RefriEco

Presents the DualCooler

An Environmentally Friendly Refrigeration System

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The Team

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Outline

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- **Business Overview**
  - Market and Competition
- **Hardware**
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- **Software**
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  - Challenges
- **Conclusion**
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Motivation

- Many of our parents store some refrigerator worthy items outside during the winter

So why not use the same cold air to cool the contents of a refrigerator?

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Motivation

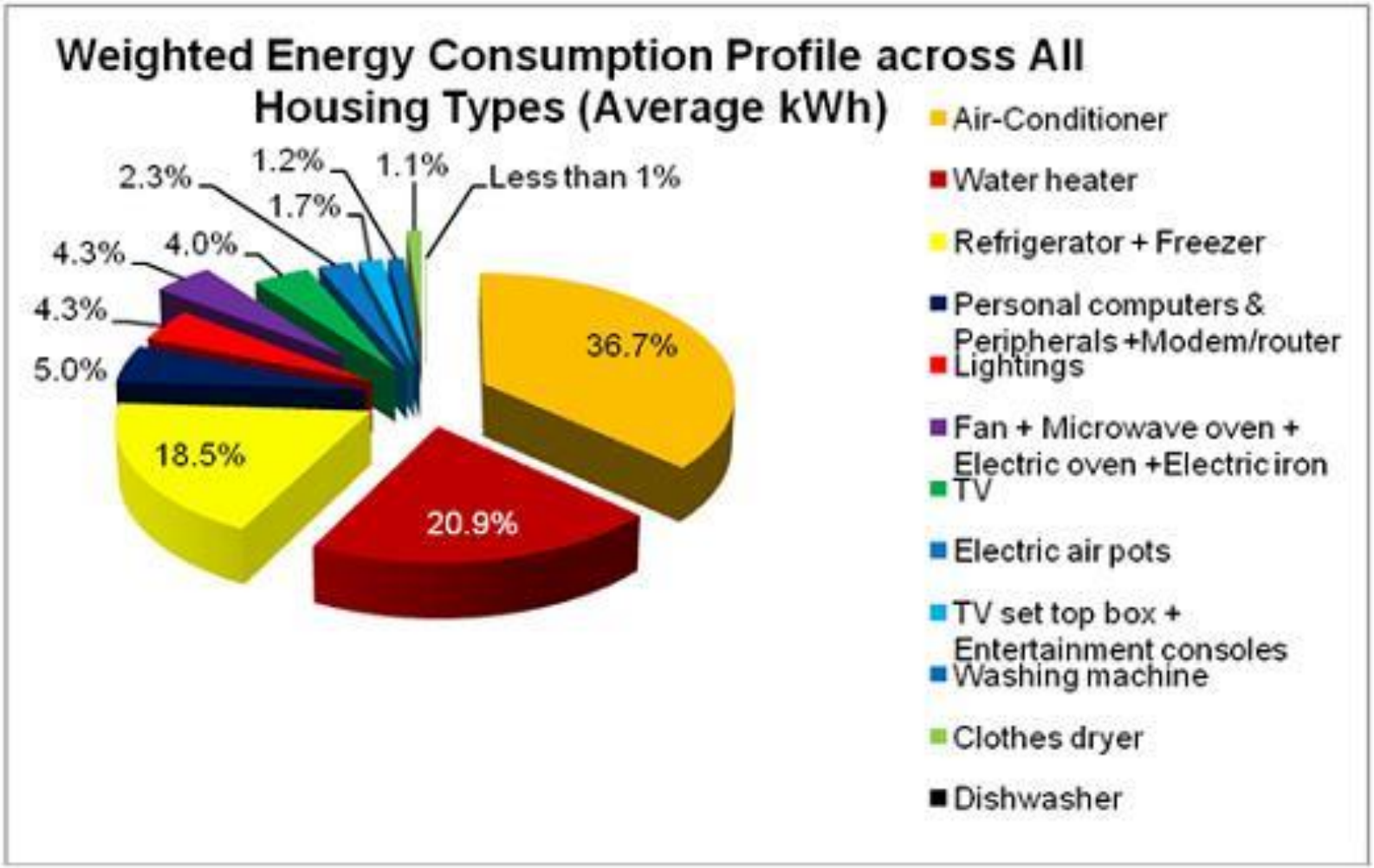

Figure 1: Weighted Energy Consumption in a typical household [1]

Background

- Our ideas and project specifications are derived off:
  - Geothermal energy heating/cooling systems
  - HVAC central air conditioning systems
  - Natural lighting – light pipes

