## **Purdue ECE Senior Design Semester Report**

## **(Team Section)**

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| **Course Number and Title** | ECE 477 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | 8 |
| **Project Title** | Condiment Express |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Binhan Xu | Comp E | Software | December 2019 |
| Yuanqiu Tan | EE | leadership, PCB, Mechanical Design, manufacture | May 2020 |
| Chengming Zhang | EE | Circuit Design, PCB, Mechanical Design. | May 2020 |
| Minghao Sun | EE | Mechanical and system design and manufacture | May 2020 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Provide a general description of the product to be delivered by this design project.

## The Condiment Express is an IoT enabled condiment distribution device that sits on the countertop. This device can distribute condiments in order with precise measurements. Users can fill in condiments in the included bottle which has a thread on the bottom and attached to the machine. The top cap is to be opened by the user to refill the condiments and the bottom thread is used by the machine for dispensing. By using our application via Bluetooth, users can communicate send information to the machine of which condiments are needed. The machine will also alert users if any condiments are running low and need a refill. To operate, it first calibrates its x-y axis and then calibrates its weight sensor. The condiment dispensing routine will happen after the calibrations are done. Since the condiments are dispensed in sequence based on the recipe, users will take the condiment directly and mix them with the rest of the ingredients in the recipes. Users need to wash the condiment collector and return it to the machine, and the machine will continue to the next sequence of the condiment dispensing.

1. What is the purpose of this product? For whom is it intended?

## As college students with little free time on our hands, cooking is a “leisure” that we don’t often have the time. As we all know, eating at restaurants or consuming fast food every day is neither practical nor healthy and expensive. After a careful look at some typical western and eastern cooking processes, we find out that for those people who are new to cooking, most of the time is wasted on measuring the correct amount of ingredients and looking through the recipe book. This product is aimed to solve this problem as it provides an automatic way to prepare those ingredients in order with precise measurement and for the users. This not only can save people’s time while cooking but also make the entire process easier and more enjoyable. Another feature that comes with this product is that it can precisely control the number of condiments one is taking, helping the user with special dietary. The targeted user for this product is anyone who cooks regularly and/or people who wish to have a controlled dietary.

1. Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

## The design process starts with walking into people’s daily lives. At the very beginning, when we were brainstorming about ideas, we wanted to invent a product that can be normally used by most people. And we stood on students’ views to take all considerations into account. Therefore, we came out with this machine. With the basic ideas settled down, we moved to the goals that we wanted to achieve and details about the operations of the machine. The next step is basically to test our solutions with an experiment.

## One of the experiments that we implemented is that we were unsure about the number of condiments dispensed. Therefore, we 3D printed the parts out and physically loaded condiments and test with multiple types of condiments. We used to design a dispensing system with a sharp board on the bottom, whose opening can be controlled by a servo motor, but with an experiment, that design was not feasible as it is hard to control how many condiments will out each time. Therefore, we then changed the system and added a motor to shake the bottle helping to dispense.

## Once we made sure each detail is working perfectly, we then started manufacture and incorporate with each separate parts. During this process, there can be lots of small errors found such as the height of our catcher is too tall to be placed under wood plate, or some of the condiments spots are not able to be reached by catcher. Then we looked for solutions of those errors and refine our machine.

1. Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

## The first design constraint is the space it takes. Since the size of our product is actually relatively large compared to other devices placed in the kitchen. Therefore, our product may not be used for families which have limited space in the kitchen. Even for those families with enough space in the kitchen, some of them may have a size preference,

## The second constraint is the environment requirement. Our product is placed in the kitchen, so the environment can be various in different homes. However, after all, our product is electronics, it can be easily broken if it touches water or other liquid sources. Furthermore, we have a weight sensor in our product that can easily be broken if the weight of the catcher plus the condiments inside exceeds the maximum weight allowed by the sensor. Also the PCB can be vulnerable to humid environment.

## The third constraint is the cleaning method. As the previous constraint stated, the machine is placed in the kitchen and the environment can be dirty and there can be condiments spilled on or in the machines. However, there are no cleaning systems contained in our machine, and our product is embedded well. As a result, it can be hard for users to clean out the machine or it takes a long and can be tricky on cleaning it after utilizations.

1. Describe how each of the following factors influenced your design specifications and constraints.

## **Health, Safety, Safety, and Welfare:** Since the product deals with condiments, food safety is one of the factors we considered. While designing the product, we made sure the container used for the condiments follows the US FDA (Food and Dietary Supplements) Food Safety Modernization Act. We choose plastic that satisfies the safety requirement to use as raw material for 3D printing. Also, to ensure the quality of the condiments, we have added a temperature and humidity sensor to the product, monitoring the interior environment.

