Smart Toaster Oven for The Future

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***Abstract* — For this project, we wanted to revolutionize the design of the toaster oven by adding smart capabilities to it. Features such as phone notifications and the ability to control toast capabilities. We wanted to add an LCD display, phone interactions, sensors, and a built-in timer to the smart toaster oven.**

***Index Terms* — Low-power electronics, manufacturing, Microprocessors, Mobile communication, Relays.**

I. Introduction

Many Americans use a toaster oven to make their breakfast daily. This technology impacts millions every morning when they want their nice heated crispy toast. The thing is though, there hasn't been any innovation to the product. Sure, the design has been modernized over the years. But what product hasn't. In the age of smart home technologies, the toaster oven is lacking. We see everything from smart fridges to smart thermostats to smart home alarm systems. Where is the smart toaster oven though? There should be a smart toaster oven that has more abilities than a standard run of the mill toaster. That's where we come in to build it.

For this year's Senior Design project our group came up with the idea of building a Smart toaster oven. When it came to come up with this kind of idea, we asked ourselves: "What is a very simple commonly used item that we can make more innovated?" We considered a few different items such as a mailbox, toaster, and microwave in which we settled on a toaster oven. The premise behind this smart toaster oven is that it is much more advanced than a standard toaster. In addition, it provides more advanced features that you typically will not see in a household toaster oven.

There are many different designs of toaster ovens on the market. One can simply research toaster oven on a search engine and find a list of them available for purchase. The problem with these designs is that usually one needs to spend a few hundred dollars to buy a toaster oven that has a timer or a dial to control temperature. There does exist smart toaster ovens that can do the things we described however it is not widely known and expensive to make.

II. Operation manual

Using the smart toaster oven should be easy for each user. So, to do that, we really dumbed down the design of a traditional toaster oven. Before we get started though, it must be plugged in so that the unit is powered on. Surprisingly people forget to plug in electronics and complain when they don't power on.

First, a user must open the door to the oven. Next, they put whatever they want to toast or cook inside the toaster oven. After that they close the door of the oven and they are all set to start cooking. To cook with the toaster oven, a user will have multiple options available to them on the LCD display. By default, the opening screen is a welcome screen that tells them to press pound in order to begin. Now the user is brought to the begin toasting screen. A user now goes to a screen where they select the desired temperature for cooking. Next, they go to a screen where they select how long they want to wait for their food to be done.

The user can now do whatever he or she wants for the duration of the time. When the timer ends up hitting 0, the user receives a notification that the toast or other food is now complete. The toaster well turn off in a certain period of time with nothing is done for safety precautions. When they get back to the toaster, they open the unit and can grab the food. The unit stops tells you to enjoy and goes back to the welcome screen. The user in this instance can now sit down and eat the toast or other food that was cooked. If they want more food, they can continue to repeat the process until full.

Cleaning the unit is also easy for the user. They first must make sure that the unit is unplugged. After that they can open the smart toaster oven and remove the tray in the center of the unit. They can hand wash this or put it in the dishwasher. After that they can use a household cleaning product and scrub both the inside and outside of the oven and remove the crumbs. It's suggested that a user goes through and cleans the smart toaster oven at least once a month. This ensures that the product is clean and safe to use. Now that the unit has been scrubbed down, the user can now put back the tray table. Close the oven door and the unit is ready to go once again.

III. Motivation

In this section, we will go over the four major motivations for the smart toaster oven senior design project. The love of toast, an open market, the ability to expand upon our limited programming skills, and the opportunity to have creative freedom while constructing and selecting the features for the project. These are the primary reasons why we ended up building a smart toaster oven over an interdisciplinary project or a sponsored project from a company like Lockheed Martin or Boeing.

We all enjoy eating toast for breakfast. Whether it's toast alone, or with guac, eggs, fruit, or bacon. Toast is one of the staples of the American breakfast. Mix it with some Greek yogurt and orange juice or milk. Now you got yourself a solid meal. So, with this being a major part of our breakfast production, we thought about building something around it for our senior design project. We researched past projects and ended up deciding that a smart toaster oven would be our best bet. So, with that in mind, we decided to do this project.

