SMART AUTOMATIC PASTA / RICE COOKER

Team 15 - Anusha Kandula (kandula2), Tae Kyung Lee (tlee82), Gautam Putcha (gputcha2)

ECE 445 Design Document – Spring 2020

TA - Jonathan Hoff

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1. Introduction

1.1 Problem Proposition

We are building an automatic rice cooker that serves students and working adults with unpredictable schedules. Our customer has a problem, and it is waiting for a long time for their rice to be cooked after coming back to their home because of the difficulty of planning when they might come home. Our product solves the customer's problem by starting the rice cooker with a simple app that can be used from anywhere and would have the rice ready when the user arrives home without any preparation beforehand.

1.2 Objective

The cultural development of our society has led to an abundance of different cuisines available to us. Among the most common food staples in most people's diets are rice and wheat which are the leading food crops in the world. [1] However, a major setback to cooking these important foods is the length of time it takes. Most supplementary foods take less than twenty minutes to cook, while the base of these meals such as rice and pasta take more than thirty minutes to cook. For example, if the pasta is already cooked, adding pasta sauce to it takes a negligible amount of time. The length of time it takes to cook pasta or rice results in a very inconvenient waiting time especially for students or working adults who have unpredictable schedules every day. When one returns home from work or school and wants to eat as soon as possible, starting a rice cooker and waiting for another thirty minutes is unsatisfactory. Using a high-pressure rice cooker [2] still takes twenty minutes and is more expensive than a simple rice cooker. An effective and unique solution to this problem has not been found yet, even though a lot of people face this issue.

Our solution is a fully automatic smart pasta/rice-cooking system that would be an extension on an existing basic rice cooker. Our system would be a module that is connected to a water supply and a rice reservoir. This rice reservoir would be filled right after buying the bag of rice or the box of pasta from the grocery store. The user, while still at school or work, could use our mobile application to prepare the desired amount of rice or pasta. For example, if the user would like to cook 2 cups of rice, the correct amount of rice would be released from the reservoir into the rice cooker along with the correct associated volume of water. The cooker would then be started so that the rice would be ready for when the user arrives home. Since a lot of people (especially college students) have unpredictable schedules, it can often be difficult to plan when they might come home or if they have already eaten by the time they come home. Our system allows you to start the cooking process from anywhere, with no preparation beforehand.

1.3 Background

There are very few “smart” rice-cookers on the market today, but none with the abilities that we are proposing. An interesting device that we found was the Xiaomi Mi Induction Pressure Rice-Cooker. [3] This has the ability to remotely start the cooking of rice through an application. Then there are other rice cookers such as Cuckoo CMC - QSB401S Q5 that can delay the timer for up to 12:50 hours. [4] These are great but have a common issue: it requires the user to have already put in the rice and water, basically rendering the system as a simple on/off smart switch. Our system, on the other hand, would not require the user to prepare for future cooking at all. Since the cooker is already connected to both the rice/pasta and water sources, a user request with the number of cups would begin the cooking process at any time.

1.4 High-level requirements

1. Lifting the lid, pouring of rice and water and starting the rice cooker operates within 3 minutes in the correct order successfully using a single start signal provided by the user remotely.
2. The device must be able to dispense the precise number of cups of rice and water(1 standard cooking cup for rice = 7 oz / 200 g, 1 standard cooking cup for water = 8.35 oz / 236.5 g) requested by the user in the mobile application with an error of at most 15%.
3. All operations must be halted at once if an abnormal rise in temperature (>170 ℉) or any form of smoke is detected, with power being cut off to every system of the design. (Normal cooking temperature for a rice cooker is about 150 ℉)

