Integrated Hydrometer System for Fermentation Testing and Control

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Project Outline

- Introduction
- Problem Statement & Solution
- System Design Overview
- Hardware Design
- Software Design
- Unit Testing and System Integration
- Knowledge Gained & Lessons Learned
- Conclusion

Introduction

- Fermentation Process
  - Stages of Fermentation
- Possible Methods of Control
  - Potassium Sorbate
- Hydrometer Purpose and Functionality
  - Archimedes' Principle

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Problem Statement and Solution

- Find the exact measurement of Specific Gravity using a hydrometer
- This shall remove:
  - Human Error
  - Constant Cleaning routines
- This shall allow:
  - Multiple vats to be monitored simultaneously
  - Control these vats using a central source
  - Transfer data wirelessly

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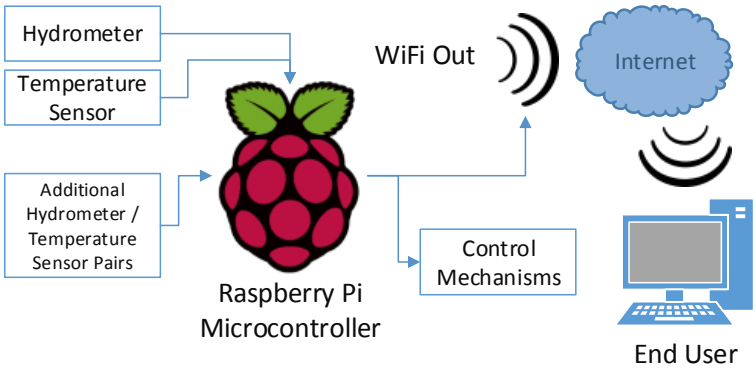
High Level Design



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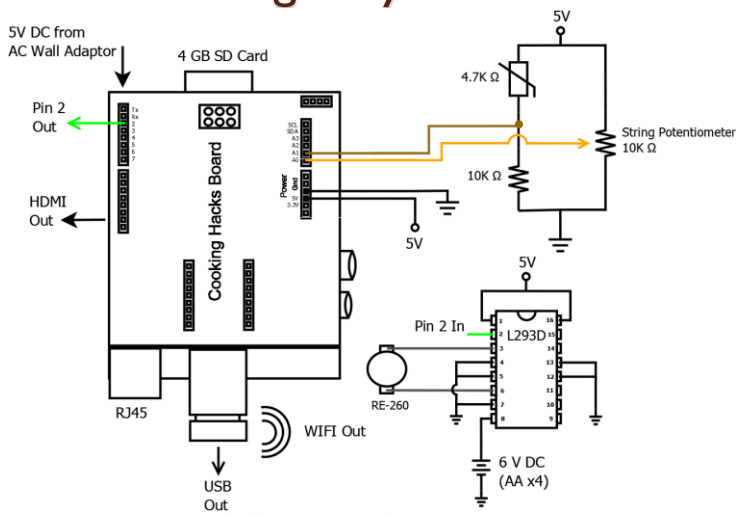
Hardware Design - Circuit Design Layout



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Raspberry Pi & Arduino Bridge Specifications

- Raspberry Pi
  - ARM 1176JZF-S 700MHz
  - 512 MB onboard Ram
  - Size of a credit card
- Cooking Hacks Arduino Bridge
  - 8 Digital and 8 ADC ports
  - i2C pins SDA and SLC
  - Sits directly on top of the RPi