Almost every household has a toaster oven, so this can have a major impact on an industry that is stuck in the past. Building the first affordable smart toaster oven is an opportunity to hit an open market. Research on Amazon and eBay shows that there aren't any advanced toaster ovens in the market that are reasonably priced. In an age where almost every product has a smart option, it's a shame there isn't a smart toaster oven. So, to capitalize on it, we built the affordable budget option for the toaster industry. Everyone should have access to this technology. Someone shouldn't have to spend almost $400 to own a smart toaster oven.

In addition to the love of toast and the opportunity to change a market, we also wanted to create a product that would be fun yet challenging and innovative. Our group is full of electrical engineering students. Our background is in hardware rather than software. Being a group full of EEs, we don't have anyone that completed CS1 or CS2. We wanted to learn a lot about coding on the spot. We had to research the different development languages to determine what's best with the board, LCD display and sensors. We also had to figure out how to set up a Bluetooth connection and to notify a user's phone when the toast or other food is done cooking. We all love challenges, so we were prepared to spend sleepless nights grinding away at this project.

The last major motivation on why we decided to go for this project is the creative freedom involved with it. We didn't want any non-EE majors or companies to tell us what we had to do for the project. In a similar sense to how musicians don't want record labels to influence or push them into a different direction for the music. We thought it was best that we communicate our ideas between all of us. We've all known each other since freshman year, so we know our strengths and weaknesses. An outside person or company wouldn't know. It's the reason for our 3-person team and the lack of a sponsored project. We didn't want to work with any big-name engineering companies. On top of that, none of us are currently going to be working there after graduation anyways. We all have other jobs not associated with engineering. It would make no sense to work with a company.

IV. SPECIFICAFTIONS

When it comes to the toaster oven, we have decided on six various aspects that could affect if a customer would buy this product or not. The first and foremost thing people look at first is the price. It obviously takes a good deal of money to prototype and create these devices, so the price to build must be lower than the selling price in order to make a profit. Next is how user friendly the device is, which is a big focus for us since we wanted to make it as interactive and smart as possible. The connection of the device would fall in this category as well. After that are some physical components such as size and durability. This is important in deciding if we want to build a toaster or a toaster oven. Lastly is the efficiency of the device and if a common user can access it with accuracy every time.

When it comes to engineering specifications, we also choose six very distant categories to look at. Firstly, as previously mentioned, the cost is one of the first things to account for. This would be the best example of positive correlation, since when the cost of making the device is higher, the consumer price for the device will also be higher. After that we have some of the inputs that are the main features of the toaster, mainly in the time and temperature domains. Following is the dimensions of the device, in which many forms of prototyping will take effect in order to balance out all the variables listed. Next is the power output of the device, which would control how fast and what quantity of food can be toasted. Lastly, we would like to include some form of smart phone connection with the toaster, aiding to the smart nature of it.

It is very important for any manufacturer to demonstrate the relationship between the marketing and the engineering design side of things. The consumer of a smart toaster oven expects certain things. They expect it to be low cost, user

friendly, durable, the right size, easy to connect, and efficient. But at the same time, the engineers need to make some compromises, or the final product will not be ideal. There must be limits to the cost as parts, manufacturing, and research and development cost money. How user friendly the design can be depending on the engineering of the final product. The user comes first, but there are things that might not be able to be implemented. The durability might limit things such as the touch screen as it wears down over time. How efficient the product is depending on the parts used along with the engineering of the final product.

We must also think of our targets per engineering specification. This gives us a goal to work towards. This must still fall within the customer specifications, however there must be achievable details mentioned or else the project planning stage would be too vague and a company looking to buy an idea would never buy into it. These precise achievements are the foundation of a great project

V. Core Process

The following diagram of Figure 1 is a high-level Block diagram that displays the relevant inputs and outputs of the system that need to be added on to a toaster oven to make it a smart one. The power source shall come straight from an outlet which across the United States is mostly standardized as 110 V single phase at 60 Hz, however there are outlets meant for more higher duty task that use 220 V such as launching machines and ovens. The Toaster Oven though is being designed to take power from 110V outlet lines and outlets can be tested beforehand to make sure this applies through a simple multimeter test. Then an AC-DC conversion is needed which shall be accomplished on the PCB or using a bought converter that shall be capable of taking 110 V AC to 5 V DC. 5 volts is needed to both run the Atmega328, the temperature sensor and numpad. All the sensors that are used for this project require 5 V. User will place Toast in the Oven set temperature on keypad and desired time. The microcontroller will be responsible for the control of the heating element and will work with the temperature sensor to verify that the set temperature is reached at that point a Led will display the temperature is reached. A digital Timer will display the amount of time left that is set by the keypad. The Wi-Fi component would be related if someone wants to be able to preheat their toaster before they see it to be able to save time by not having to be right there and enter the preheat stage. After the timer is finished an alert on the screen will go off to let the user know the oven has finished.