## **Global:** Considering the various cooking styles all over the world, it can be hard to implement our product such as the layout of each condiment and the utilization of each kind of condiment. That can be a constraint during the production of our machines because the design has to be various in different places of the world.

## **Cultural:** We have thought that people with different cultural backgrounds have different cooking habits, and the food Chinese people cook is very different from the food that the French make. Therefore, our design enables the user to choose which condiments to put at each container, and they can upload recipes to the machine telling the device, step-by-step, what condiment is needed at each step and how much.

## **Social:** The society is heading towards the direction with the Internet of Things (IoT) where most of the devices we have are connected to the internet and can be easily controlled. In our product, there is a traditional rotary switch that can be used to control the machine, but also, we have enabled BlueTooth so that users can use their phones for more functionalities.

## **Environmental:** Currently, the environmental factor has limited influence on our product, but regarding the contribution of our product to the IoT, it is possible that our product can promote more environmentally friendly kitchen circumstances.

## **Economic:** During the design, we have tried to use materials that are common and easily machinable so that the cost is not too high. We are also 3D printing a lot of the pieces and avoid buying as much as possible. For each module, we have compared different options and selected the one that is the “best” in terms of functionality, price, durability, and other aspects. For our PCB, we also selected an international vendor that is able to provide better quality and a lower price (including shipping).

1. Describe the appropriate engineering standards incorporated into the creation of your product.

The engineering standard we adapted is FDA 21 CFR 178.3570 for incidental food contact on all 3D printed part that has contact with the condiment. We are also in met standard wireless communication standards such as IEEE 802.11 b/g/n and IEEE 802.15.1.

1. Describe the final status of your product.

In this stage, we have all the PCB board been soldered and the mechanical parts except the wood board and aluminum sheet for the sides. We have assembled the x-y table and the bottom base of the machine. And the other units have been 3D printed. For the software, all the separate algorithms have been finished and tested, leaving the script of the process of each recipe for users to select. The separate software module finished includes the temperature and humidity sensors, weight sensors, operation of stepper motors and servo motors, and iOS application interface through BLE.

1. Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

## Our team has done an ECE 362 mini project together before and worked in the same club, and we started to prepare ourselves one semester before writing the proposal. Four of us as a team have professional experience in the algorithm, embedded system, circuit design, computer architecture, and mechanical design for achieving our goal in this design. By knowing each other, we easily choose the parts we were interested in and wanted to learn. And we discussed every day about the progress and met up for resolving problems as we lived close. In this way, we kept track of the progress and make sure everyone was motivated to make progress.

1. Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audience for whom these materials were intended.

## We do require user manual for users to operate our machine, which includes the description of the product, the general operation process, maintenance process and potential solution to troubleshoot. At the same time, we do require manual for potential users to update their firmware for more options of recipes.

1. Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

## The type of design review that we aim for is a product unveiling event, much like the Apple event where they reveal their new product. The composition of our design review can be broken down into these categories: mission statement, product spec unveiling, target audience and pricing, potential impact and hands-on interactive review. our target audience for this final review is anyone who is interested in technology. There is no prior knowledge needed to attend the event.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Section)**

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| **Course Number and Title** | ECE 477 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | Team 8 |
| **Project Title** | Condiment Express |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Yuanqiu Tan | EE | Team leader | May 2020 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## As a team leader, the first thing I was responsible for was to keep track of the process and timeline. I kept tracking each teammate’s work and negotiate for solutions, and I ordered and analyzed the material we need in the first stage. At the same time, I switched between helping the hardware and mechanical design. Chengming and I designed the two PCB using Eagle: one is for the connection between each servo motor in solid condiment dispenser unit to the main PCB, and the other is the HX711 board for weight sensor. And, I did the CAD design for some parts like moving tray in the x-y table using Inventor and revised my teammate’s CAD design like the user spoon. In the manufacturing stage, I went to BIDC every week to prepare the required material using bandsaw, gantry and milling machine, and I also soldered the PCB board I designed. In the last stage, I assembled our machine with my teammate and debugged the PCB and software.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## First, with my two-year research experience at Purdue, I could negotiate for better resources for our projects and help my teammates choose the part they are interested in. For example, Minghao wants to know more about mechanical design, so he did the CAD and manufacturing processes. With ECE 362, which teaches the embedded system, I can understand and use EAP32 easily and smoothly. And with the experience I gained from ECE 362 and research projects, I can do PCB design and analyze the circuits. Also, the materials from ME 270 helped me analyze the force of the system when I did the mechanical parts.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## I didn’t learn CAD design and I haven’t used any facilities in the machine shop before. Therefore, I used the online video to learn how to do CAD in Inventor, and my teammate and teaching assistants in BIDC helped me learn how to do CAM and use machines there. Also, even though I have experience in PCB before, I learned a lot from my teammates and professors in this course as my teammate designed a 4-layer board. Since I seldom did software implementation, I gained some knowledge of iOS Application design from my teammate and online resource in this project.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## I learned about the patent and ethical responsibilities from the ECE 20000 course and other projects, and I learned more from the lectures in this course. For this project, since the previous related products are limited, I used a lot of time to make sure we do not violate the law with learning patent law and analyzing other products. And when I write the user manual, I tried to make it clear and professional that our rights and other people’s rights won’t be violated.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## In this modern society, as people are busy and pursuing a healthy lifestyle, our product could help many people save time on making their own food, which they can easily control the quantity and quality of your food. Economically, as there are limited products solving the same problem, this product can prompt the development of this new industry aiming at offering cooking preparation. At the same time, our product can build a better environment with potentially less waste of food in cooking. For the whole society, as this product can be part of the smart home, it will lead to the trend of healthy life with high efficiency.