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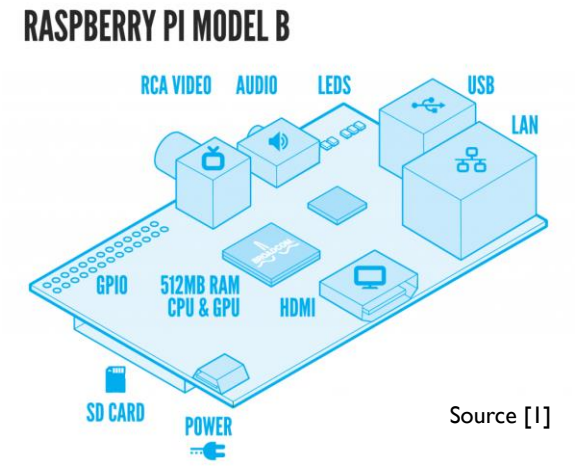
Raspberry Pi Layout



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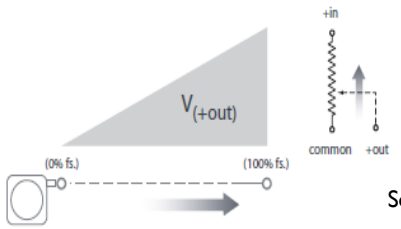
SP2-12 String Potentiometer Specifications

- Rated at 10KΩ, 12.5" pull range
- Measured at 10.3KΩ at rest
- 390 Ω at full stroke
- Resistance decreases/ Voltage Increases

Output Signal:



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NTC Thermistor and L293D Specifications

- 4.7K Ω NTC Thermistor
- B Value: 3984

- L293D Push-Pull Four Channel Driver
- Outputs 600mA per Channel
- Outputs 1.4 V Norm / 1.8 V Max
- Measured to be 1.1 V during operations

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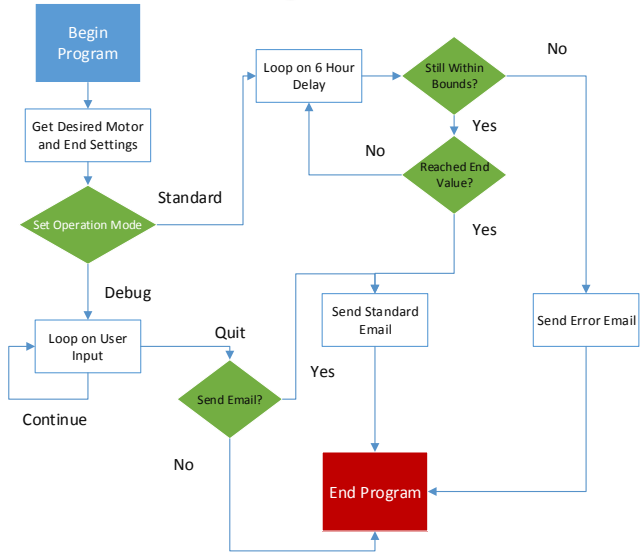
Software Design



Programming Language and IDE

- GNU GCC C++ Compiler
- Written with Nano, Leafpad and Code::Blocks
- Compiler Call:
  - g++ -g –I/include/ -I/local/include –I/local/lib/pkgconfig –lrt –lpthread finalprog1.cpp ardupi.cpp –o finalprog –lcurl

Important Segments of Code

```
//Set up Cooking Hacks Bridge
void setup(){
  Wire.begin(); // join i2C bus
  pinMode(2, OUTPUT);  //for L293D chip control }
}

//Channel 0 ADC
Wire.write(byte(0xDC));
//Channel 1 ADC
Wire.write(byte(0x9C));
```

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Important Segments of Code Cont.

```
//Motor Control
printf("Activating Motor.\n");
digitalWrite(2, HIGH);
delay(300);
digitalWrite(2, LOW);

//cURL File Pointer
curl_easy_setopt(curl, CURLOPT_READDATA, fp);
```

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Software Troubleshooting

- RPi is UK made, defaults to UK Keyboard
  - Changed Default Keyboard Layout
- Arduino Library i2C-tools not functional
  - Installed the i2C-tools and modified the /etc/modules file
- cURL not reading 'payload' data
  - Changed data into a File Pointer to a .txt file
  - curl_easy_setopt(curl, CURLOPT_READDATA, fp);

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Software Troubleshooting Cont.