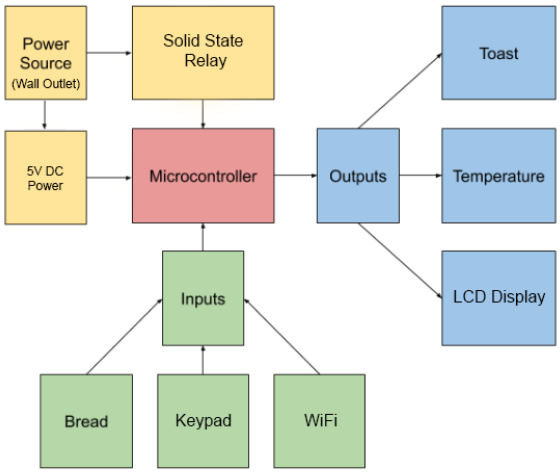

Fig. 1. Showcases the smart toaster block diagram for out smart toaster oven

VI. Core Components

A. *ATmega328*

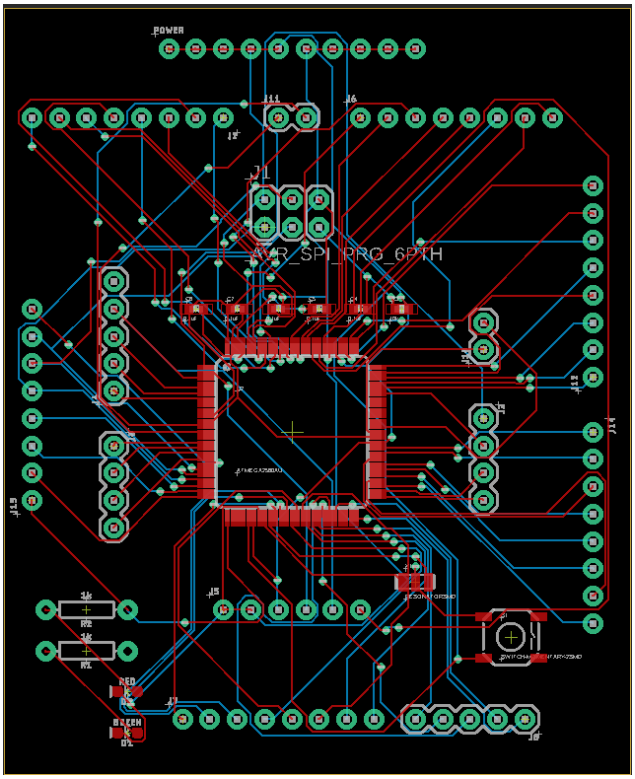

Fig. 2. Showcases our PCB layout that we designed

The job of the microcontroller is part into two significant errands. to quantify the time the wheel takes to pivot one full revolution, using an attractive reed sensor, and convert

that into a speed estimated in the unit's miles every hour (MPH). This speed would then be yield onto an LCD. In our decision for a microcontroller, we remembered this errand of what processor would be the best decision for this undertaking. Another however considered would be the language that the processor would comprehend, and that we would take a stab at a language that is natural to our software engineer.

Moreover, the MCU will take in throttle input that will be utilized to alter the created a high recurrence PWM signal for engine control. We would require an MCU with a high handling pace that is fit for creating such a sign. We additionally would need to discover a microcontroller that is amazing enough to take on the assignment while keeping the expense sensibly speaking.

The ATmega328 is an ordinary and well-known decision in microcontroller for most undertakings since they are, generally, easy to understand. The positives about the Arduino is that there's not a substantial arrangement for the processor, code-wise, and that taking simple sources of info is a lot simpler to program than most different sheets. The ATmega328 runs on a preparing rate of 16MHz and has a working voltage of 5V which is a low voltage that the sunlight-based board can supply.

