Automated Specialized Coffee Machine

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Background

Problem Statement:

- No automated coffee machines for specialized coffee
- Process takes precision and time
- Costing individuals a lot of time and effort

Proposed Solution:

- Automating the process of making an AeroPress Coffee

Market:

- US coffee industry is estimated at $48 billion
- 55% of the market space is specialized coffee
- 20% increase in speciality coffee sales every year

Types of Coffee Machines

Filtration

- Drip machine
- Percolator
- Chemex

Seeping

- French Press
- Soft brew

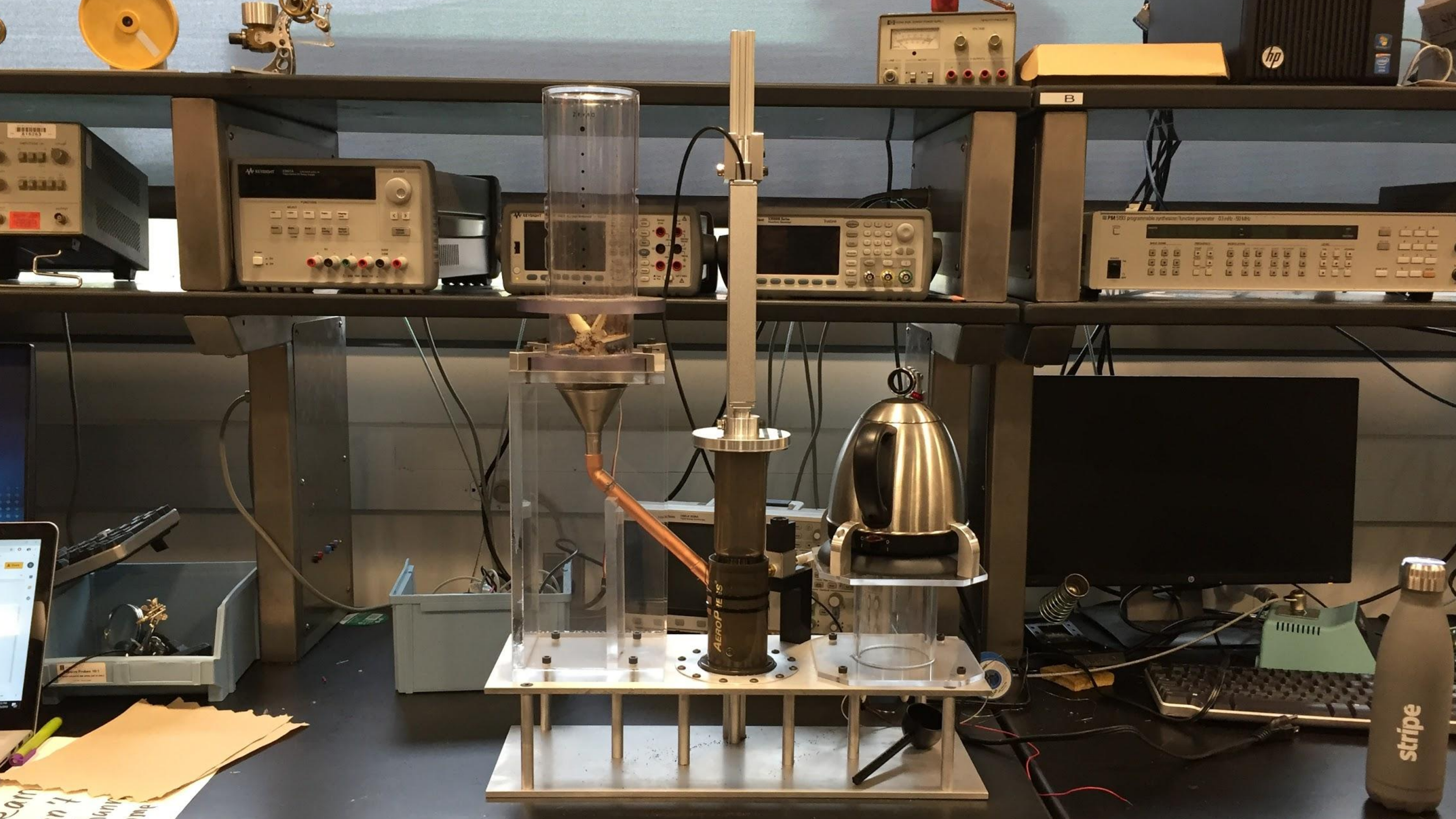
Pressure

- Espresso Machine
- Moka Pot
- AeroPress

Introduction

AeroPress:

- What is an AeroPress?
- Process of an AeroPress
  - Loading coffee grounds
  - Water heating
  - Pressing the mix through the filter
- Similar products
  - No mass manufactured industrial products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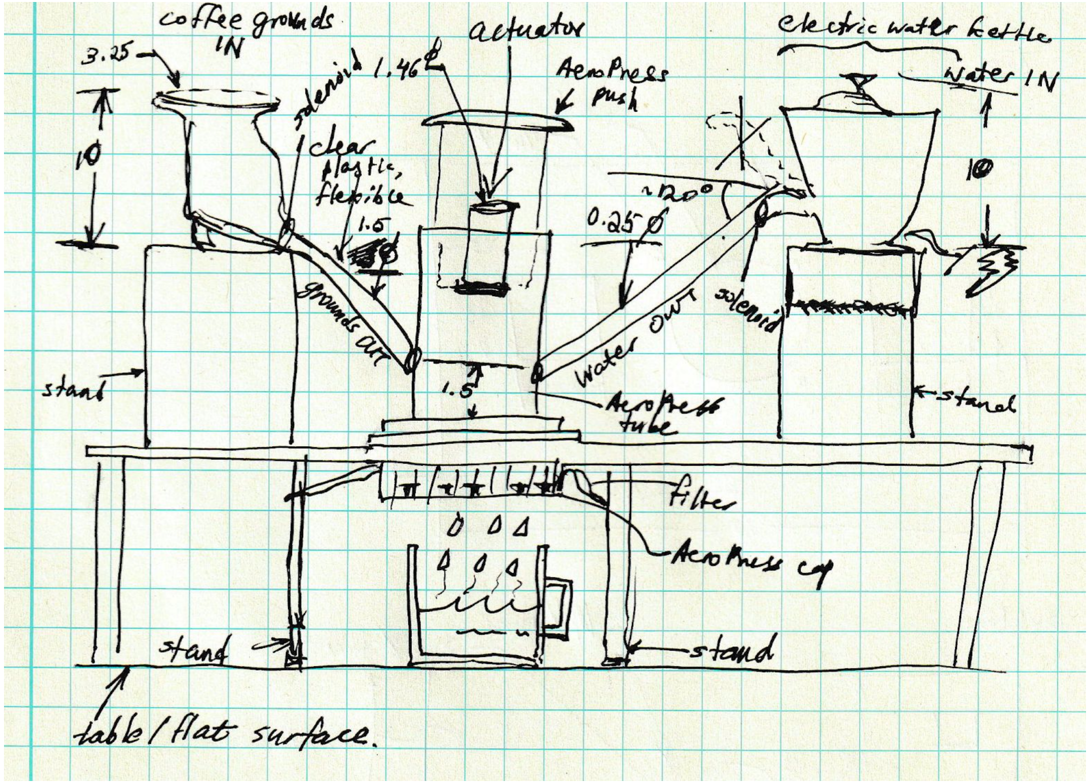
High-Level Requirements

- The coffee machine brews and dispenses one cup of AeroPress coffee at a time.
- The kettle temperature is programmable between 175 °F – 210 °F in 5 °F increments.
- The pressure used is 0.55 bar for pressing the coffee beans, and it must be consistent within a range of ± 0.2 bar.