- Gmail SMTP server not responsive
  - Switched to Windows Live SMTP Server
- Compiling the program with all libraries
  - g++ -g –I/include/ -I/local/include –I/local/lib/pkgconfig –lrt –lpthread finalprog1.cpp ardupi.cpp –o finalprog –lcurl

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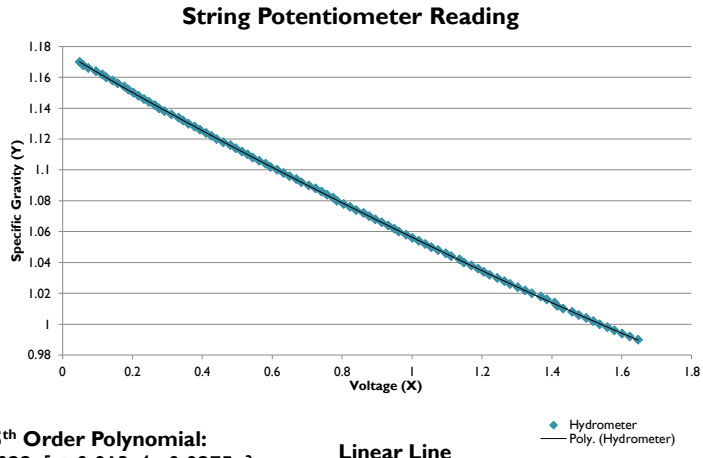
Unit Testing and System Integration



5th Order Polynomial:
$y = -0.0022x^5 + 0.013x^4 - 0.0275x^3 + 0.035x^2 - 0.1387x + 1.1767$
$R^2 = 1$

Linear Line
$y = -0.113x + 1.1711$
$R^2 = 0.9986$

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Measurements

- String Potentiometer: rated at 10KΩ
  - Actual: 10.3K Ω at rest
  - 390 Ω when fully extended.
- Thermistor- rated at 4.7KΩ
  - Found to be accurate at 5KΩ @ 74°F, which is accurate to the datasheet.
- 3 V DC Motor
  - Requires external power source, using 4 AA batteries.
  - Found to turn a large piston effectively and consistently.

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Formulas Used

- Resistance of the Thermistor

$$Rt = \frac{Va * Rs}{5V - Va}$$

- Simplified B Value Steinhart Hart Equation

$$\frac{1}{T} = \frac{1}{T_0} + \frac{1}{B}\ln\left(\frac{R}{R_0}\right)$$ Units in Kelvin. Source [3]

- Specific Gravity Correction Formula
  - Final Specific gravity =

Current Specific gravity + (((1.313454 - 0.132674*F + 0.002057793*F^2 - 0.000002627634*F^3) * .001) Source [4]

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Formulas Used Cont.

- ABV = (Initial SG Reading – Final SG Reading) * 131.25
- US Standard Proof = ABV*2
- Brix = (((182.4601 * SG -775.6821) * SG +1262.7794) * SG -669.5622)

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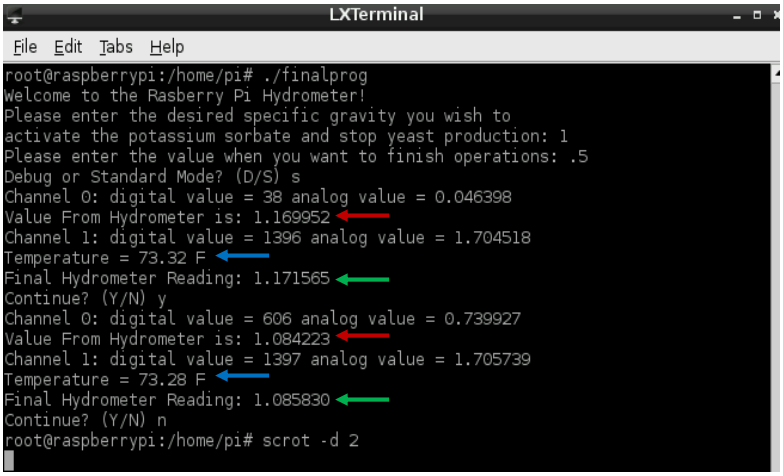
Terminal View