The ATmega328 additionally has an increasingly reasonable rationale while interfacing with an LCD screen for UI yield. The expense of the ATmega328 doesn't delve deep into our spending limit since most sites sell it for a minimal effort of just $16.

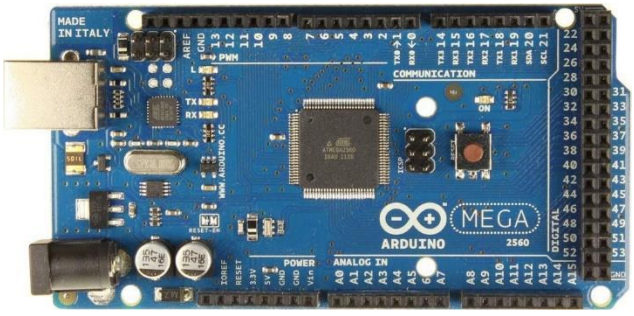

Fig. 3. Showcases the Atmega 2560 Processor

B. ESP8266 Wi-Fi Module

Wi-Fi systems have no physical wired association among sender and recipient by utilizing radio recurrence (RF) innovation - a recurrence inside the electromagnetic range related with radio wave proliferation. At the point when an RF current is provided to a radio wire, an electromagnetic field is made that at that point can proliferate through space.

The ESP8266 Wi-Fi Module is affordable and easy to set up to the Arduino board. Some of the features included in the Wi-Fi module are: Working voltage: 3V, integrated with a TCP/IP protocol stack, sensor interaction, flash disk size: 1mb, 8 pins, and a max voltage of 3.6V. The ESP8266 Wi-Fi Module can also be picked up on multiple websites for around $8. So, it's very budget friendly for the project.

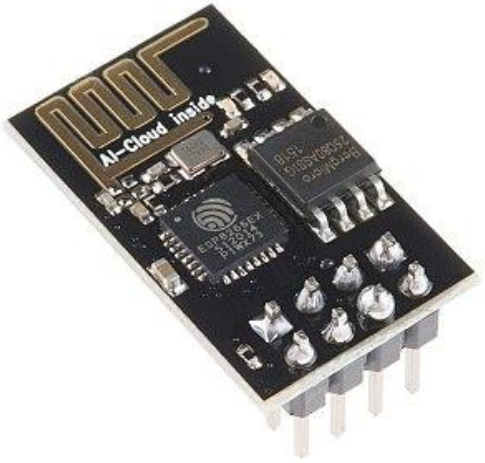

Fig. 4. Showcases the ESP8266 Wi-Fi Module

C. 3.3V 5V ESP-01 Serial Adapter Module

An adapter module for ESP-01 Wi-Fi module. 3.3V voltage regulator circuit and onboard level conversion circuit. Interface logic voltage: 3.3V / 5V compatible **(**On-board level shift circuit)**.** It can make 5V microcontroller easy to use with ESP-01 Wi-Fi module**.**

D. Arduino 4x4 keypad

To improve the overall design of this toaster oven we will consider in revamping the user interface with a numerical keypad for the user to input the commands. One of the parts we look at was a 4 x 4 numerical keypad for Arduino. With this keypad you're can punch in your mystery key into this numeric network keypad. This keypad has 16 catches, orchestrated in a phone line 4x4 network. It's made of a dainty, adaptable layer material with a glue backing so you can append it to about anything. The keys are associated into a network, so you just need 8 microcontroller pins (4-sections and 4-columns) to look over the cushion. This part on average would cost $3.95 and requires 1 V for power.

We used a keypad interface rather than a touch screen. Being a kitchen application, users are more likely to have dirty fingers. This is going to cause the screen to get dirty.

On top of that, since a toaster oven is used almost daily, there is going to be wear and tear. Overtime this is going to scratch or wear down the display. The touch screen is the newer technology & it's technically better for the user experience, but we believe it's better to optimize the toaster for long term use.

E. Sainsmart max6675 module with k type thermocouple

A thermocouple is a kind of temperature test that can withstand the very high temperatures (>100C) of the toaster broiler. There are a variety of thermo-watts out there. The sort K thermocouple is the most widely recognized (in any event as I would like to think). Type-K alludes to the two sorts of metals that are joined to make the thermocouple sensor. The precarious part is taking the voltage change appropriated by the physical idea of the thermocouple and transforming that into a temperature. This over the top expensive DIP bundle was worked for a wonder such as this. Append a K-type thermocouple, control the thing at 5V, and you have a 10mV/C yield. There are numerous different approaches to skin this feline, many are less expensive, however all are unquestionably progressively complex then this tight bundle.