2. Design

2.1 Block Diagram

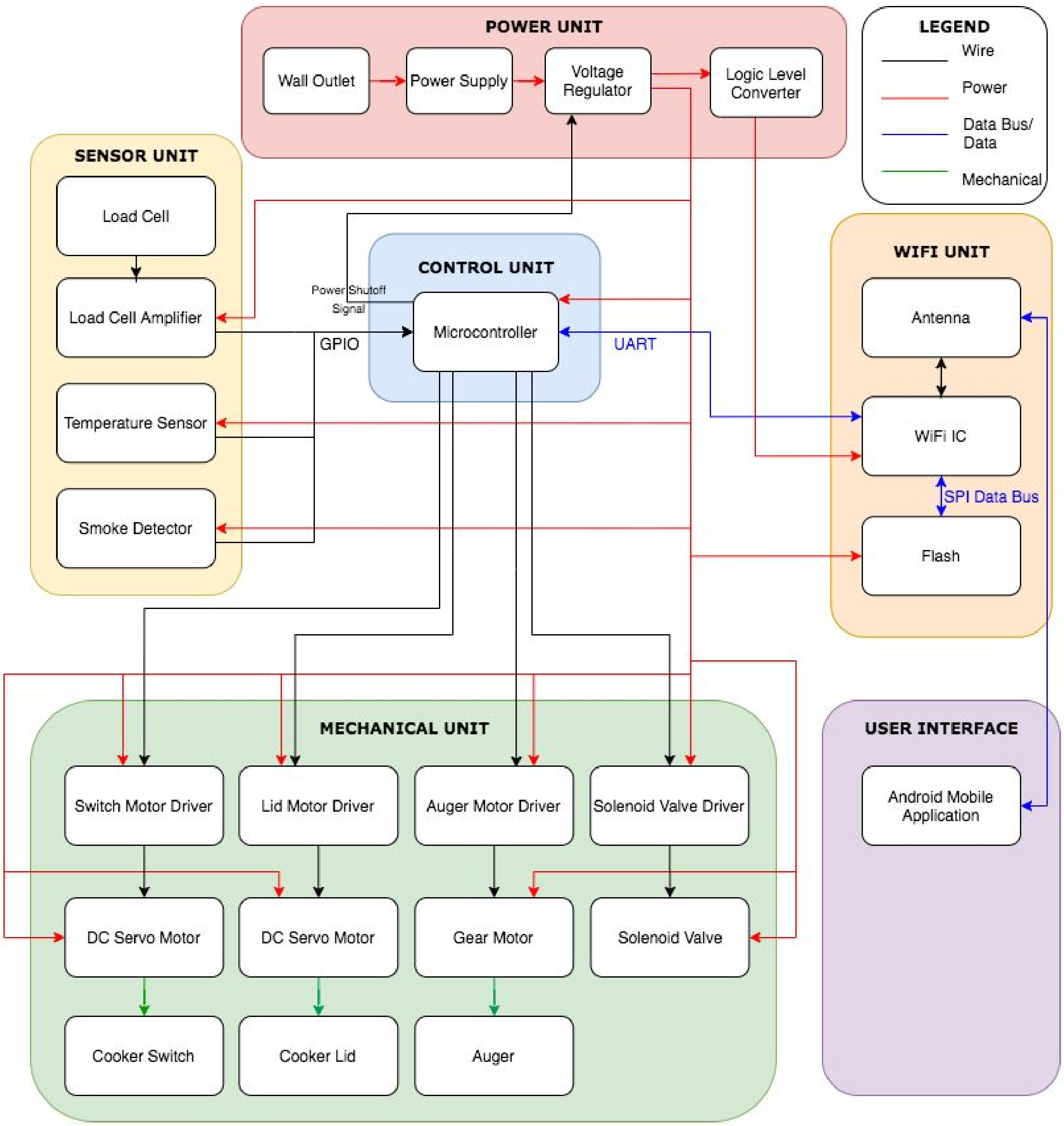


Figure 1: Block Diagram for our proposed design of the smart automatic rice cooker