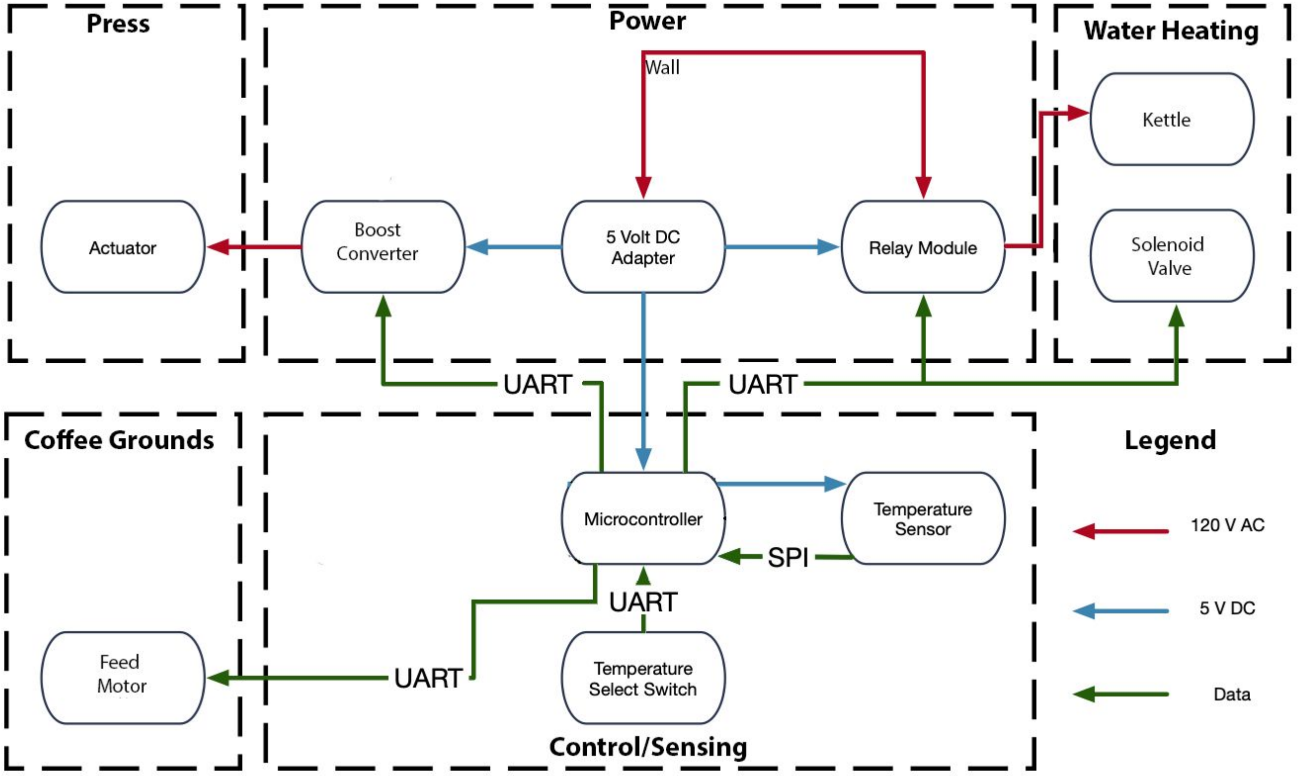
Ethical and Safety Concerns

- Machine uses food-grade components since coffee is for human consumption
- Grounded electrical inputs
- Temperature capped
- Water components physically separated from electrical components
- Association of Computing Machinery (ACM): “avoid harm”, including “unjustified physical or mental injury”
- Coffee “dangerously hot” so keep temperature low

Physical Diagram



Block Diagram



Grounds Subsystem

- User inserts desired coffee grounds
- Consists of a feed motor
    - PWM control
- Allows most grounds into the AeroPress
- 120 degree incline