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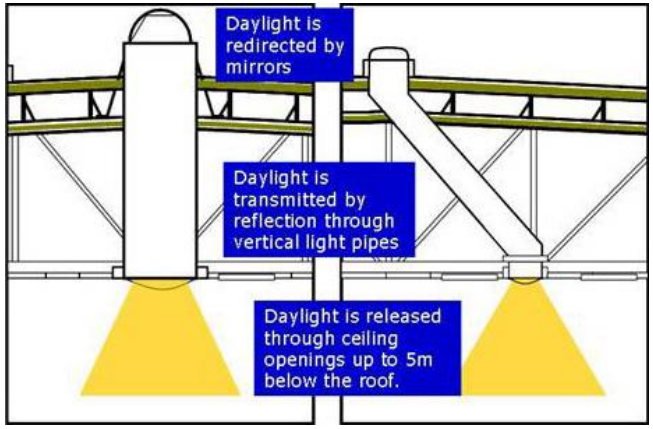
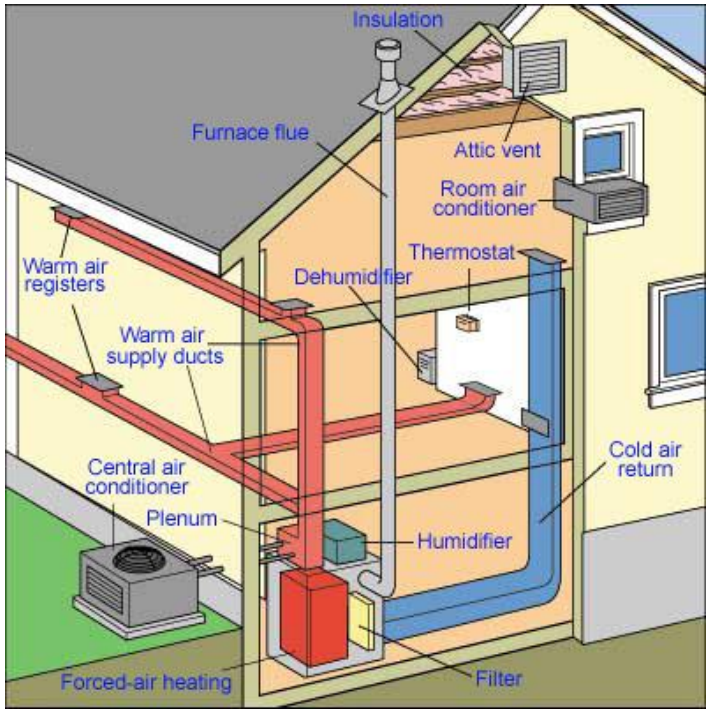
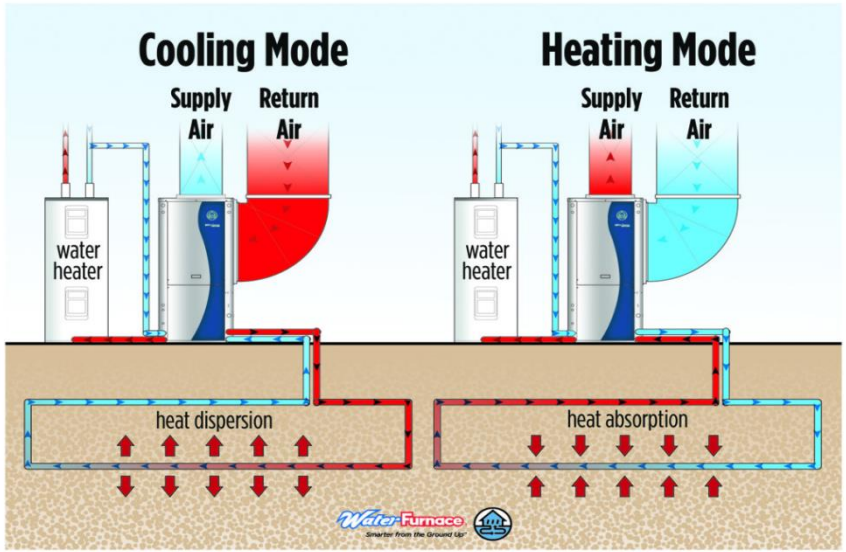
Background







Clockwise from Top Right: Natural Lighting (Light Pipes) [1], HVAC Air conditioning[2], Geothermal Heating/Cooling [3]

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Implementing a Solution

Solution 1:

- Cooling just the radiators behind the fridge
- Speeds up cooling the refrigerator
- Compressor stays on for shorter time
- Saves Power!

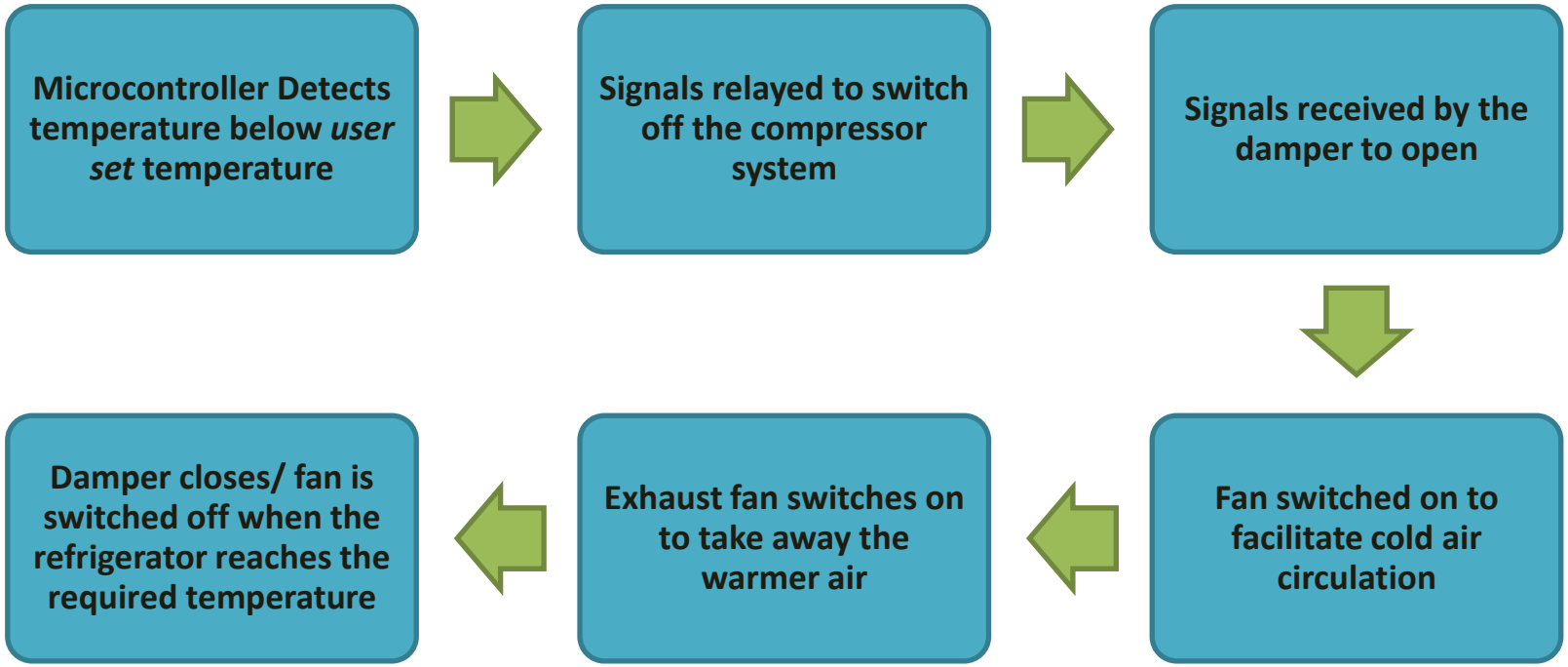
Solution 2:

- Route the cold air into the fridge and cool it directly
- Compressor not in use at all as long as temperature outside is cold enough
- Saves More Power!