2.2 Physical Design

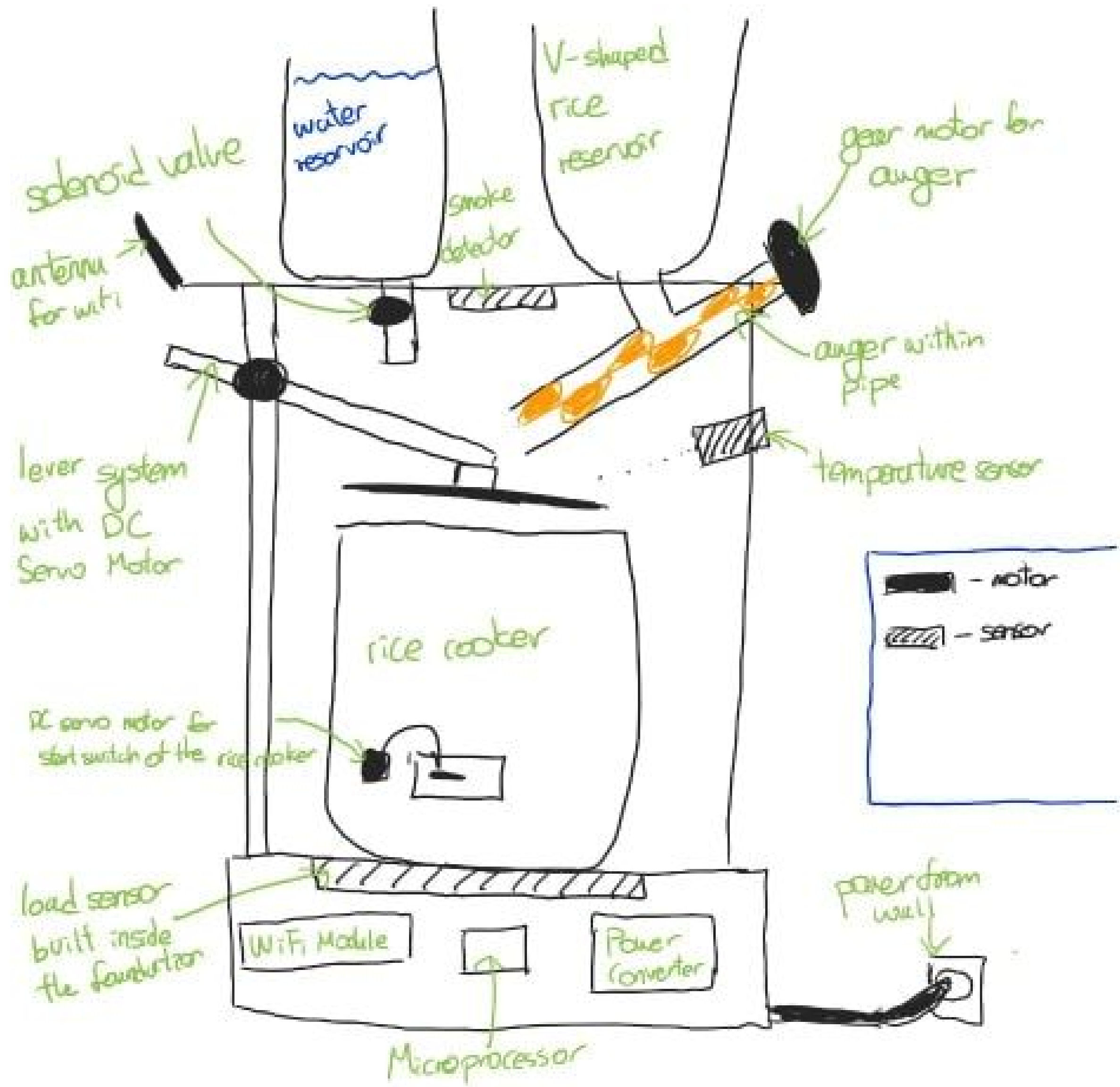


Figure 2: Physical design for our proposed design of the smart automatic rice cooker

The system will make use of a standard simple off-the-shelf rice cooker. For our design, we will use a simple *Black+Decker* rice cooker as shown in Figure 3.

Figure 3: Standard basic rice cooker around which our proposed design will focus

2.3 Functional Overview

2.3.1 Control Unit

The control unit will process the user input received from the user interface, and use the data to run the necessary motors. It is responsible for carrying out the entire cooking sequence by:

1. Running the lid motor to open the cooker lid.
2. Running the auger motor and solenoid valve to release the rice and water respectively.
3. Stopping the release of these materials when the desired load has been reached based on the data collected from the load sensor.
4. Closing the lid, and switching the cooker into “Cook” mode.

Additionally, the control unit is responsible for cutting off power to the entire system in the event of the detection of smoke or an abnormal rise in temperature.

2.3.1.1 Microprocessor

We will use the ATMEGA328P microprocessor. This microprocessor will be a part of our PCB and will be responsible for conducting all of the essential functions of the system. It will also be critical that all of the functions are executed in a sequential manner in the right order. Our microprocessor will also be responsible for communicating with the WiFi module using SPI.

2.3.2 Power Unit

This power unit will provide all of the necessary power requirements for the components of the system.