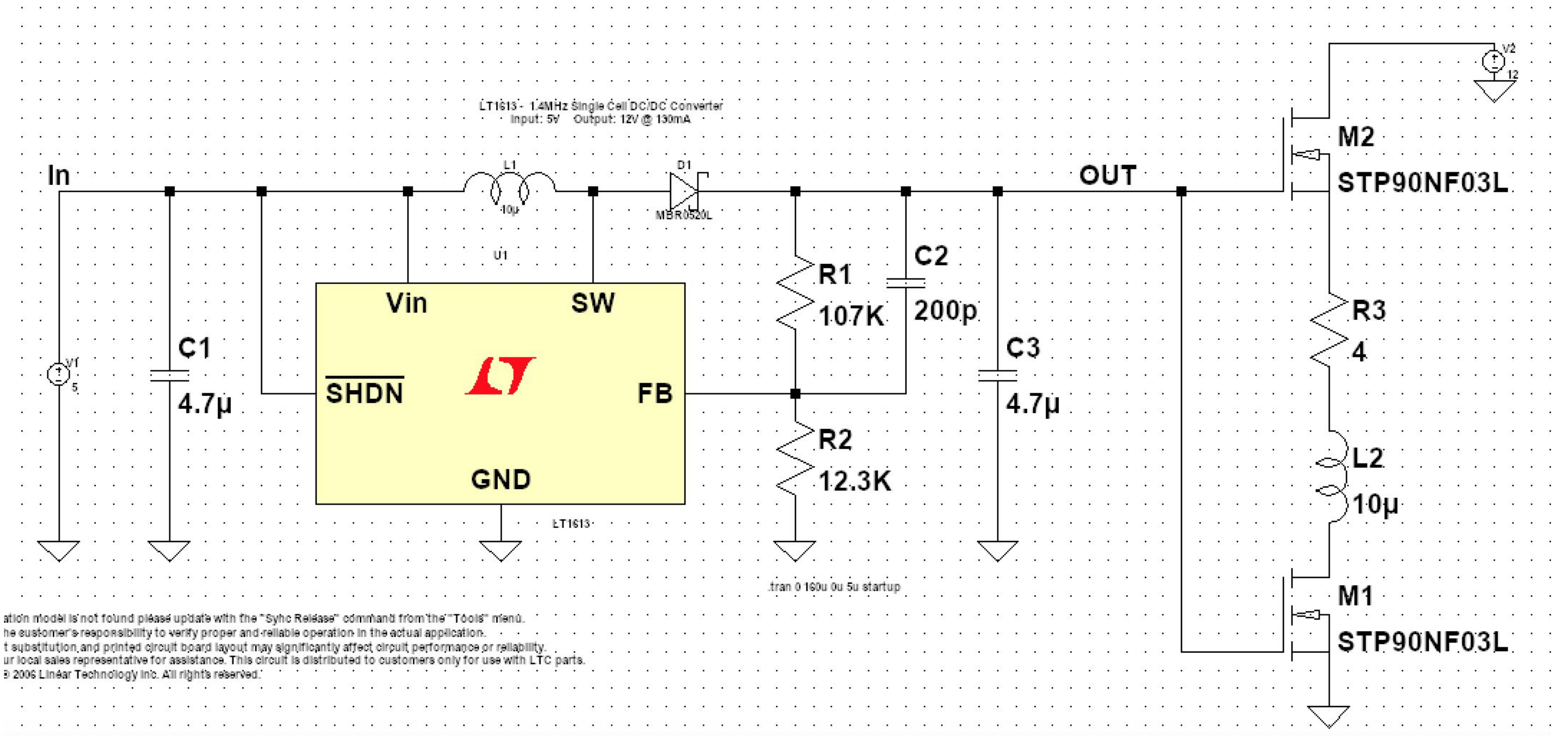
Requirement and Verification

Grounds	**Grounds**
1) Must be able to fed into the chamber using the feed motor.	1) a) The feed motor turns on after the coffee grounds are fed in. Verify that it turn on. b) Feed coffee grounds into the feed motor pipe and verify that they come out the bottom.