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Email Results

Date Collected: Mon Apr 29 07:29:23 2013

Desired Hydrometer Setting: 1.100
Desired End Hydrometer Reading: 1.000
Initial Hydrometer Reading: 1.172
Final Hydrometer Reading: 1.061
Initial Brix Reading: 38.65
Final Brix Reading: 14.98
Alcohol By Volume of this Vat: 14.54%
29.08 Proof

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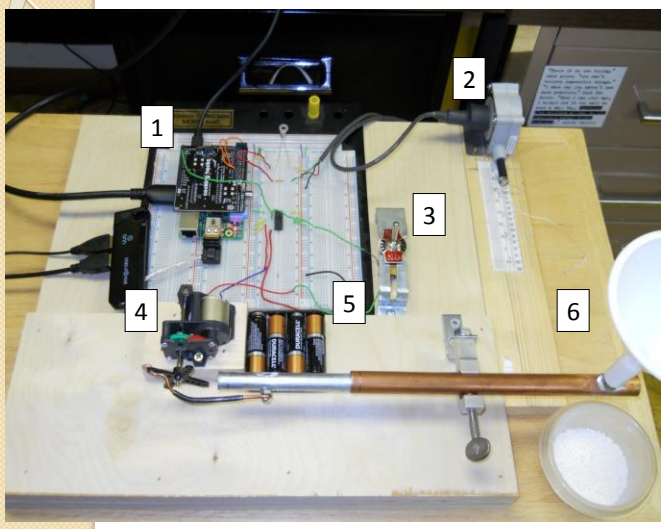
Physical Layout



1. Cooking Hacks Arduino Bridge / RPi

2.SP2-12 String Potentiometer

3. Motor Control Switch

4.RE-260 Motor and Gearbox

5. AA Battery Pack

6. Output Piston with Potassium Sorbate

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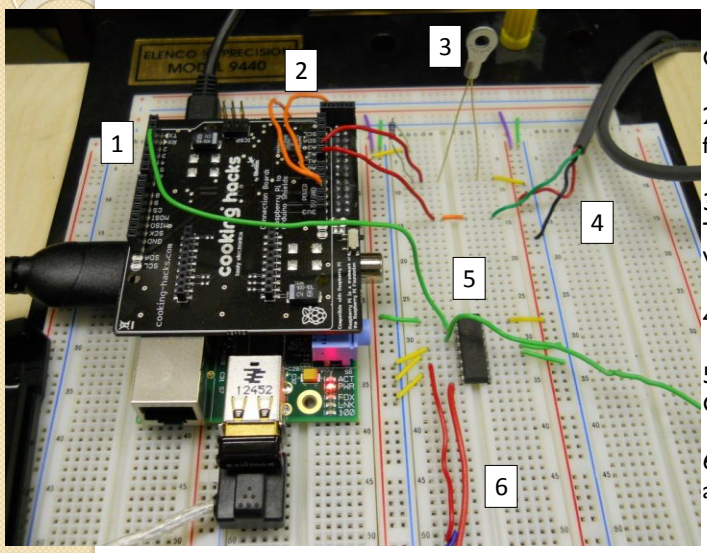
Physical Layout – Small Components