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| **Course Number and Title** | ECE 477 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | 8 |
| **Project Title** |  |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Minghao Sun | EE | Mechanical and system design and manufacture | May 2020 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## During this project, I provided the initial thoughts about the projects which are to do an automatic condiment dispenser that can dispense a certain amount of condiments according to the menu sent from the user’s mobile device. After the project started, I am mainly in charge of incorporating the overall system and refine the details of how the mechanics of our product are working. At the same time, I made a lot of CAD models and assembled them together with CAD made by Chengming. After all of the details of our products were finished, I started to manufacture the parts needed in our products. I made the CAM that is needed to manufacture the top wooden plate of our products, and I spent a couple of days in BIDC to discuss and manufacture the CAM and parts with TA. Meanwhile, I assembled the parts with my team and modified the materials if any changes needed.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## Since I transferred from the school of polytech, I learned some CAD skills as well as CAM. And those two skills helped me a lot when I am doing this project because not only, I knew the software skills of how to use CAD, but only the knowledge about considering the performance of the overall system and details of mechanical operations. Also, the knowledge from physics courses and feedback controls helped me to analyze the actions of the machine.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Even though I learned about CAD and CAM, it’s been a long time, and I was actually not taught a lot about them, I put a lot of effort learning how to use the software. Usually, the strategy that I used to learn those CAD drawing tools is to search for specific questions online or watch tutoring videos on YouTube. But from this project, I found out that asking someone who is good at that field is so much helpful and efficient. I spent days in BIDC to ask questions to TA there, and I am lucky that most of them are very nice.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Because I didn’t have many chances to physically design such a great project, and I never think about ethical problems related when I am doing a project. Therefore, throughout this project, I learned about the importance of intelligence protection especially about patents and commercial products. Since this time, I become the one who wants to protect my intelligent achievements. This kind of switching positions makes me understand the importance of ethical and professional responsibilities even as an engineer.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or made) an informed judgment as to your product’s impact in each of these four contexts?

## I am very confident about our project. I think our project can make a great impact in all areas. In the economic context, our project can attract many consumers and produce significant profits upon it. It may even promote the development of a smart kitchen. For environmental contexts, this project may have little impact, but in the future, we may consider improving our product by using recycled materials. And since our product is convenient, it may change people’s behavior and lifestyle, such that people will tend to cook at home instead of eating unhealthy food outside. As for global context, if we can make our projects globally, we can introduce this product to the whole world, and then people can taste all kinds of food from anywhere in the world.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Section)**