We were searching for +/ - 1- or 2-degree C precision over the stove. So, we can take the 10mV/C voltage levels straightforwardly into the 10-piece ADC found on most 16F PIC microcontrollers. We have the microcontroller to pursue temp information, presently we must kill on and the broiler. With a 1500W broiler on 120VAC, 12.5A that should be turned on and off. Any typical transfer would presumably dissolve or flop after a couple hundred cycles.

F. Sunfounder I2C 1602 LCD display

The liquid crystal display is a full-grown innovation that is at present pervasive in the shrewd gadget showcase just as different markets. As a non-emissive innovation, LCD must use an outer light source to see the presentation. This backdrop illumination adds some extra thickness and weight to the equipment; however, this shouldn't be an issue since the toaster is not a handheld gadget. The backdrop illumination likewise lessens dark level portrayal and can make hues look more cleaned out. Numerous illuminated screens can likewise be difficult to see in brilliant lights, and kitchens are generally splendidly lit, so perceivability could be an issue.

Some lucidity issues can be countered by utilizing thin-film transistor innovation, a 31active-grid innovation, which gives a more splendid and more honed showcase and would be desirable at little display sizes, for example, utilized in the smart toaster oven. Another issue with LCD perceivability can be to some degree constrained review point. This can be exceptionally reliant on the nature of the LCD. The quantity of hues that can be spoken to is very great and ought to be more than satisfactory to show the photos utilized by the toaster. Reaction time is reasonable and ought to be satisfactory since the toaster oven will not be using moving pictures like a TV.

G. Opto 22 solid state relay 240D25-17

For the solid-state relay, we went with the Opto 22 solid state relay 240D25-17. It features a turn-on/turn-off time of ½ Max Cycle, an operating frequency between 25 - 65 Hz, and can be turned on and off with a 5V DC output from PCB. The main purpose of this is to control the AC flow. It was only $28 on Amazon so it fit in perfect within our final budget.

H. AC 100-240V to DC 12V 1.5A Power Supply Adapter

When dealing with batteries, many things must be taken into consideration. Even though this is a very vital piece of our product, and really any project requiring power, there is some safety features we needed to implement and always be aware of. Without a battery or any kind of source of power, there would be no way our project would be able to function at all. Since we are dealing with batteries that contain various currents, we must be aware of them so that, even with various other currents going around, the toaster oven still operates as it should. Since the toaster heats up to a fairly high temperature as well, we should always be monitoring the battery to make sure it doesn't have any issues concerning overheating and possibly exploding. Therefore, the standards put into place by IEEE and various other standard developers were considered to aid in the safety of both building and operation something of this caliber.

I. Arduino IDE Code

Uses C++ in order to code the program that is sent to our PCB and allow it to function properly. Each part is compatible with Arduino and has the libraries available online. All of us are Electrical Engineers so the coding isn't our strongest suit; however, all the resources online have made the process straight forward for us all to understand and adapt to the situation at hand.

VII. Mechanical Aspects

A. Problem Examination

Since we bought a toaster oven and are remodeling it, many mechanical changes must be made. This begins by gutting everything out, leaving only the shell of the toaster oven. The knobs are of no use to us so that must carefully be removed as well. This was done via the help of various screwdrivers, scissors, and a bar. The amount of space required for all the electrical components must remain in mind. This is one of the main reasons we have decided upon building a toaster oven as opposed to just a toaster. Furthermore, the electrical components must no be affected by the heating of the toaster oven. This doesn't mean suppress the heating though, both devices must be up to optimal values and accuracy. The last aspect that must be examined is the front of the toaster oven. It is originally not a flat surface where an LED display and a keypad could be placed, since there was a slight curve for believed to be aesthetic purposes. Thus some form of flat surface must be placed on top of where the knobs are to make room for these devices and well has hiding any unnecessary wiring from the user to give them the best experience possible as they are making their toast.