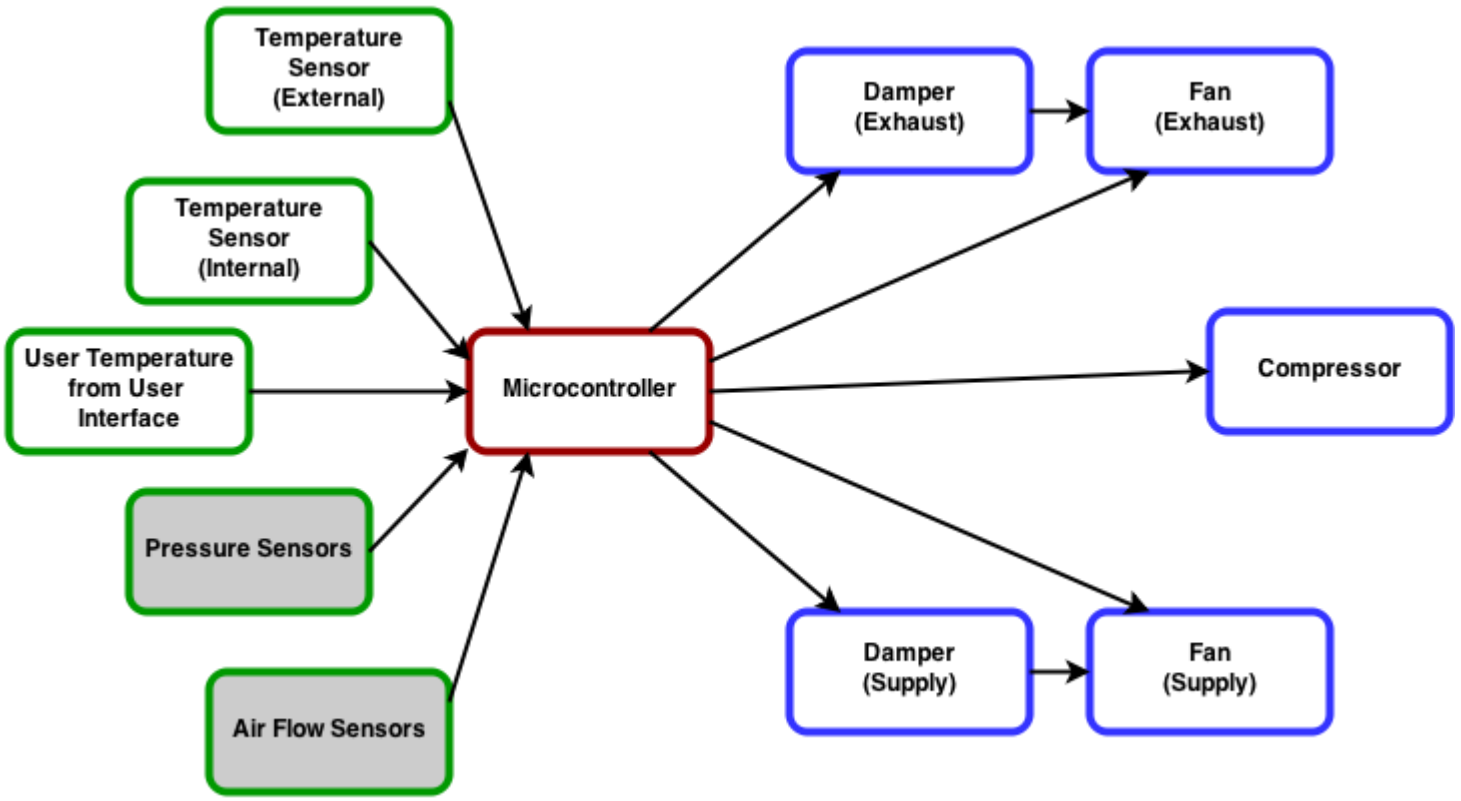
System Overview

- Two modes:
  - Compressor Mode
    - External temperature ≥ User Set Temperature
  - RefriECO Mode
    - External temperature < User Set Temperature

RefriECO Mode



Block Diagram



Facts

Normal Average Energy Consumption:

= 325 kWh/year

Energy Consumption with DualCooler:

= 216.46 kWh/year

Savings

= 108.54 kWh/year ≈ $12.85/year

*Based on Calgary temperature statistics for 1998 - 2012

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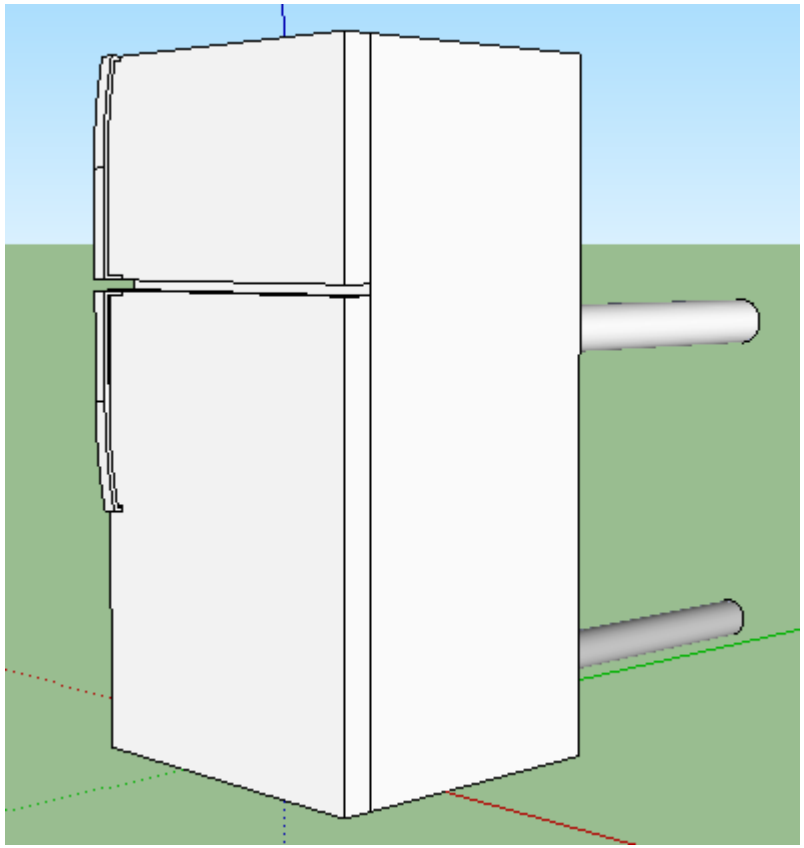
Our Results