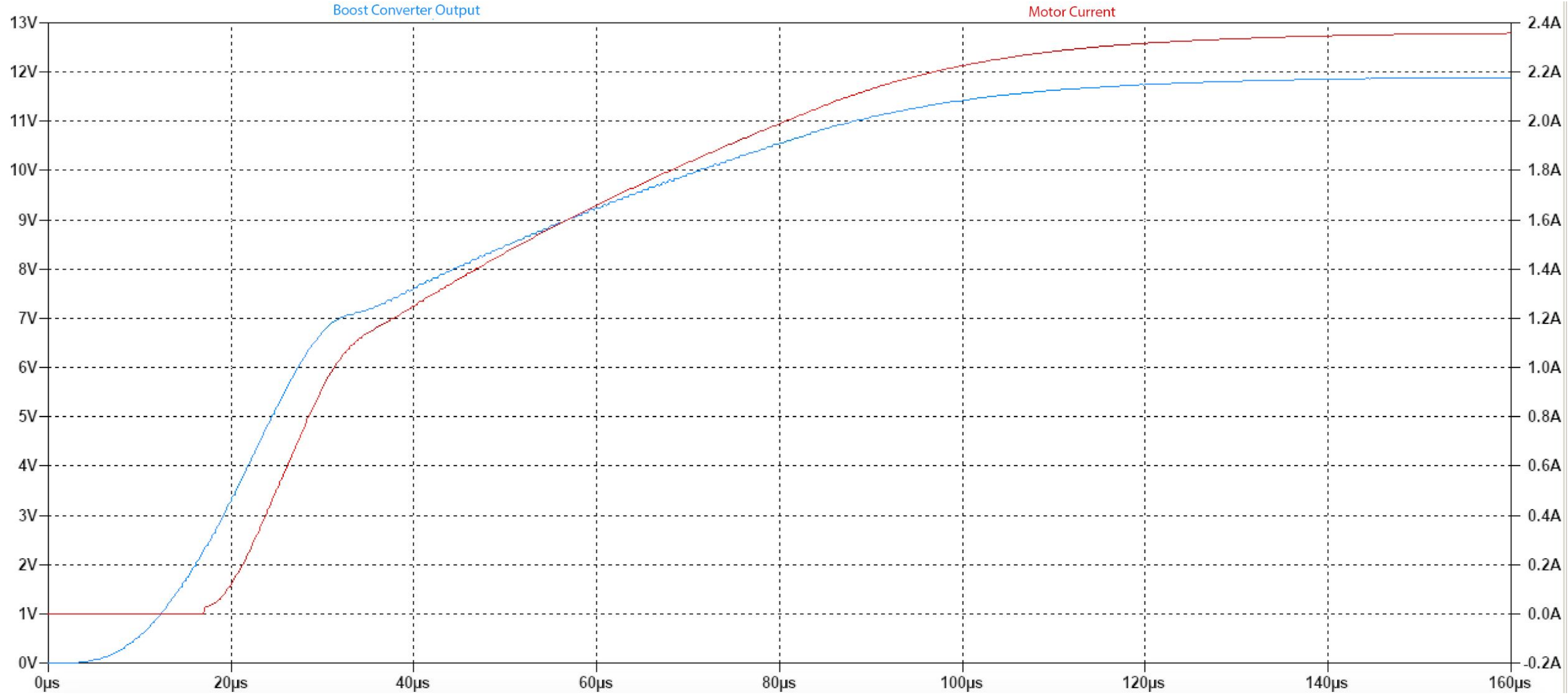
Actuator (Press) Subsystem

$$F = P \cdot A \approx (10.87783 \text{ psi}) \left(\frac{2.5 \text{ in}}{2} \right)^2 \approx 53.4 \text{ lbf}$$