Name	Requirement	Verification
120V - 12V AC/DC Converter (Power supply)	Power supply provides 12V ± 0.2V when on and provides 0V when off	1. Probe the output of the power adapter with a multimeter. a. When the device is off, the multimeter should read 0V. b. When the device is on, the multimeter should read a value between 11.8 V and 12.2 V.
Linear Voltage Regulator	The voltage regulator must be able to output 5V +/- 0.2V for any input	1. Provide varying DC currents (8V, 12V, 16V) using a function generator and rectifier as an input to the regulator. 2. Use a multimeter to verify that the output current remains between 4.8V and 5.2V.
Logic level converter	The logic level converter must convert an input 5V signal into a 3.3 +/- 0.05V signal for use in the WiFi module.	1. Provide a 5V source from a voltage regulator to the converter. 2. Measure the output of the converter using a multimeter and verify that it is 3.25V and 3.35V every time.

2.3.2.1 Power Supply

We are going to use PLT 55-3075-99 step-down transformer. This will step down the standard 120V wall power to 12V that will be connected to the Linear Voltage Regulator for use in our design.

2.3.2.2 Linear Voltage Regulator

The linear voltage regulator will convert 12V from the power supply to be converted to 5V, which will be used by the micro controller and 3.3V which will be used by the sensor unit.

2.3.2.3 Logic Level Converter

This converter will be used to step down a 5V signal to a 3.3V signal for the WiFi module. The ESP8266 THING WiFi module we have chosen to use does not have inbuilt 5-3 logic shifting [5] and requires a logic level converter to step down the voltage to the necessary 3.3V.

2.3.3 Sensor Unit

Name	Requirement	Verification
Weight Sensor	The load cell must be able to measure within +/- 10g of the actual weight of an object.	1. Load cell is connected to an amplifier circuit which is connected to an Arduino with a program running that outputs the data read. 2. Multiple items of varying weights (5g, 10g, 15g, 20g) are placed on the load cell and the output value is compared to the actual weight of the item.
MQ-2 Smoke Sensor	1. MQ-2 smoke sensor must differntiate between smoke and steam.	1. Smoke sensor is connected in a circuit to Arduino and is tested with a lit match as well as steam. 2. The smoke sensor should respond to the smoke while not producing a positive output for the steam.
Thermistor (temperature sensor)	1. Thermistor must be able to detect the increase in temperature above the rice cooker at 70 degrees celsius. 2. Thermistor must not be affected by the steam produced during cooking.	1. Thermistor is connected to a resistor circuit with input to an Arduino. The thermistor is then brought in contact with a cooker that is turned on and above 70 degrees Celsius. It is then verified that the change is detected in the arduino circuit. 2. Thermistor is tested 3 times with the rice cooker on various positions on the design to determine the best location that is not affected by the steam.

2.3.3.1 Load Cell

The load cell is able to measure the weight of the object that is placed on it. This will allow us to measure the weight of the rice and water added to the rice cooker. The changes in weight will be used to calculate the amount of rice or water that has been added.

We will use the TAL220B load cell. It has a 5kg weight limit and connects directly to the load cell amplifier with no additional connections.

2.3.3.2 Load Cell Amplifier

The load cell amplifier acts as an interface between the load cell and the control module. It transfers the data collected by the load cell to meaningful data to the control module.

We will use the HX711 load cell amplifier. It will be connected to the load cell and the control module using a custom serial protocol specific to the chip. This will be connected to the 5V power supply.

2.3.3.3 Smoke detector

We will have a smoke detector built into the system to detect the presence of any kind of smoke in the vicinity. MQ-2 smoke sensor will be used to detect smoke by outputting greater voltage when it detects greater concentration of gas. The change in voltage will be processed by the microprocessor and if smoke is detected, power will be cut off to the entire system.

2.3.3.4 Temperature sensor

1K NTC Thermistor will act as a temperature sensor for our design. This will send digital data to the microprocessor since it decreases in resistance according to a proportional rise in temperature up to 125 degrees celsius. Any abnormal rise in temperature detected will cause the control unit to cut off power to the entire system.