- Without our system, with just the compressor:
  - 66.4 kW•h
- RefriECO Mode:
  - 0.25 kW•h

BUSINESS OVERVIEW

Marketing and Competition

Envisioned Product



Market

- Generally, our targeted audience is people living in colder countries, i.e., North America, Russia
- Approximately 340 million people could be benefitted
- Let also include the fact that this can be used in industrial applications and apartment complexes

Marketing

- Unit cost would significantly reduced when mass produced
- Cheaper sensors
- Drop in the cost for redundant components

Marketing

Unit Price ($)	104.78
Expected Sale Price ($)	150.00
Profit ($)	45.22
Profit Margin (%)	43.2

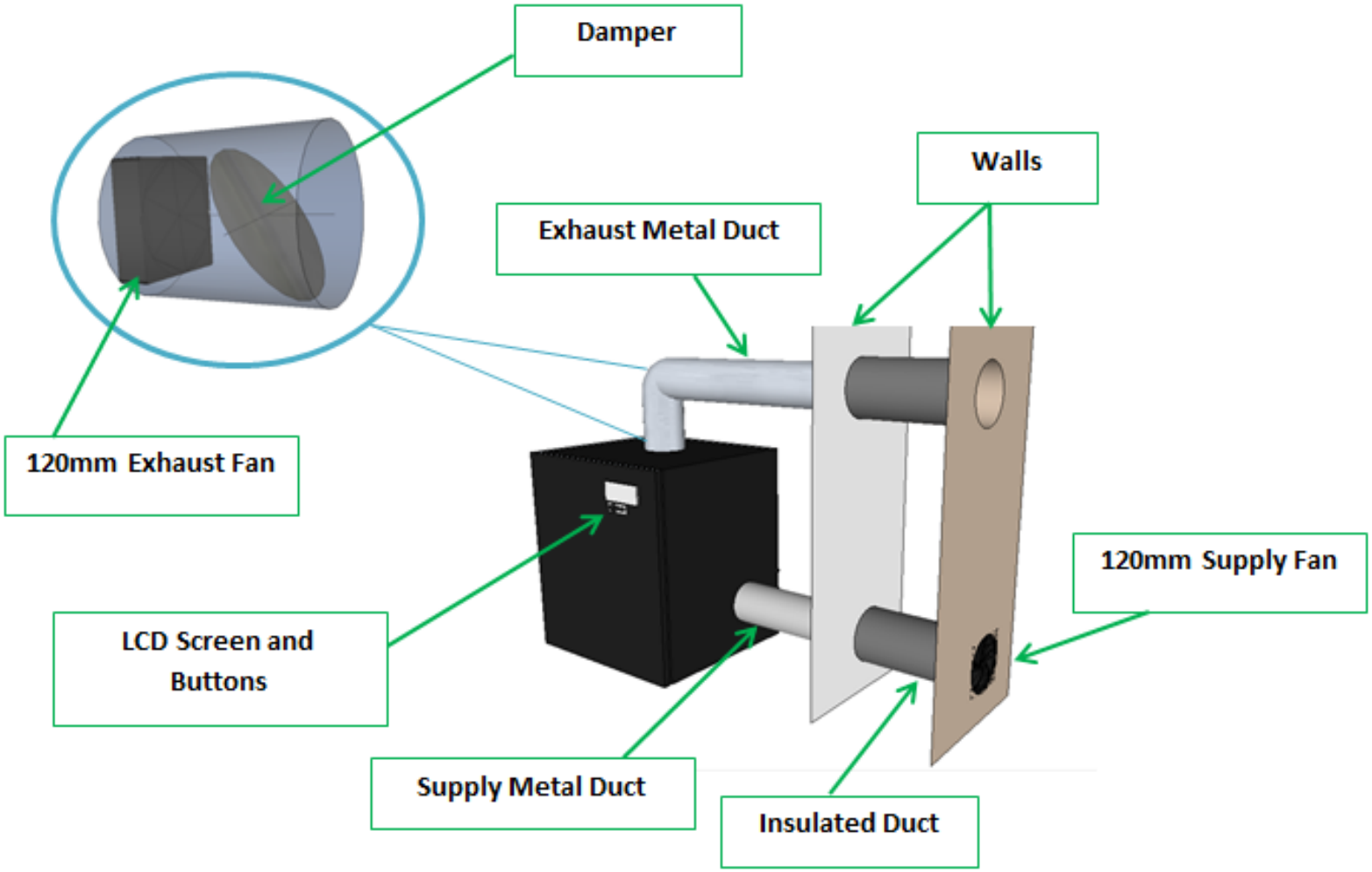
Competition

- Sun Frost Refrigerators utilizes top mounted cooling system to reduce energy consumption
- Vestfrost Refrigerators saves energy by having built-in condenser and cooling tubes

HARDWARE

Components and Description

Parts of the System



LCD Screens and Buttons

- Creates a user interface that allows the user to:
  - Select temperature scale
  - Select the desired internal Fridge Temperature
- Quick Start Guide illustrates the steps briefly

Ducts

- Two Ducts
  - Exhaust
  - Supply
    - Needed to be well insulated
- Contains the fan and connects to the damper

Dampers

- create a closed system when in compressor mode
- Dampers open when in the alternative mode
- Supply and Exhaust dampers
  - Controlled by servos mounted on the outside