B. Problem Solutions

In order to get the holes to where the knobs were to be big enough for some of the wires (mainly the one connected to the keypad and LED display), a Dremell was used to slowly makes the holes better. The Dremell is a two-speed rotary tool that has many capabilities. The accessories used on the Dremell were two grinding/sharpening tools of varying sizes. Basically, after the accessory was placed on the top of the Dremell, it begins rotating the end at high speeds thanks to a motor inside of it. Then it uses this high speed to slowly grind the metal hole into a bigger one virtually by ripping off pieces of the metal from the inside out. This had to be done for all three holes the knobs were located at and the process toke around ten minutes per hole. The next solution we had to think about concerned the front of the toaster oven not having a flat surface where the LED display and keypad would go. This was done with the use of a heavy-duty cardboard whose original purpose was to be used behind a vinyl. The pieces were cut using a strong pair of scissors. They were then formed together to create a type of shell that would go over the knobs. The pieces were all held together with a strong adhesive tape that won't easily be heated or mess with any of the electrical components involved. After this is still wasn't straightforward though. The touchpad was easy to mount, but the display wasn't as sturdy. Therefore, we implemented some screws on all four corners of our LED display so that it can constantly stay in place and promote a more user-friendly environment. The cardboard cutout was placed in front of the holes and held to the toaster using the same type of adhesive used in holding the cardboard together.

C. Testing

Each part of our project was tested individually and was verified to work. The order in which the section is written is chronologically how they occurred. The code was developed to use each part in conjunction with each other. The PCB was created, and parts were soldered. Even though we were able to get basic code onto the device to make the LEDS on it flash, it was unable to take in our full code and implement in our project acting as the Arduino device. Therefore, the Arduino was just used since any shipping of new parts was unavailable due to the Corona Virus. Thankfully the development board worked as intended, so we moved forward wit testing. The mechanical design was finished up in order to complete the revamped user control. The website was then developed for both desktop and smartphone user control. The Wi-Fi and ESP module was coded to work with the website successfully.

VIII. Demo walk through

A. Explanation of components

The first thing shown is our board, the Arduino mega, it uses the 2560. Next shown is the original PCB. We designed this PCB and ordered it online with the task to mimic the original. This has the 2560 soldered onto it, but due to virus delaying everything when we found out there was a slight error, we were unable to get any new parts in time. We were able to flash the lights on the board but couldn't get code onto it. Therefore, we finished the project on the Arduino. There's a lot of wires connecting our project together so next we have some connections to go through. Firstly, the way this is connected we have a power coming into the toaster connected to the wall outlet. It starts by connecting to one end of the solid-state relay (which controls the AC flow). The next line shown (white and red) are the heating elements. Then there are two ends that are connected to the Arduino mega. The program on the board sends a 5v dc signal to open and close the relay to control the power. We power the Arduino via a 12v dc adapter. The thermocouple is connected against the toaster oven's wall to promote accuracy for temperature. The Wi-Fi chip is connected through wires some wires as well, so we set it up against the wall alongside the thermocouple to get the best signal. All these components are inside of the toaster oven, however for the purposes of the demo everything was taken

out so that it is easier to follow how everything is connected and be shown on camera. There is a shell that goes over all these components so nothing electrical is shown to the user which could greatly degrade the quality of our oven. Without the shell the wires would be lose which would make them more easily breakable, as well as having various safety hazards present.

B. User perspective start

From the user's standpoint, looking at the front of our toaster while it is plugged in shows the LED display. It defaults to welcome page which welcomes you and askes the user to press pound to continue the toasting process. After you press pound, it asks for a preheat temp and to once again press pound to proceed. It Should take 10-15 seconds to turn on the heating elements and preheat. The bars inside the toaster oven will begin glowing red to prove this is occurring. The next step the user must input on the pad is the time. The led display asks for the time and the user must press their desired time and press pound. Then the countdown begins. When it finishes, it says done and enjoy. You can always enter more time by pressing star (which acts as the back button). If not, the toaster will automatically turn off slowly for safety reasons after about 30 seconds.