2.3.4 Mechanical Unit

Name	Requirement	Verification
Solenoid Valve (Water Dispenser)	1. Solenoid valve and opens and closes on command. 2. Leakage does not occur when solenoid valve is closed	1. Connect the solenoid valve to the arduino and verify if it can release and stop water flow on command. 2. Fill in the water reservoir to the brim and wait for 1 minute after several close commands.
Rotatory Gear Motor (Rice Dispenser)	1. It must provide enough torque to overcome potential friction between the rice, the auger and the cylinder that contains the auger.	1. Testrun the rotatory gear motor 3 times (empty, half full with rice, full with rice) with 3 different brands of rice (Nishiki, Lundberg, Mahatma).
Parallax Standard Servo (Lid Translation)	1. Motor must provide enough torque to support and lift a load of upto 0.75 kg and move the cooker lid on/off. With precision of ±2 cm in x,y,z positions.	1. A graph of x,y coordinates will be attached to a wall and tested with program to reach specific destination
Parallax Standard Servo (Switch Motor)	1. Angle of the robot arm must be precise ± 5 degrees.	2. A graph of x,y coordinates will be attached to a wall and tested with program to reach specific destination

2.3.4.1 Water Dispenser

Water dispensing will be controlled with a solenoid valve that is going to be connected to the microprocessor through a PCB. The solenoid valve that we are going to use is HFS 12V DC electric solenoid. The valve will remain open until the appropriate weight of water has been dispensed as signaled by the microprocessor. The volume of water added to the cooker will be calculated based on the mass added and the density of water.

2.3.4.2 Rice Dispenser

Rice dispensing will be controlled using a rotatory gear motor on an auger. When the start signal is received from the microcontroller, the auger is rotated to release the rice. Similar to the functionality of the dispensation of water, when the required weight of rice has been released into the cooker based on the signals from the microcontroller, the release of rice stops when the motor comes to a halt. The volume of rice added to the cooker will be calculated based on the mass added and an average density of rice.

2.3.4.3 Lid Translation

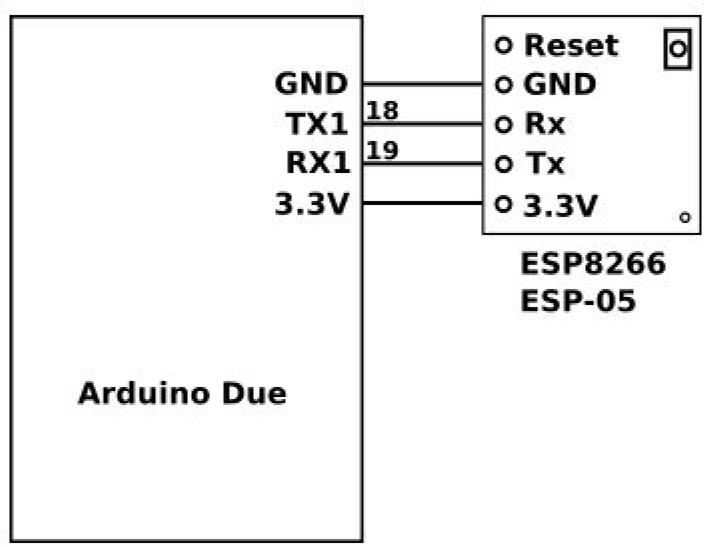
A motor will control the movement of the lid on and off of the cooker. Our system will employ a lever mechanism to lift the lid off of the cooker to prepare for the rice and water to be dispensed. When the ingredients have been added, the system will employ the same mechanism to place the lid back onto the cooker before cooking begins.

2.3.4.4 Switch Motor

This motor will be responsible for toggling the “Cook” button on the cooker so as to begin cooking when all of the preparatory processes have completed.

2.3.5 Wifi Unit

Data must be transferred between the user and the control module via SPI to be accessed on a WiFi network. Wifi Soc (System-on-a-Chip) operates based on an SPI flash program memory and uses an antenna to communicate with the user.



Requirement	Verification
1. Must be connected with 5Mbps access at 20m without obstruction / 5m with obstruction between the router and the module. 2. Must successfully be able to relay information such as number of cups of water/rice and start signal from the application to the microprocessor.	1. Check if ESP-12E Wi-fi module that will be connected to the Arduino with its PCB antenna can be connected through open space, with walls, and with multiple devices that use wifi in range. 2. Send dummy data input to the WiFi module to store into Flash. Then check if data write has occurred by checking Flash.

2.3.5.1 Antenna

Molex 1462200200 PCB trace antenna will be attached to the Wifi IC to gain maximum range. We will aim for 5Mbps access at 20m. This is within the specifications of the product and will allow the user to connect with the product within the boundaries of a household.