Fans

- Two fans
  - Supply fan located on the outside of the building to pull in cold air
  - Exhaust fan located right above the fridge to pull out the warm exhaust air from the fridge

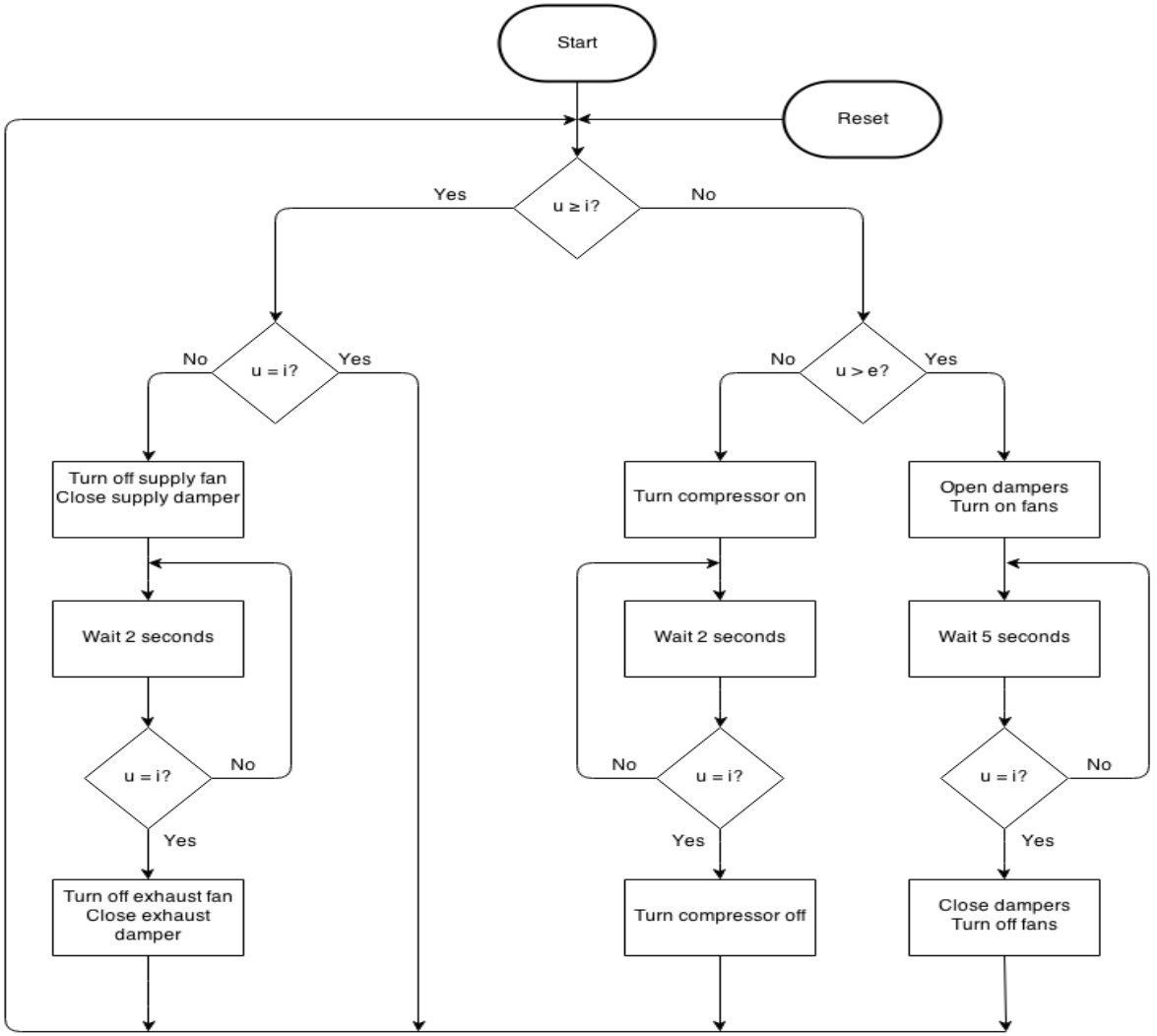
Temperature Sensors

- Two temperature sensors
  - One outside the building (External Temperature)
  - One inside the fridge (Internal Temperature)

SOFTWARE

Flowcharts and the Arduino IDE

Flowchart


Start
Reset
u ≥ i?
Yes
No
u = i?
No
Yes
u > e?
No
Yes
Turn off supply fan
Close supply damper
Wait 2 seconds
u = i?
No
Yes
Turn off exhaust fan
Close exhaust damper
Turn compressor on
Wait 2 seconds
No
u = i?
Yes
Turn compressor off
Open dampers
Turn on fans
Wait 5 seconds
u = i?
No
Yes
Close dampers
Turn off fans

Arduino IDE

- First time using it for a lot of us
- Most of the libraries were ready to use
- Tested one part at a time and integrated
- Adhered to the flowchart

