

# Automated Specialized Coffee Machine

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## Introduction

### Objective:

The coffee industry is one the biggest industries in the United States. The retail value of the U.S. coffee market is estimated to be \$48 billion dollars with specialty coffee comprising approximately 55% value share. [2] Specialty coffee sales are increasing at an impressive rate of 20% per year. Coffee statistics show the average consumption per individual is 3.1 cups of coffee per day in the United States. [3] These statistics prove that the American people are obsessed with drinking specialty coffee. The problem that they face is that the process of making specialized coffee like the French press and Aeropress takes a lot of effort, time and precision.

We plan to make the process of making a cup of Aeropress coffee completely automated, which would not only save individuals time, but also effort every morning. Our design for the automated Aeropress consists of two main subsystems: boiling the water and extracting the coffee. The subsystem for the boiling of water will be user temperature controlled and will be set to five-degree increments. The subsystem for extraction of coffee will pump the water and the coffee beans together and push the plunger which will produce the cup of coffee. While there are many existing coffee machines on the market, our solution will be focused on making high-quality Aeropress. We seek to create a low-cost product that can produce coffee with the desired settings.

### Background:

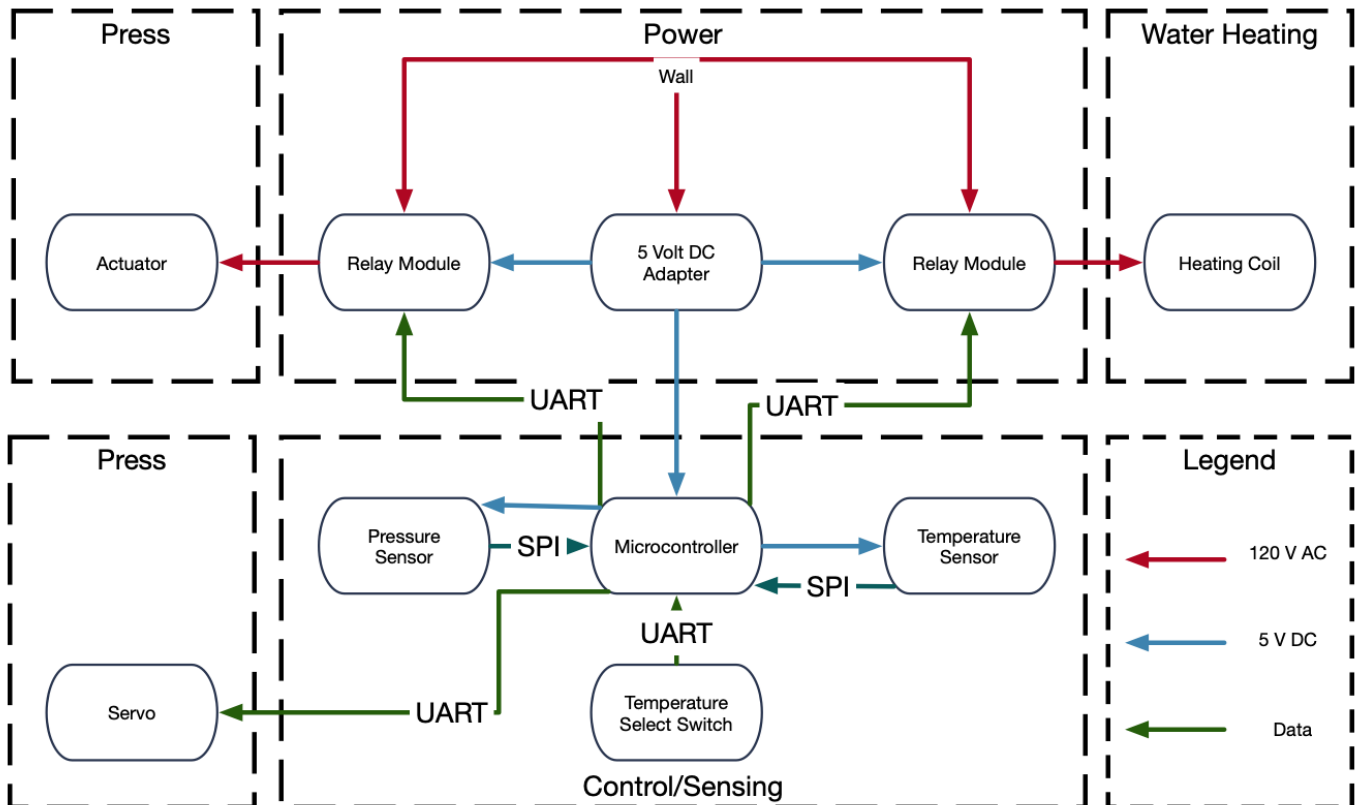
Automated coffee machines cost anywhere from \$200 to about \$10,000. There are also no machines which make Aeropress. Most of machines are oriented towards primarily cappuccino and espresso. The more selective coffee drinkers prefer specific specialized coffee like the Aeropress. We plan to give the user just the right amount control in the process as the user will be able to select the temperature the water is boiled to and the user can also insert the grinded coffee beans into the system. The system we propose creates an affordable way for individuals to automate the bothersome process of making specialized coffee.

### High-Level Requirements:

- The coffee machine should be able to prepare a cup of Aeropress coffee.
- The machine should be affordable and cost less than a \$100
- The user should be able to control the temperature of boiling in the water hearing unit.

## Design

### • Block Diagram



### • Physical Design

The physical design of this design is particularly important as the project will involve many moving mechanical parts. The main moving parts consist of the coffee grounds, water, and an actuator.