2.3.5.2 WiFi IC

ESP8266 THING Wifi Module is chosen for our project because it is very cost-effective and efficient for our communication. Our product does not require speedy transactions between the user so a cheaper model is used. It can operate at 160MHz when overclocked and has integrated power management units and Wifi transceiver. This module will communicate with the microprocessor via SPI.

2.3.5.3 Flash

ESP8266 THING Wifi module comes with a limited RAM memory of 12kb for user programs and variables/data. A Flash IC will be used, if necessary, to hold the program memory for the WiFi IC. This must operate at 80MHz for the WiFi microcontroller to operate at full speed. Currently, we are not certain of our program size for the microcontroller. We will prototype the size of 1Mb Flash IC and downsize for cost measures.

2.3.6 User Interface

Requirement	Verification
1. The application must have a preset value as well as a custom option for the user to input their desired amounts of rice and water. 2. A limit of 4 cups of rice and water must be set on the maximum amount of rice/water entered by the user so as to prevent an overflow of water/cooked rice.	

2.3.6.1 Android Mobile Application

We will use an Android application to get the user's input on the amount of rice and water desired to be cooked. We will have a custom option as well as a preset option for the amount of water. However, there will also be a limit on what the user can input into the application as there is a physical limit on how much rice can be cooked in any given rice cooker (Ex: More than 6 cups cannot be cooked in a 6-cup rice cooker). Most importantly, the user may begin the cooking process by pressing the "Start" button.

2.4 Tolerance Analysis

The most critical feature of our project is being able to dispense the correct measurements of rice and water. In one of our high level requirements, we specify that we should have at most an error of fifteen percent. In order to achieve such an accuracy, we must analyze the load cell, the load cell amplifier, the servo motors, the dimensions of the dispenser, solenoid valve, and the auger.

We will first look at the load cell's role in achieving accurate measurements. Our load cell is strain gauge and it can translate up to 5kg of pressure (force) into an electrical signal that shows the change in electrical resistance. In most of the load cell data sheets, there is a RO (Rated Output) accuracy specification. The rated output basically gives us an error range of how accurate the specifications listed are. The TAL220B load cell has a rated output of 1.0 ± 0.1 mV/V and our capacity is 5 V from the linear regulator. This gives us the following:

Maximum rated output of load cell = (1.0 + 0.1 mV/V) ∗ (5V) = 5.5 mV

This is the maximum output in voltage and this is actually measured by the change in electrical resistance ΔR by the load cell amplifier. It measures the increase of length over the original length. The role of the load cell amplifier, HX711, is to amplify smaller changes in electrical resistance and then calculate what is read from the load cells into weight in kilograms. In this context, as the capacity is at 5 kilograms and the rated output is linear, 0 V is 0 kg and 5 V is 5 kg. As the amplifier has a maximum gain of 128, the maximum rated output after amplifying the smaller change is:

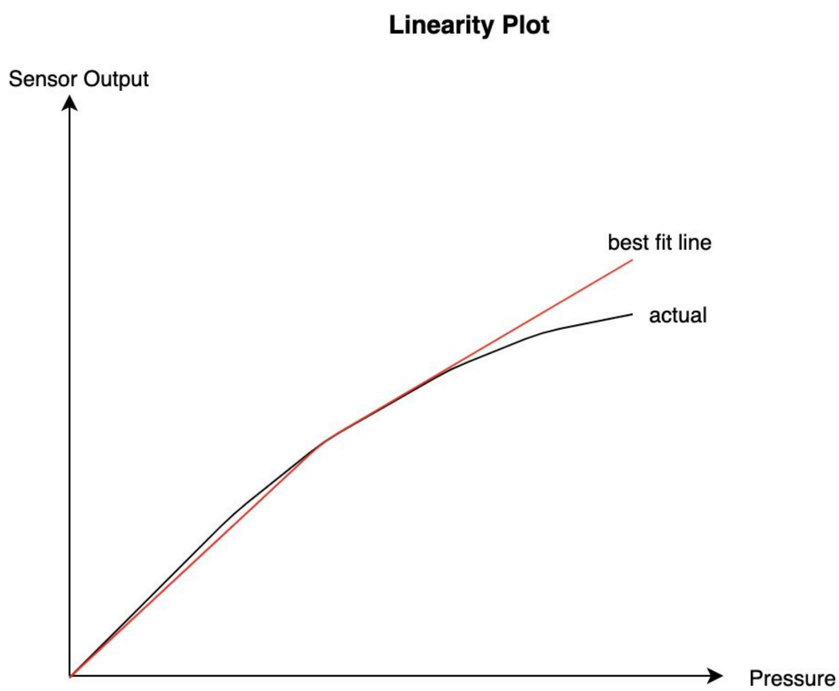
Max. rated output (new) = 5.5 mV x 128 = 704 mV

The only noise comes from the 128 (2^7) bits so there are 2^17 bits which do not have noise that we can use. This gives us a digital voltage of **5 V/(2^17) = 0.03815 mV**.