PROJECT LOGISTICS

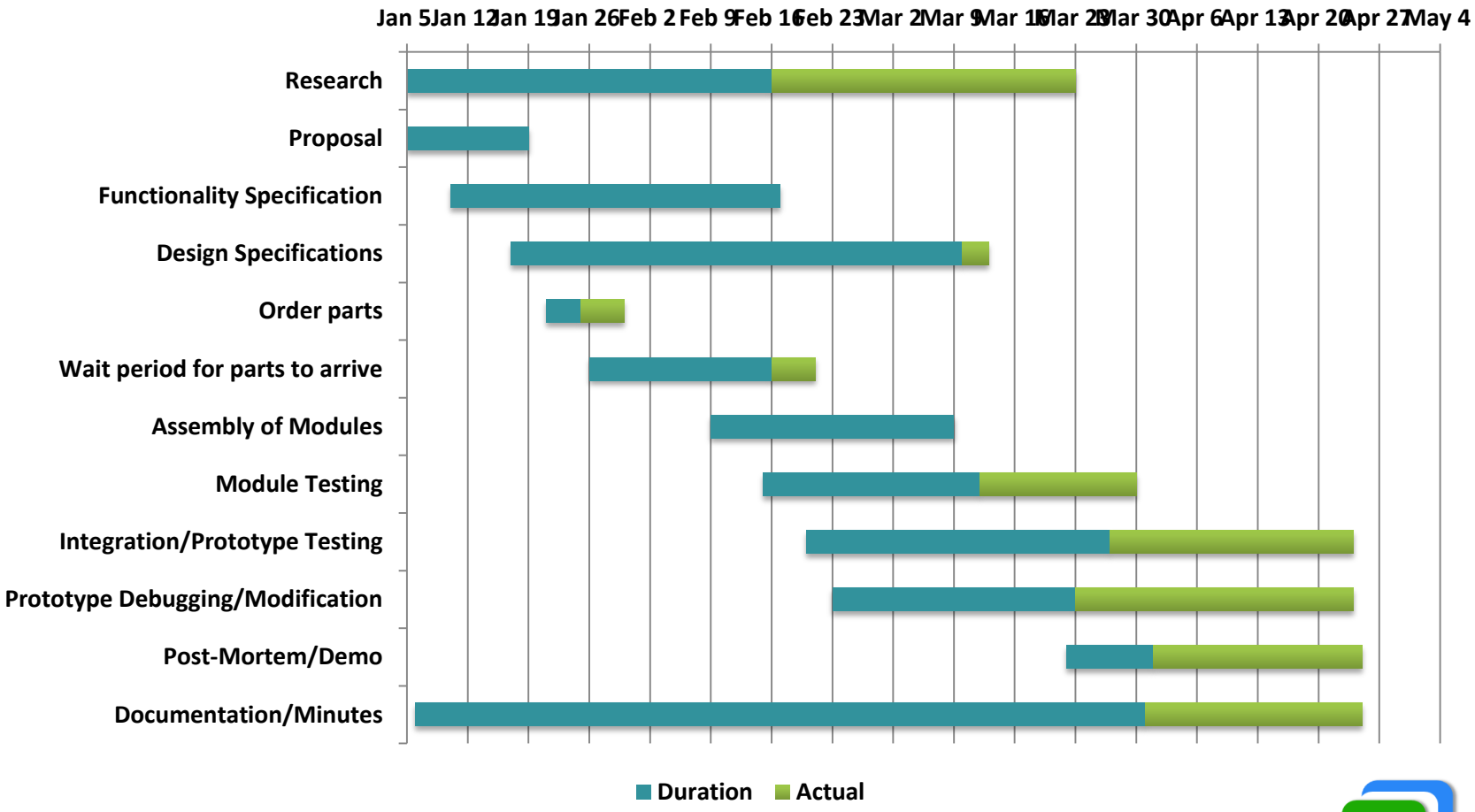
What we wanted and what really happened…

Budget

Component Type	Expected Cost ($)
Mini Fridge	50.00
Analog Temperature Sensor	5.580
Arduino Uno Microcontroller	20.88
Servo Motor	10.00
4 Inch Damper	20.00
5 inch Duct Pipe	30.00
Fans	30.00
Filter	10.00
Miscellaneous Cost	50.00
Total Expenditure	226.46

Component Type	Actual Cost ($)
Mini Fridge	159.99
Pipe Insulation	16.490
2 “5 inch Dampers”	23.980
Waterproof Temperature Sensor	10.500
Digital Temperature Sensor	6.300
IC LM335Z Temperature Sensor	5.000
LCD Shield 2 Pin	29.800
Servo Motor	11.250
2 Channel Relay Board	23.300
2 “5 inch Duct Pipes”	12.760
2 “120mm PWM Fans”	27.980
48 QT Cooler	26.000
Copper clad Presensitized board	17.800
Positive Resist Developer	12.950
Energy Meter	20.000
Miscellaneous Cost	65.000
Total Expenditure	469.10

Timeline


Jan 5
Jan 12
Jan 19
Jan 26
Feb 2
Feb 9
Feb 16
Feb 23
Mar 2
Mar 9
Mar 16
Mar 23
Mar 30
Apr 6
Apr 13
Apr 20
Apr 27
May 4
Research
Proposal
Functionality Specification
Design Specifications
Order parts
Wait period for parts to arrive
Assembly of Modules
Module Testing
Integration/Prototype Testing
Prototype Debugging/Modification
Post-Mortem/Demo
Documentation/Minutes
Duration
Actual

Challenges

- Broke a refrigerator and had to start over again
- Hardware issues:
  - Angular placement of Servos
  - Standalone powering methods for the circuit
  - Switching off the fan
  - Cutting through the fridge
- Trouble ordering parts
- Illnesses

Challenges

Conclusion

- Project looks much better than envisioned
  - Managed to add more features (ie. LCD Display and pushbuttons)
  - Implemented PCB for our circuit
- We're still friends … I think ☺
- Over budget but we have learned our lessons
- Time management is a continuously evolving skill

Future Work

- Possibly add more sensors such as airflow sensors that would help monitor airflow
- System should be simplified/optimized
  - More compact PCB's
  - Reduce clock frequency to save power
- Make it wireless
- Implement system with freezers