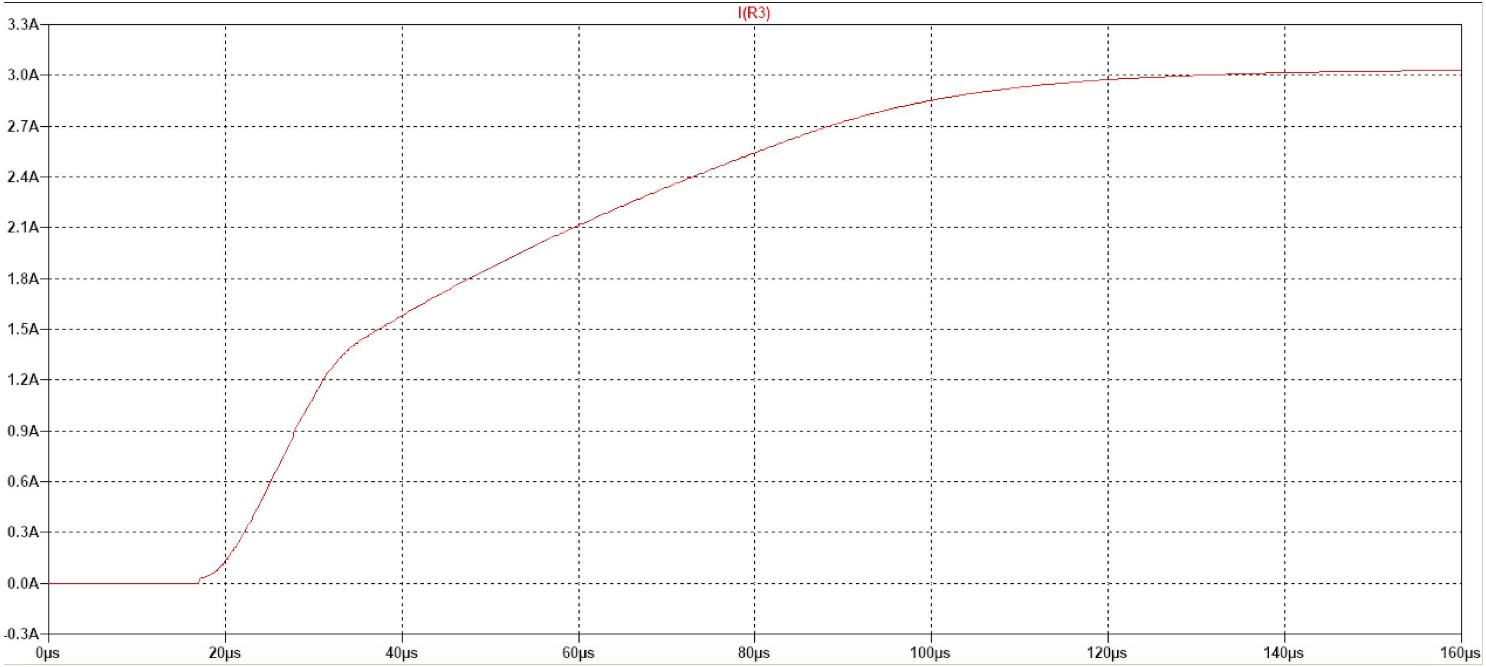
Boost Converter SPICE Model



Boost Converter Simulation



Minimum Internal Motor Resistance



Requirement and Verification

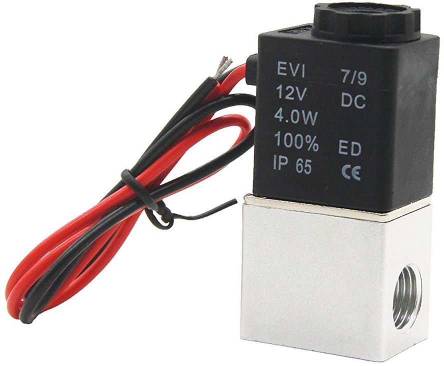
H-Bridge	**H-Bridge**
1) Must supply 1 +/- 0.5 A to the actuator under a realistic load	1) a) Manually fill the AeroPress with water and coffee grounds. b) Forward bias the leads on the actuator to begin the press. c) Using an ammeter, measure the current flowing through the H-Bridge.

Requirement and Verification

Boost Converter	**Boost Converter**
1) Able to to supply 12 V to the gate of the power MOSFET	1) a) With the help of the multimeter probe the ends of the gate to check if the boost circuit works.

Water Heating Subsystem

- User defined temperature between 175 - 212 °F
- Water heating consists of
  - Temperature sensor
  - Relay Module
  - Solenoid



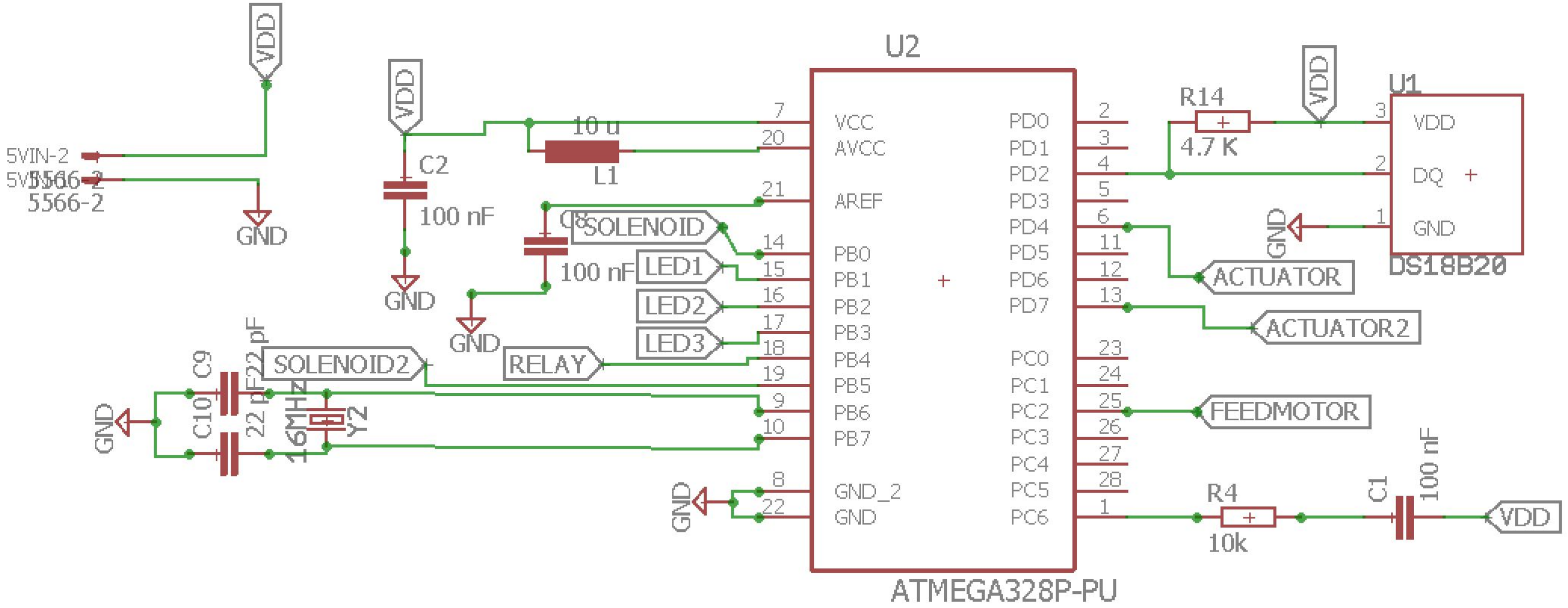
Requirement and Verification

Relay Module	Relay Module
1) Module is able to switch wall power to the water kettle	1) Connect ground and Vcc to respective outputs of a power supply on a breadboard 2) Connect an ohmmeter between the COM and NO terminals of the relay module 3) Switch the input terminal between high and low voltage and note the resistance. If COM and NO are connected, the resistance should go from OL to a lower value.