1. Green Pin 2 Digital Output

2.Orange 5V DC PWR from RPi

3. 4.7KΩ NTC Thermistor with 10KΩ Voltage Divider Resistor

4. Input from SP2-12

5. L293D Motor Control Chip

6. Battery PWR Input and Motor Circuit Wire

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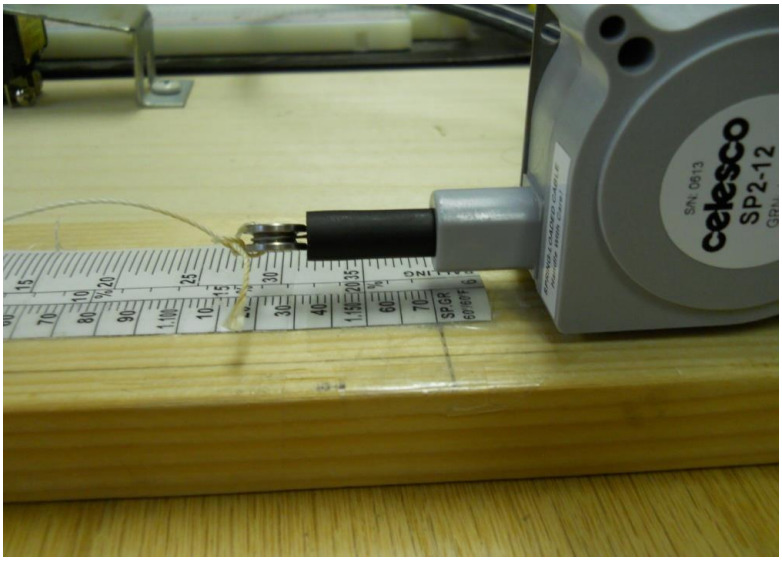
SP2-12 High Resolution



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Piston Output

Grains	Grams
12.3	0.797045
12.5	0.810005
14	0.907206
11.7	0.758165
13.2	0.855365
12.9	0.835925
12.9	0.835925
13.9	0.900726
12.5	0.810005
12.9	0.835925
Average in Grams	**Standard Deviation**
0.834629	0.045391

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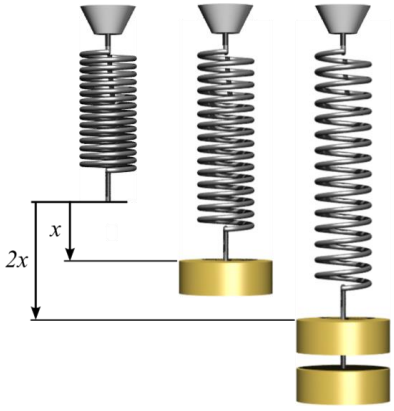
Problem – Hooke's Law

$$F = kx$$



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Primary Requirements Met

- 3. This system shall allow for multiple hydrometers to be installed and controlled.
- 6. Hydrometer shall be accurate to Specific Gravity, g/cm^3, by ±1 degrees.
- 22. The project shall have the microcontroller wirelessly communicate with the user.
- 25. This project's user interface shall display all the required information.

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Knowledge Gained

- Resources and Hardware
  - Use of the cURL and its Library
  - Use of the Raspberry Pi interface and OS
  - Use of the Arduino Library
  - Further Knowledge of several small components

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Lessons Learned

- Time Management
  - Plan Ahead
  - Not to take on a project lightly
- Risk Management
  - When to brainstorm and when to act
  - Consider other possible methods.
  - Further insight into the debugging process

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Conclusion

- Project simulated successfully
- All parts can be used for future projects
- All programs can be reused for future projects

References

- [1] “FAQ," Raspberry Pi, [Online]. Available: http://www.raspberrypi.org/faqs [Accessed 29 April 2013].
- [2] Celesco, "Celesco.com," 26 February 2013. [Online]. Available: http://www.celesco.com/_datasheets/sp2.pdf. [Accessed 29 April 2013].
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- [4] V. &. Company, "PrimeTab," 25 Mar 2002. [Online]. Available: http://www.primetab.com/formulas.html. [Accessed 15 4 2013].
- [5] "Hooke's law," Wikipedia, 28 April 2013. [Online]. Available: http://en.wikipedia.org/wiki/Hooke%27s_law. [Accessed 29 April 2013].

Demonstration