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Alireza Rahbar
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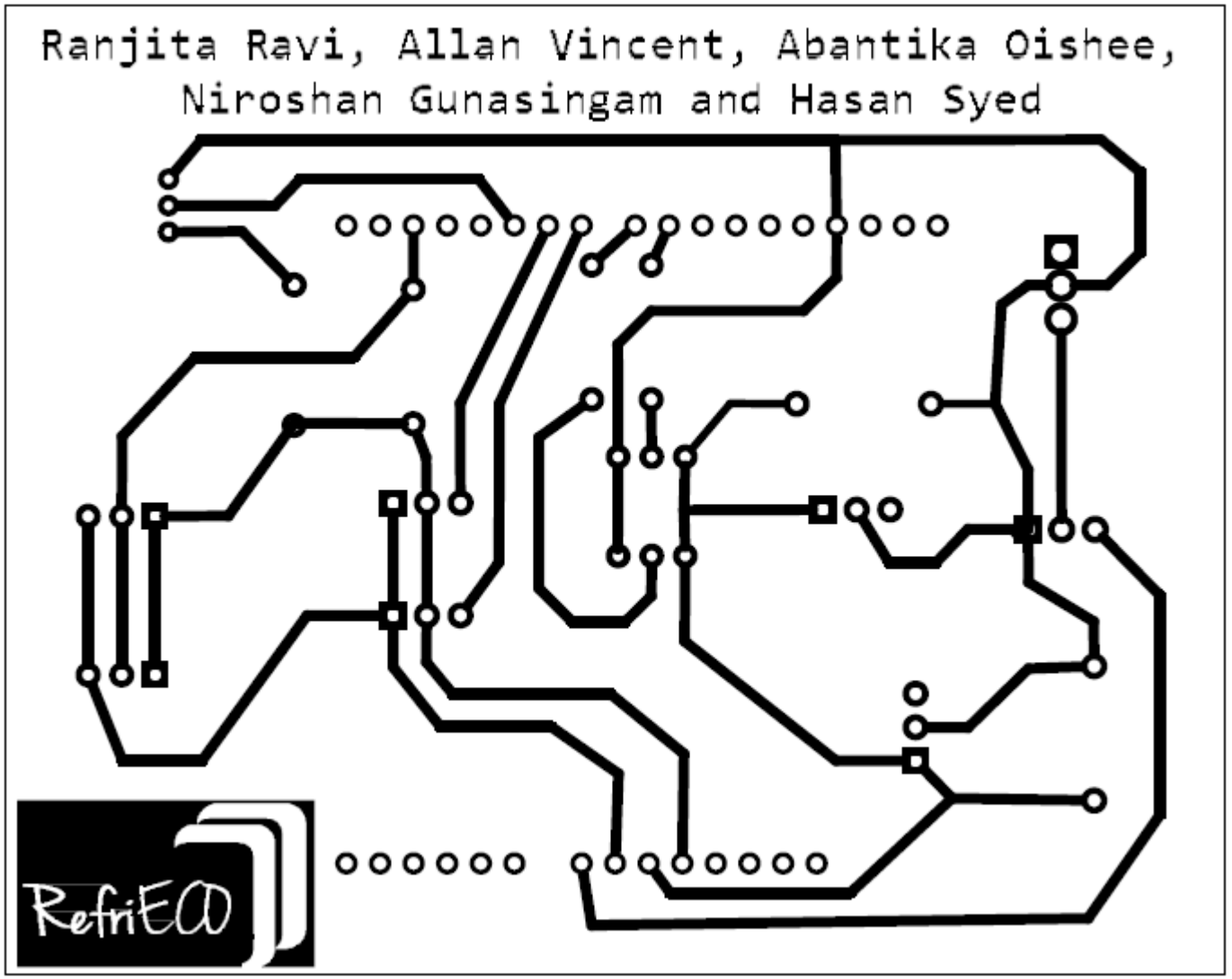
Gary Houghton
Wael Jendli
Ibrahim (Kofi) Appiah
Riddhi Bhide
Sunny Bains
Our Families