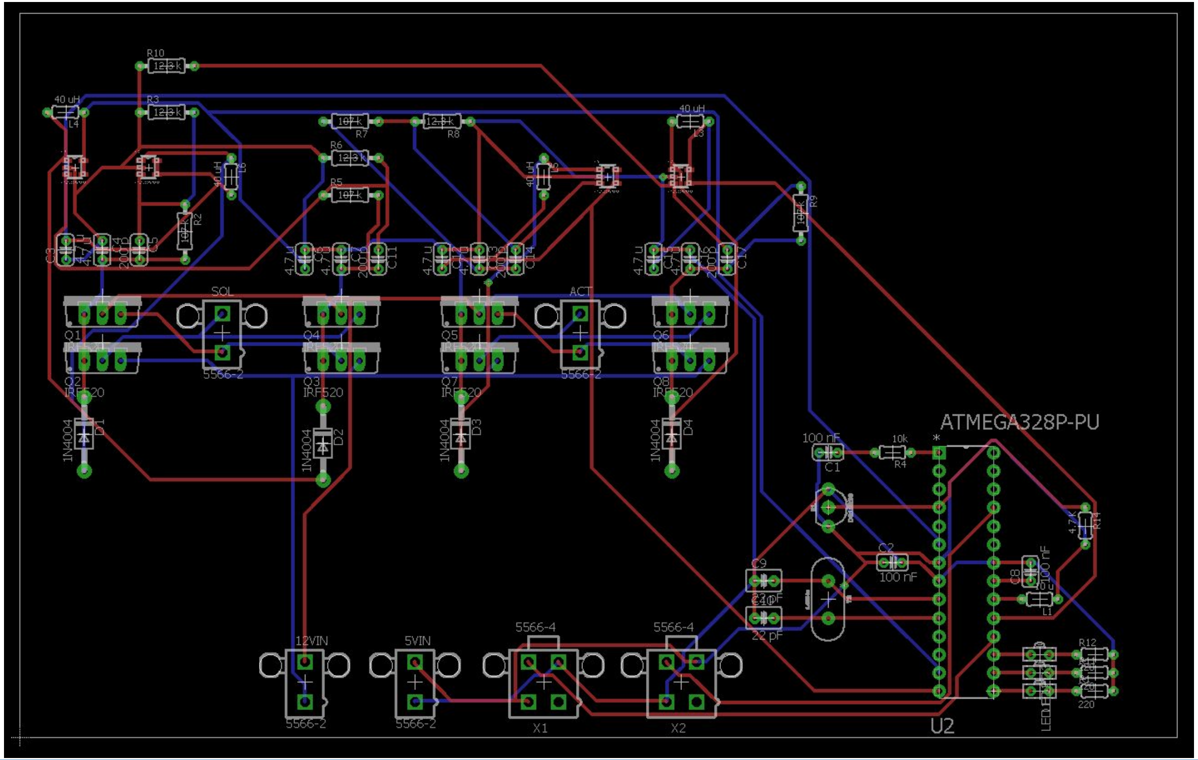
Requirement and Verification

Temperature Sensor	**Temperature Sensor**
1) Must use Serial Peripheral Interface (SPI) 2) Must be precise to 1 degree Fahrenheit	1) a) Physically connect the temperature sensor to a single board microcontroller (such as an Arduino Uno). b) Write a simple Arduino program to print the output of the temperature sensor. c) Warm water on a conventional stove top. d) Place the temperature sensor in the water, and compare with a physical thermometer to verify precision.