#### **Coffee Grounds**

The coffee grounds must be moved into the Aeropress to be extracted later on into the process. In order for the process to be successful, pre-ground beans will be delivered into the Aeropress by a chute opened by a servo.

#### **Water**

The hot water must be transferred from a kettle (used for heating the water) into the Aeropress. The least mechanically complex way to achieve this is to pump the water out of the kettle and into the Aeropress.

### **Actuator**

In order to complete the hot water extraction, the Aeropress must be pressed. To do this, we will utilize an actuator to mechanically press the plunger on the Aeropress. In order to seamlessly mate the plunger and the press pot, the plunger will be on a set of rails. This will allow the actuator to press the plunger directly into the press pot.

## • **Functional Overview**

The process of making the cup of coffee can be broken down into a few sub problems – grinding the coffee beans, heating the water, and the hot water extraction. Because ground coffee is reasonably priced, and highly available, we will focus on heating the water, and performing the hot water extraction.

For this project we will be using an Aeropress to do our hot water extraction. The water will be heated in a kettle and pumped into the Aeropress. A servo will be used to open/close a door, allowing ground coffee beans to be delivered to the press. The Aeropress will be pressed by an actuator. A pressure sensor will be present to determine whether the actuator needs to press harder, press lighter, hold pressure, or disengage. Prior to the hot water extraction, the water will be heated to a user-selected temperature. The temperature will be monitored with a temperature sensor and used to control the heating coil (i.e. according to the temperature the heating coil will turn on or off).

In order to reduce the cost and complexity associated with having a custom IC fabricated, we will be using a microcontroller (ATMEGA328) to read input from the switches and sensors. The microcontroller will use this information to perform the control flow. Using relay modules [1], it will control the power to the actuator and heating coil accordingly.

## • **Block Level Requirements**

### **Temperature Sensor**

- Must be compatible with the SPI, because it must have (at least) 1°F precision

### **Relay**

- Must provide isolations between the power from the wall and the microcontroller

### **Actuator**

- Must be able to apply enough force down onto the plunger

### **Pressure Sensor**

- Must be precise in the 0 to 9 bar range (9 bar is required for espresso)
- Must be waterproof
- Ideally, it should be food grade as it is in contact with the coffee.

### **Heating Coil**

- Must be made from a high-temperature material (e.x. Tungsten)

### **Servo**

- Must be able to be driven by the microcontroller (for cost purposes)

## **• Risk Analysis**

The pressure-based plunger is a significant risk in our project. The plunger must be able to move smoothly and apply pressure as the pressure in the system increases. The plunger should be able to make precise, controlled movements due to the desired control necessary in order to keep the coffee beans at the appropriate temperature and pressure. As such, there is some risk associated with the mechanical control for the plunger to move appropriately. Additionally, the pressure sensor in the system needs to properly communicate with the motor control to provide a feedback loop for the plunger movement to appropriately terminate. The sensor output and PCB design will determine how the sensitivity of the plunger behaves.

Another risk condition to consider is the aquatic system for the introduction of water to the ground coffee beans. Since, the water is required to be heated, as well as move from the kettle to the main mixing pot, the boiling water needs to be compatible with the tubing and rest of the system. This also requires the water to not be able to melt the plastic or corrode the metal in the device. Furthermore, the water needs to be prevented from leaking. In addition to concerns from contaminating the end coffee product, as well as concerns about leakage onto the table or into the environment. The water at a boiling temperature, could damage the electrical components, including the power supply, interconnects, and the PCB, which could result in an electrical hazard.

This mechanical system must be resilient to wear and tear due to continued usage, especially considering that the system contains moving parts. Certain components, such as coffee filters, are designed to be used and replaced. In other cases, we can prototype and secure once we have the final physical design appropriately configured.

## **Ethics and Safety**

There exist some ethical and safety concerns around the design and implementation of our project.

Since the coffee machine will be used for making coffee primarily for human consumption, the machine and its components need to be food-grade. Based on the design of the coffee machine, we will be using food-grade plastics and materials so as not to introduce an excess of harmful chemicals into the acidic coffee solution.

Furthermore, we must be careful about the safety of the device since we are going to be powering the coffee machine with a voltage source. We expect to use a standard household US (grounded) wall outlet, so we will need to have safety precautions around the usage of power, so

as not to melt the device. We will monitor the voltage at different areas in the device to ensure that the device does not malfunction or provide too high of a voltage output. As a standard household kitchen appliance, we need to ensure that the electronic components encased so that they are water-resistant should a spill or leak occur.

Furthermore, we must have safety for the grinding portion of the device, so that one's hand or body will not be cut. We will test each component of the device in isolation during our build phase to make sure that everything works according to plan before we move to have the components work together.

One of the general ethical principles for the Association of Computing Machinery (ACM) is to "avoid harm." [4] The operation of our device involves electrical equipment, so we will ensure that in a commercial or user environment that appropriate warning, notices, and safeguards are placed on or made available prior to the operation of the device to ensure that appropriate care is taken. Furthermore, the product of our device produces hot coffee, which under certain conditions can be "dangerous hot." [5] For the safety of the ultimate consumer, the coffee machine will carry warnings and be designed appropriately so as to minimize the risk associated with the consumption of coffee.

## References:

[1] Guide for relay module with arduino. [Online]. Available:

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[4] ACM Code of Ethics and Professional Conduct. [Online]. Available:

<https://www.acm.org/code-of-ethics>. [Accessed: 7-Feb-2019].

[5] The McDonald's Hot Coffee Case. [Online]. <https://www.caoc.org/?pg=facts>. [Accessed: 7-Feb-2019].