Furthermore, we get the load cell maximum weight increase by calculating what the maximum percentage of error would be through the rated output.

% of rated output * maximum weight = (0.03815 mV / 704 mV) * 100 * 5 kg = 0.0000542 * 100 * 5 kg = 0.02710 kg

As a result, we get a 0.542% maximum error and therefore, we are well within the fifteen percent accuracy that we want from our high level requirements. This is great because it is a good system that accurately reads the amount of rice and water dispensed into the rice cooker.



Plot 1: Load Sensor Linearity

3. Ethics & Safety

3.1 Ethics

We would like to build a system that is accurate in dispensing the correct measurements of rice and water. Even though we would like to get the exact measurements perfectly, it is one of our high-level requirements that we aim for an accuracy of eighty-five percent or above. We did this to be realistic and not lie about the efficiency of our product. We are abiding by the [6] IEEE Code of Ethics #3 by doing this.

As our dispensers will be storing food that is primarily for human consumption, it is crucial that we do not harm the quality of the rice or the water. Hence, we will be using food-grade plastics and materials to not contaminate the cooked food. Our device will not introduce any harmful chemicals into the user’s food and will prevent any harm to our user, therefore following the [7] ACM Code of Ethics and Professional Conduct #2.

3.2 Safety

We plan to address the safety concerns with a few precautions so that our users are not afraid that their houses might catch on fire. We will be adding a smoke detector and a temperature sensor, which on detection of smoke or heat will send a message to the user's mobile phone and immediately cut off power to the entire device. We will also have an in-built surge protection to safeguard against a potential voltage spike. Additionally, we will be using a converter to change 120 V to 5V for some of our devices which would avoid any potential electrical hazards. Since we will be working with wall power, we have to be extra careful with high voltage outlets.

We will first test our project in a safe lab environment where we have a guaranteed 5V source, then we will test our voltage converter to see if it does indeed provide 5V source. This way, we will prevent potential damage to the sensors and microprocessors as well as ourselves. All these precautions comply with the lab safety guidelines. As our system contains two plastic dispensers that hold the rice and water, we will be using plastics that are [8] FDA approved for food consumption safety.

4. Schedule & Cost

Schedule:

Weeks	Anusha	TK	Gautam
02/24 - 02/28	Design Document	Design Document	Design Document
03/02 - 03/06	PCB/ Ordering Initial Parts	PCB/ Ordering Initial Parts	PCB/ Ordering Initial Parts
03/09 - 03/13	Talk to the Machine Shop again	Test the load sensor with amplifier	Test the load sensor with amplifier
03/16 - 03/20	Spring break	Spring break	Spring break
03/23 - 03/27	Integrate and test Solenoid valve and auger	Integrate load sensor onto the project (machine shop)	Integrate and test motors
03/30 - 04/03	Start unit testing the control unit/sensor unit	Start unit testing the control unit/sensor unit	Start unit testing the control unit/sensor unit
04/06 - 04/10	Start unit testing the control unit/sensor unit and wifi unit	Start unit testing the control unit/sensor unit and wifi unit	Start unit testing the control unit/sensor unit and wifi unit
04/13 - 04/17	Work on integrating software unit with hardware unit	Work on integrating software unit with hardware unit	Work on integrating software unit with hardware unit
04/20 - 04/24	Work on integrating software unit with	Debugging	Debugging

	hardware unit		
04/27 - 05/01	Final Proposal	Final Proposal	Final Proposal

<u>Cost</u>: (sample)

	Model	Price
Load Cell	TAL220B	$10.95

Labor Costs:

As we will be working on the project for ten weeks and there are 3 teammates, we will be spending around 15 hours per week. 150 hours divided by three people is 50 hours per person and the total salary for a project is usually around $20,000 so the overall hourly rate should be around $400/ hour.

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