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| **Semester / Year** | Fall 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | 8 |
| **Project Title** | Condiment Express |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Binhan Xu | Cmp E | Software | December 2019 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I am the software engineer of this team and responsible for all software development. During the initial prototyping stage, I was helping the electrical engineer with deciding the peripherals and also the modules needed for this project. After that, I prototyped all modules used in the final product and made sure each individual component is functioning and I know how to use it properly. During the prototyping stage, I was going over the datasheet for many I2C modules to understand how to correctly send packets to and read data from the module. One of the hard parts was that there are many libraries developed for Arduino, but I barely found anything for ESP32. Therefore, I did look at some of the Arduino libraries and translate them into ESP32 libraries. After that, I was helping with the PCB debugging and putting together all prototyping code into the final product so that it functions as expected.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## The most helpful class I took before doing this project is ECE 362. While prototyping each individual component, I was able to apply the knowledge I learned in ECE 362 about microcontrollers and different peripherals. Especially with the I2C protocol. Having learned what it is and how it works helped me a lot when I was writing code for all those slave modules. And the experience in ECE 362 helped a lot when reading the datasheet to understand the communication. Also, the coding experience in ECE 362 also helped me understand the difference between coding regular application for computers and microcontrollers.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Something that I was not so familiar with was the entire ESP32 system and its libraries. During the initial stage, I had a lot of trouble with the development and did not know where to start. The part that really helped me was reading over the official documentation as well as examples provided by the Espressif system. Another part is that although I have learned I2C protocol, applying them to different modules still requires reading over the datasheet and that was challenging at the beginning. I have started to be more familiar with the I2C protocol as more development I have done. Recently, I wrote the I2C communication code for the multiplexer without any external resources other than its datasheet.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## One of the most important ethical and professional responsibilities for a software developer is using code from the proper source and knowing what it does. During the entire development process, I did use some example code from the Espressif official Github page with modification, which is allowed based on the license provided. It is important to me not to use any code that does not have a license, or its license prohibits private use and/or commercial use. Another thing is that even though some of the code is modified based on given examples, it is important to understand what the code does. Importing code with unknown functionality can have severe consequences.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## Our original target was to improve people’s cooking experience, and I believe our product can achieve that. Economically, this product has a huge target user group with a relatively low cost of production, which can potentially lead to high profit. The product does not have too much impact on the environment due to limited waste during production and only uses electrical energy for operation. Socially, it can change the traditional way of measuring condiments with a cup or spoon, which is both time-consuming and not so accurate. This product can provide a more automated routine for condiment preparation with computer measured precision. We have made our product modulus where users can choose what to put in each condiment container, allowing users of different cuisine can all benefit from our design.

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| **Semester / Year** | Fall 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | 8 |
| **Project Title** | Condiment Express |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Chengming Zhang | EE | Electrical Engineering and Mechanical Design | May 2020 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## My contribution to the project mainly falls into these three categories: Circuit Design, Mechanical Design, and 3d manufacturing & part sourcing. I have designed a four-layered PCB with ESP32 Microcontroller on board, that has the capability of controlling 5 stepper motor, 15 servo motor, measuring acceleration, temperature, and humidity. I have also designed most of the mechanical components used in the machine, on the component such as catcher and the solid condiment dispenser. I have also 3d-printed all the parts that are used in this machine and sourced most of the parts from either amazon, mc-master carr, Digikey, and Ali-express.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## Since PCB design is one of my contributions, my experience from ECE255 helps me design anything that has to do with a MOSFET or BJT. My experience from ECE362 helps me design a functional microcontroller system with all the correct i/o configuration and power delivery. It also helps me design better PCB by following the I2C, UART high-speed signal design guidelines that were mentioned in the class.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## The most important skill that I have to learn to properly contribute to this project is the proper PCB design. I learned about proper PCB design from the senior design lecture. Although I have previously designed many PCB board, I still have things to learn, for example, always place microcontroller’s decoupling capacitor directly underneath the microcontroller and calculating thermal values to select a proper ic package. I have also learned that we can calculate the life expectancy of an electronic circuit by using the formula from the military handbook. My learning strategies is always to utilize online resources to gain my knowledge. However, if there are no available resources to resolve my question, I always turn to the senior design staff member for help.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## When I design this machine, I always think about my end-user and how this machine will impact their life. One such thing that I always put in mind is the safety of the machine. I will never sacrifice my user’s safety to cut corners in my design. Such a safety feature included in my machine is the accelerometer, stepper motor over current protection, temperature and humidity sensor. The accelerometer is used to detect if the machine is placed in an unlevel surface. since our machine is very heavy, we will need to make sure that the machine is installed securely. The overcurrent protection is used to protect the motor from drawing too much current when it is installed to avoid a fire hazard. The temperature and humidity sensor is used to protect the user from ingesting spoiled food that was affected by high temperature and high humidity environment.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## I made our product in such a way that it would impact all of these categories. First, the condiment express could have an impact on the economic market by taking some market share from the food delivery industry and restaurant industry by encouraging people to cook at home more and increase the efficiency of a modern restaurant kitchen by automating away the process of adding the correct amount of spices and condiments. Environmentally speaking, with our refillable condiment cartridges, we save the need of buying more and more of those individually packaged condiments. Societal speaking, we simplify the process of cooking, so that we could invite more and more young adults these days to feel the joy of cooking without the worries about measuring all the condiments. Finally, we made a global impact by automating one more thing from people’s daily life, just like the washing machine did. With a future product such as an automatic cooking robot, we could achieve a small-scale automated cooking process that could cook food more efficiently for those cities that suffer food waste problem.