C. Mobile Interactions

If one uses the make toast using our website we have created, the first step would be to make sure the ESP module is on and connected to the device that will access the website. Move over to the website, it has various toast profiles to choose from. This demo uses the lightly cooked one. Pressing it opens a new prompt saying the light toast is cooking, it will be ready in 3 minutes, and enjoy! Pressing it also sends the signal to the toaster to begin the preheating process as well as stating the timer countdown. As shown in the demo, the bars are heating up since they are slightly red and the timer has already begun counting down from the three-minute mark mentioned in the website, so we know the toast profiles are working. One can also change the time of the toaster oven. Again, by hitting star (back) we can change the time left for the toast. In this example we change it to ten seconds. Therefore, it counts down from 10, says the done enjoy message, and then it's the same deal as before with adding more time or waiting 30 seconds for the toaster to rest automatically.

D. Website Breakdown

There is a break in the video where we go over the different labels on the led screen, since the video might not have captured the glowing screen clearly. Various messages from the screen are shown in picture form to ensure it working capabilities. Now for our website we used WordPress with Elementor. If you go under plugins in WordPress, you can see how Elementor is connected to it. To check out the actual site one must go to our link. There are 5 main sections: home, toast profiles, about the toaster, the committee, and results. First the home page is simple and sweet. It contains a nice picture of our toaster oven with a little intro of who we are and a nice quote the get people in the toasting mood. Next is the profiles which include light, medium, and heavy cooked toast. Each has the info pertaining to each profile regarding time and temperature and even a picture of how the resulting toast will end up as. These buttons will also start up the toaster oven assuming you are connected to our Wi-Fi chip. Next there's a section about the toaster. There are some skills we learned invested in it as well as other topics of interest concerning our journey of building this device. Then we have a thank you to our review committee showing what professors are helping us out and going to be our judges. Lastly, we have our results which shows some pictures and diagrams of our story from the beginning of our project up until now. The demo ends alerting people that food cooked via our toaster oven through this video is in fact some great toast. One might even say "Nice" after a very satisfactory crunch occurs in the first bite followed by some chewing. serif

Fig. 5. Showcases the home page for our website

IX. Conclusion

As with all projects, there were several difficulties encountered. Everyone has different backgrounds and schedules, so everything didn't align up perfectly. We are also all Electrical Engineers, so we don't have a large background in coding and development compared to our skills with hardware design. The difficulty in obtaining certain parts due to the Corona Virus was also interesting

to work around. However, over the last eight or nine months we ended up with a project that operates properly. The toaster oven can successfully cook various foods with the use of the components comprised in it. Although a smart device, this could be a great step into manufacturing devices such as these to be used in an everyday household. Especially concerning its capabilities of Wi-Fi use he can be a nice add on into any home trying to make the toasting aspect smarter.

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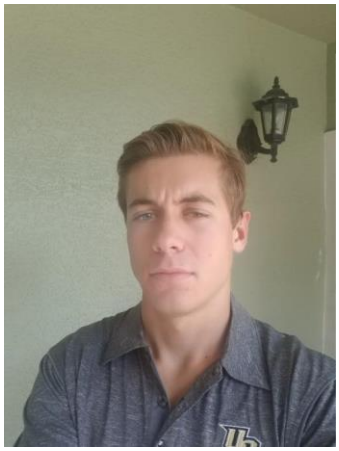
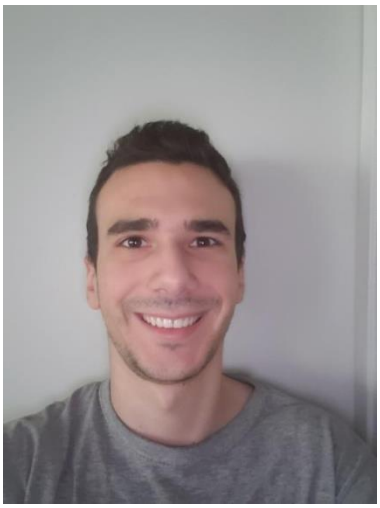
THE TEAM



Ryan Nolan is a Senior at UCF studying Electrical Engineering. After graduating, Ryan will be moving to Las Vegas to work on his Search Engine.



Alexander Tsangarakis, a graduating senior majoring in Electrical Engineering. Upon graduation, Alex will be commissioned in the United States Air Force as a 2nd Lieutenant. From there, he will be moving out to California and will start his job as a test flight engineer.

James Chorma is graduating with an Electrical Engineering Major and a Music Minor. He will be returning to his family in Vero Beach to work in his father's house flipping company where he will be working on all electrical components on them.