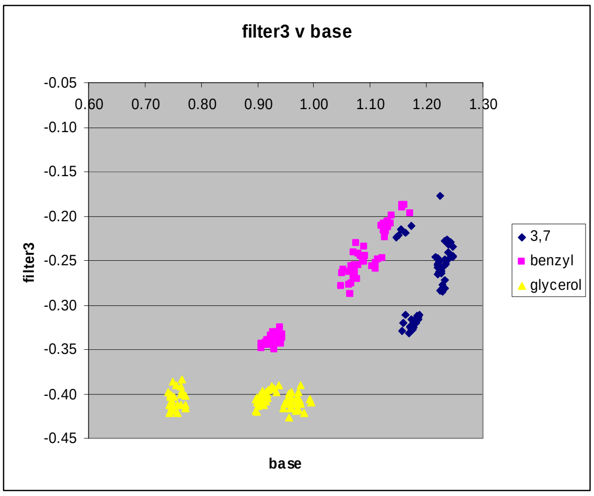




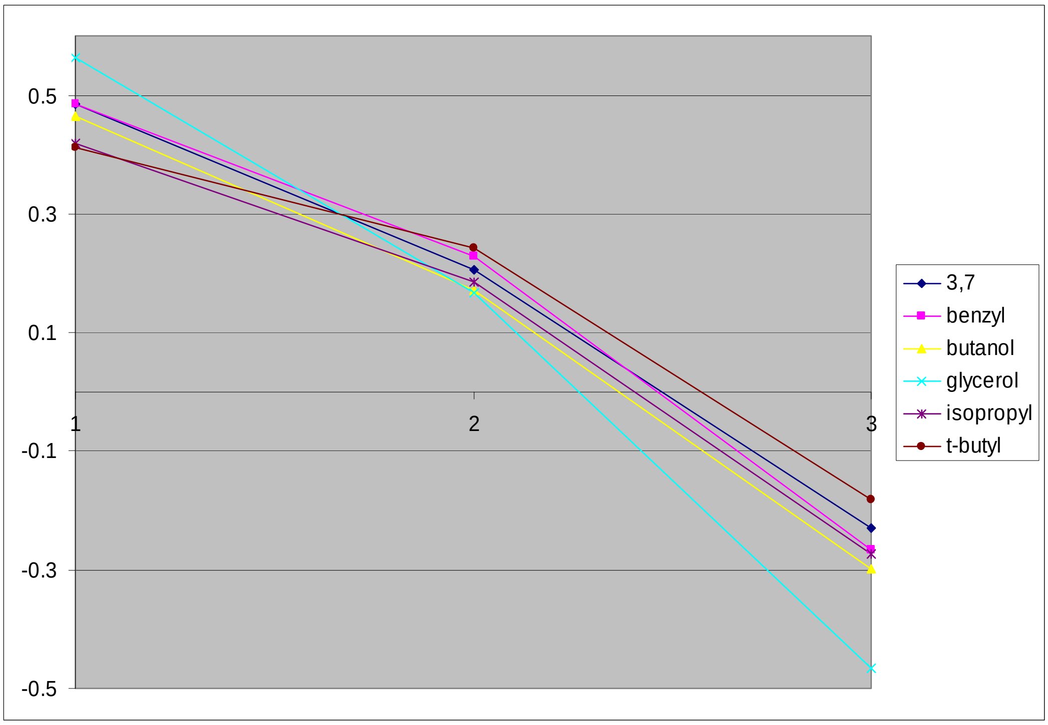
Non-pulsed Data



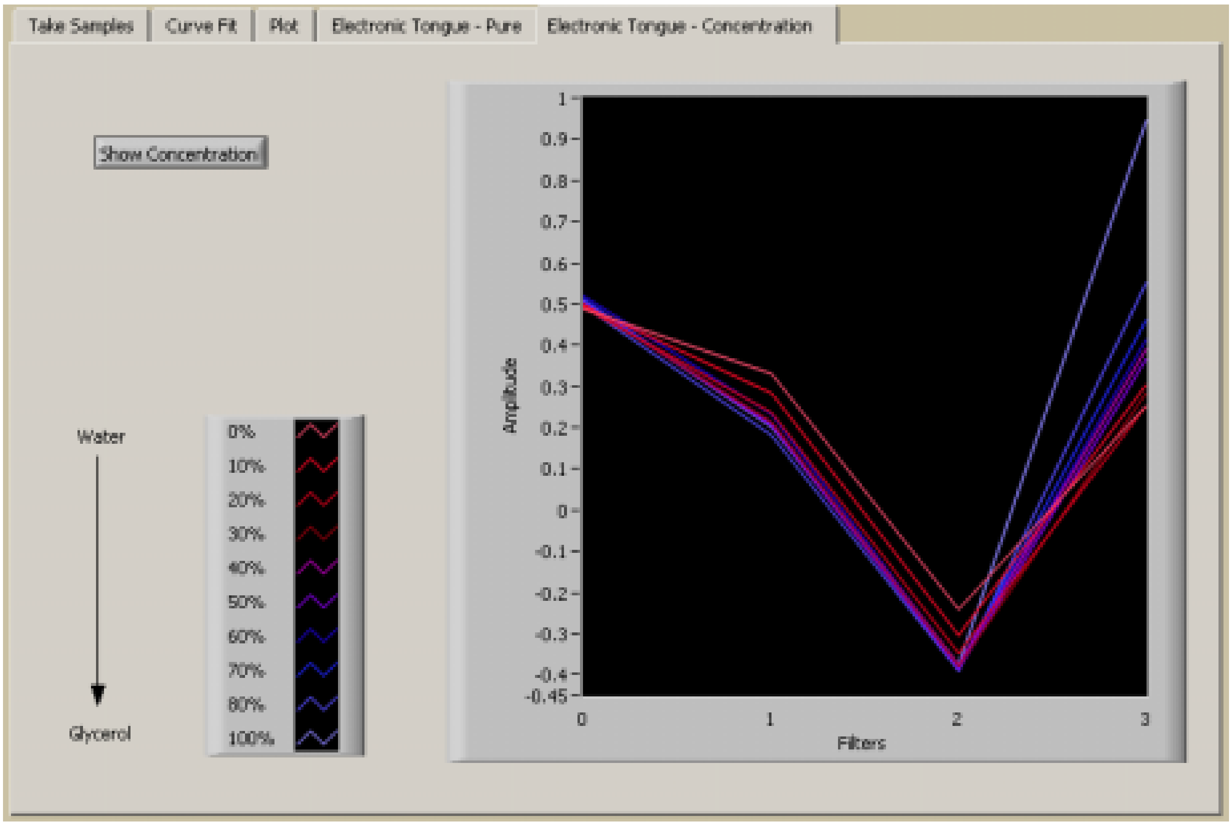




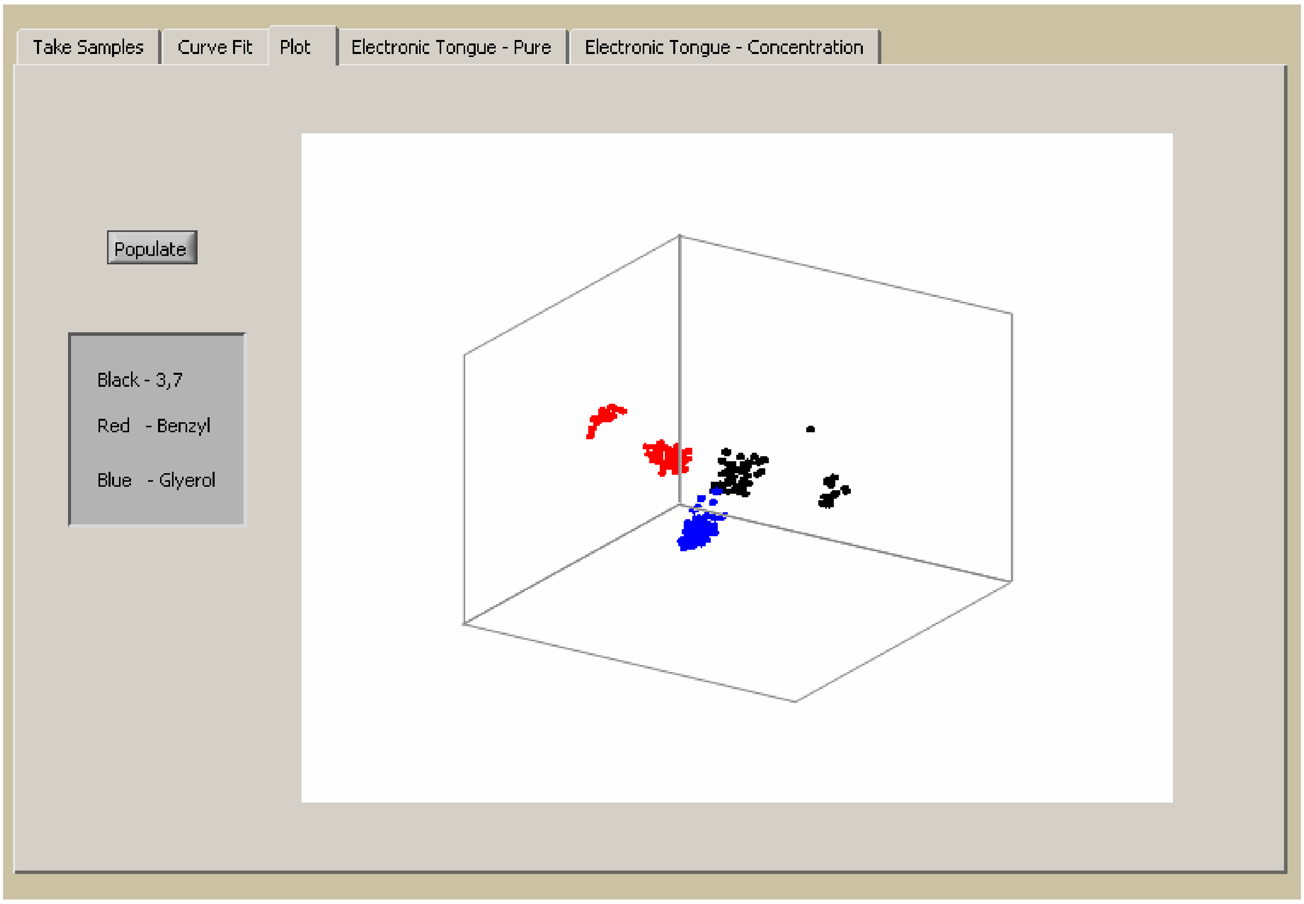
5.3 Fingerprints of 6 Alcohols



5.4 Concentration Results



5.5 Raw Data with Sensors as Axes



5.6 Analysis of Results

Electronic Tongue Pure Alcohols:

According to our results (see section 5.1 and 5.2), this functionality has been implemented and tested fully. We used three alcohols: benzyl alcohol, 3,7-dimethyl-1-octanol, and glycerol as our test subjects and the Electronic Tongue can distinguish between them.

Electronic Tongue Concentrations:

According to our results (see section 5.4), the ability to determine concentrations in water has been proven to be possible. Theoretically, the same results should be available as mixtures of alcohols also. We did not implement the matching function, so we only display the data we have acquired by concentration.

6 COURSE DEBREIFING

- *Did our group management style work? If we were to do the project again, what would we do the same, what would we do differently?*

  We broke tasks up by who had the most experience in that area. This worked very well for us. We used our class time wisely and had two meetings a week. We would continue to do these things if we had to do it again, but we would spend more time outlining exactly what we want to do before acting on it.