Circuit Schematic



PCB Layout



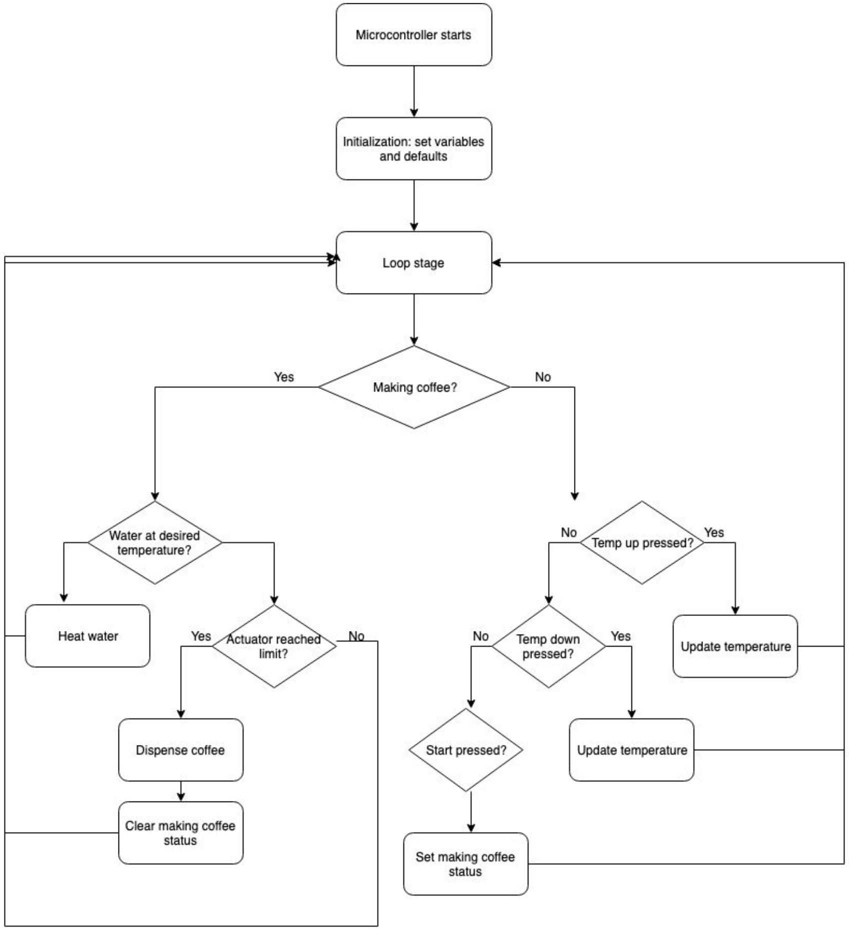
R10
R3
40 uH
L4
R7
R8
R6
R5
40 uH
L3
R9
R2
SOL
ACT
Q1
Q2
IRF520
Q4
Q3
IRF520
Q5
Q7
IRF520
Q6
Q8
IRF520
5566-2
1N4004
D1
D2
D3
D4
ATMEGA328P-PU
100 nF
C1
10k
R4
C2
100 nF
C9
22 pF
22 pF
4.7K
R14
R12
220
12VIN
5VIN
5566-4
5566-4
5566-2
5566-2
X1
X2
U2

Requirement and Verification

Software

- SPI (Serial Peripheral Interface)
- UART (Universal asynchronous receiver-transmitter)
- PWM (Pulse Width Modulation)

Software



Microcontroller starts
Initialization: set variables and defaults
Loop stage
Making coffee?
Yes
No
Water at desired temperature?
Temp up pressed?
No
Yes
Heat water
Actuator reached limit?
Yes
No
Temp down pressed?
No
Yes
Update temperature
Dispense coffee
Start pressed?
Update temperature
Clear making coffee status
Set making coffee status

User Interface

- User interacts with system through LCD and button
- LCD displays current state of system
- Button allows user to select temperature desired

Coffee Grounds Software

- Grounds are fed through a feed motor
- Feed motor can be controlled to rotate to a certain position
- Keep track of current and desired positions (in degrees)
- Delays set to change speed and overall time

Relay Module Software

- Normally Open (NO) and Normally Closed (NC) pins
- When ready to turn on the kettle, drop connection low
- Raise high after heating complete

Temperature Sensor Software

- Poll temperature at any given moment, calibrated in Fahrenheit
- Wait for temperature to reach user-defined temperature

Solenoid Software

- Can be controlled to both open and close.
- Speed and overall time can both be controlled through delays

Actuator (Press) Software

Controls

- Forward and backward motion
- Speed of actuation
- Duration of press
- Stops after limit switch hit

Successes

- Prepared a cup of AeroPress coffee
- Actuator was able to press the Aeropress
- Water was heated to temperatures between 175 – 210 °F

Challenges & Reasons for Failure

- Problem with a short when we were close to done
  - led to broken components, which we did not have time to replace
- Voltage from coax came out as +/- instead of grounded, leading to higher voltage output
- Limited I/O pins on ATmega328
- Delays in receiving parts and PCBs made original test and build timeline infeasible
- Inefficient use of space on the PCB

Further Work

- Add additional user-defined settings for pressure
- Add grinding subsystem so as to use whole beans
- Voice-user interface (VUI) integration
  (e.g., Alexa, Google Assistant)

Acknowledgements and Resources

Special Thanks

Channing Philbrick
Dave Switzer
Soumithri Bala
Casey Smith

Thank You