Questions

Additional Information

Schematic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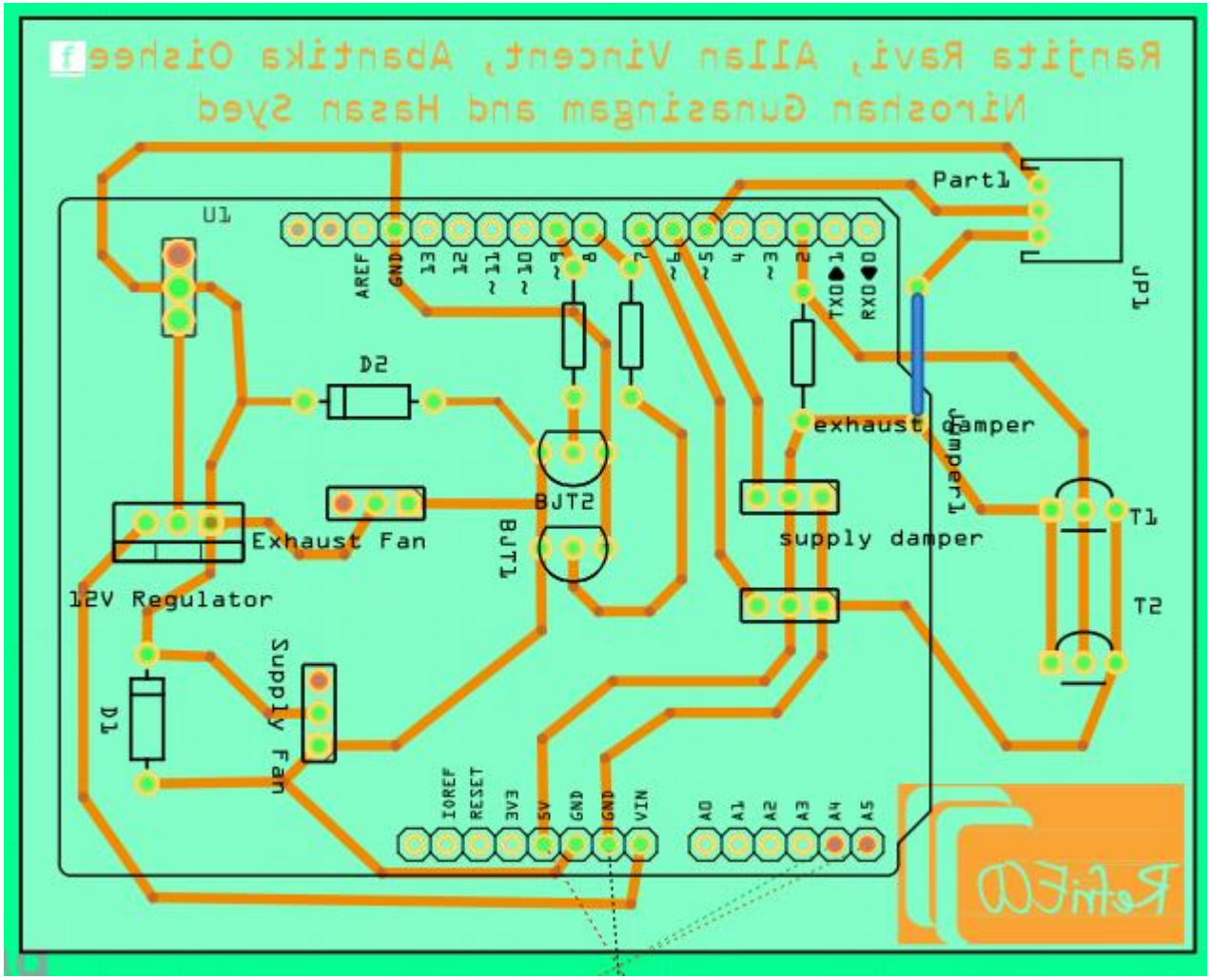
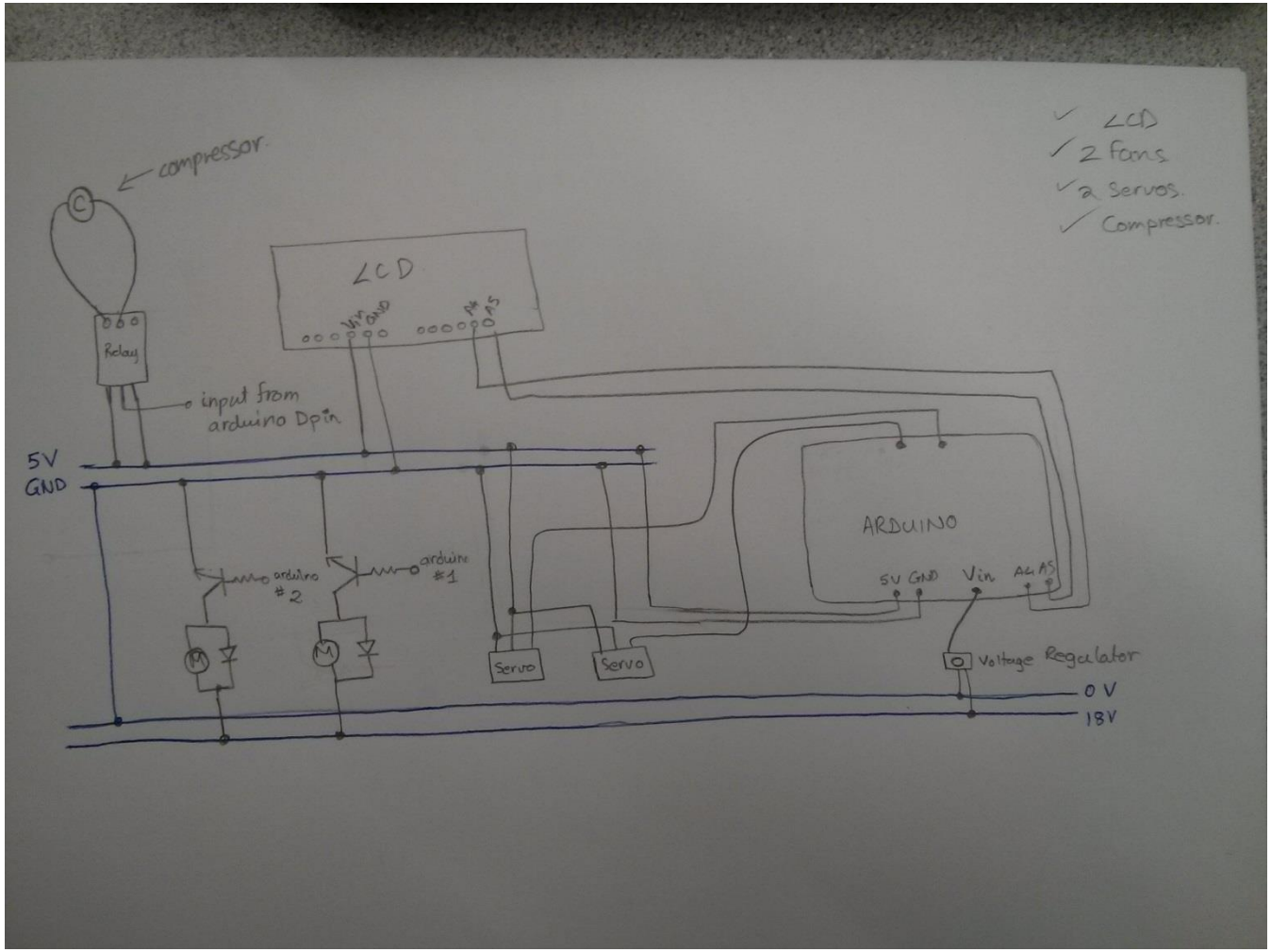
Schematic


Ranjita Ravi, Allan Vincent, Abantika Oishee
Nirosha Gunasingam and Hasan Syed
U1
Part1
J1
D2
exhaust damper
Jumper1
BJT2
BJT1
Exhaust Fan
supply damper
T1
T2
12V Regulator
D1
Supply Fan
AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TXD 1
RXD 0
IOREF
RESET
3V3
5V
GND
GND
VIN
A0
A1
A2
A3
A4
A5

Schematic


compressor
LCD
Relay
input from arduino Dpin
5V
GND
arduino #2
arduino #1
Servo
Servo
ARDUINO
5V GND Vin A4 A5
Voltage Regulator
0 V
18V
LCD
2 fans
2 servos
Compressor

References

[1] "National Environment Agency," Government of Singapore, 3 June 2013. [Online]. Available: http://app2.nea.gov.sg/grants-awards/energy-efficiency/eenp-awards-2012/news-release. [Accessed 24 April 2014].

[2] "Singapore Government," Building and Construction Authority, 2010. [Online]. Available: https://www.bca.gov.sg/zeb/daylightsystems.html. [Accessed 17 April 2014].

[3] "Dan Vandervort's Home Tips," Dan Vandervort's Home Tips, 2014. [Online]. Available: http://www.hometips.com/how-it-works/forced-air-heating-systems.html. [Accessed 17 April 2014]

[4] "How It Works: Geothermal Heat pumps," BGE Homes: A Constellation Company, 2014. [Online]. Available: https://www.bgehome.com/geothermal_howitworks.php. [Accessed 17 April 2014].