- *Are there any particular safety and/or ethical concerns with your product(s)? What steps did your group take to ensure these concerns were addressed? Are there any additional steps you would have taken if you were to do the project again?*

  Working with chemicals will always require safety precautions. We wore goggles and gloves when handling the alcohols. The chemicals are flammable, but we consulted a chemistry professor to determine how to store them.

- *Did you test your product(s)? Do they work as advertised? Can you think of any relevant situations in which you haven't tested your product(s)? If you were to do this project again, what additional verification and testing procedures might you add?*

  Yes, it has been tested, yes it identifies pure alcohols. It has not been fully tested with concentrations and mixtures, though theoretically possible and we would implement these if we had more time.

7 APPENDICES

7.1 Bibliography

Baker http://www.wooster.edu/chemistry/is/brubaker/ir/default.html

Sliney DH, Vorpahl KW, Winburn DC.

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=1054562&dopt=Abstract

Company Websites:

- Dexter Research
  http://www.dexterresearch.com
- International Crystals
  http://www.icmfg.com/
- Hawkeye
  http://www.hawkeyetechnologies.com
- National Instruments
  http://www.ni.com

7.2 User Manual and Installation Guide

This section is designed to walk a user through installation and use of the Electronic Tongue.

Set up:

- Obtain and Install National Instruments LabVIEW on your pc.
- Install the included drivers for the National Instruments 6009 DAQ Card from the included CD-ROM.
- Install the Electronic Tongue (.vi) from the included CD-ROM.

Running the Electronic Tongue:

- Attach the 9 Volt batteries to the battery leads inside the product box.
    - Please be sure to charge them fully prior to use.
- Prepare a sample to be tested by placing one drop of an unknown compound between two of the silver chloride plates. (Please store these plates in a dark place).
    - Be sure to use the flat sides of the plates to receive good readings.
- Place the plates into the white holder, and place inside the box.
- Run the ElectronicTongue by double clicking on it.
- Click the white arrow to begin the program.
- Follow the on screen instructions.

7.3 Product datasheets

Please see the following pages.

- IR Microsystems Examples
- NI DAQ Card
- Hawkeye Infrared Emitter
- International Crystal Laboratories – Cell Kit
- Dexter Research Thermopile Detector
- MOSFET
- Burr Brown INA118
- Voltage Regulators

7.4 Material Safety Data Sheets

Please see the following pages.

- 1-Octanol, 3,7-Dimethyl
- Benzyl Alcohol
- Glycerin Alcohol