Smart Grill

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***Abstract* — This project involves building an electric grill that can cook food on its own with minimal involvement from the user. The Smart Grill allows the user to choose from a menu of food options and also pick their desired cooking temperature of what is being made. The grill will then preheat automatically and notify the user when it's time to place the food item of choice onto the grill burner or rotisserie rod. Once the food is on the grill, Smart Grill takes care of the rest and notifies the user when their next meal is ready to eat.**

***Index Terms* — Relays, Thermistors, Bluetooth, Food technology, Heating, Graphical user interfaces, AC motors**

I. Introduction

The goal of this project was to create a fully functional electric grill that can be controlled with an LCD touchscreen and mobile application. The user who is cooking the food should be able to cook their food effortlessly and easily. When the grill is first powered on the LCD touchscreen prompts the user to select a menu item from the screen. The grill has four choices of menu options available to the user: chicken, hotdog, steak, and hamburger. Once an option is selected, the grill burner will begin to preheat to 450 degrees Fahrenheit.

A thermistor located on the burner of the grill monitors the heat of the burner and displays it to the user on the LCD touchscreen and through the mobile application. Once the burner reaches the desired preheat temperature, the user will be notified that it is time to place their food onto the grill burner or rotisserie. Some food options, such as a hotdog, can be cooked with the rotisserie feature instead of using the burner.

When the user is placing a hotdog onto the grill, they will be prompted to select if they would like to cook it utilizing either the grill burner or rotisserie. At this point, the user can also select what temperature they want their food to be cooked to. A temperature probe will also need to be inserted into the food item being cooked and then cooking begins when the user selects the "Begin Cooking" option on the LCD touchscreen. During the cooking process the burner heat will be regulated to stay at 450 degrees Fahrenheit and is measured with the temperature sensor attached to the burner.

To ensure even cooking throughout the food item while using the burner, the user will be notified if the food item needs attention and needs to be flipped over. If the user is instead using the rotisserie, the rotisserie rod will spin to ensure even cooking throughout the food and will not require any action from the user. Once the food has reached the required temperature the user is notified that cooking is complete and they are able to remove their food item from the Smart Grill.

II. System Components

The Smart Grill is designed by putting together many different system components. There are some technical details behind each component that need to be introduced to assist with fully explaining how the design was implemented. This section discusses the individual components and how they contribute to the final product.

A. Microcontroller

The brain behind the Smart Grill project is the microcontroller, which is an ATmega328. There are many different components running all at once so this microcontroller was perfect for handling all of the processes quickly and efficiently with its 16MHz clock speed. The temperature sensing circuits for this project required the use of three analog input pins, which the microcontroller was able to handle with no problem. Another important need for the ATmega328 above other microcontrollers was its readily available libraries compatible with our LCD touchscreen. The rest of the requirements from the microcontroller were pretty standard and were easily met by the ATmega328.

B. LCD Touchscreen

The primary user interface for the Smart Grill is the LCD touchscreen. The grill has a separate enclosure mounted on its right tray that houses the touchscreen interface. The uLCD-70DT was picked due to its compatibility with the ATmega328 microcontroller. Both products operate at 5V, which made it easier to supply power to both components.

The touchscreen hardware came with a free program to aid in designing the user interface. This program was preferred over other design tools as the LCD needed to have sixteen different display screens and the program made it easy to keep them all looking consistent and flow nicely between one another. The touchscreen also features an onboard 2GB micro SD card that allows all of the graphics to be stored separately from the microcontroller memory storage making this graphics intensive project possible. The grill also needed to be able to notify the user with an audible tone that it needed attention or that the food was finished cooking. The LCD touchscreen conveniently has an onboard speaker that allows .wav files to be stored on the micro SD card and to be played as needed.

C. Bluetooth Module

The mobile application needs a way to communicate to the microcontroller in order to receive the temperatures. The connection is made using the BlueSMiRF Silver module, which is a device that allows Bluetooth capabilities. BlueSMiRF allows the user the ability to be at most, eighteen meters away from the grill.

The inputs for the BlueSMiRF are the temperature from the sensors, which output the information to the Android mobile app. There were originally considerations to also have Wifi capabilities, but it was determined it would add an unnecessary cost and there also were no justifiable reason why a user would use a grill beyond the eighteen meter range.

D. Mobile Application

Smart Grill also allows the user to view the temperature for the following: the food, the ambient air, and the burner. The app will also have the cook time. The main purpose of the app is to display the information to the user. The mobile app was developed specifically for Android phones. Android was selected due to the fact the app will constantly be updated; which is common and easier to do for Android than iOS.

All four members of the group having an Android device also contributed to using Android, since everyone would be able to contribute to testing the app. Originally, there were plans for the mobile app to be able to modify the temperature of the grill and control the rotisserie, but the idea was removed due to possible safety hazards. User errors are so often that allowing the users to control the grill from a far distance could lead to severe consequences. A goal for the future is to determine how can we ensure a safety feature if the mobile app was allowed to control the grill.

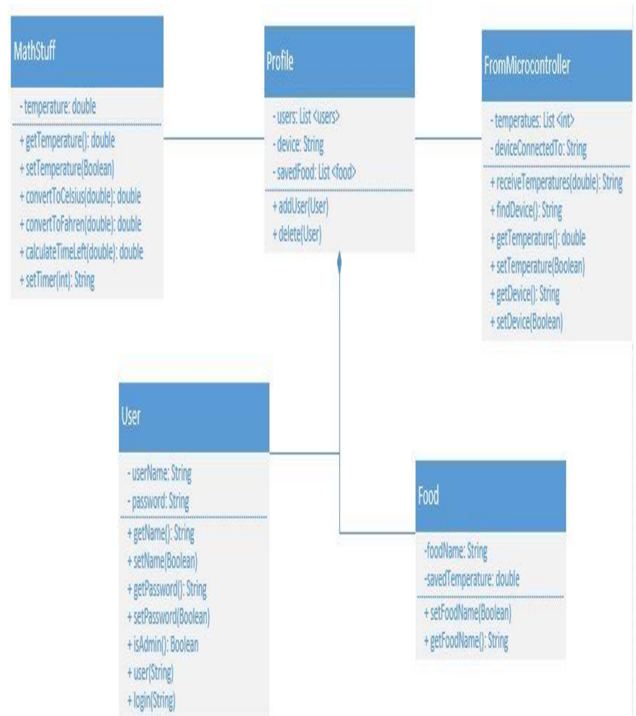


Fig. 1. Class diagram for the mobile application.

E. Temperature Sensors

To measure the temperature as accurately as possible we need three temperature probes. One temperature sensor measures the ambient air, one temperature sensor measures the temperature of the burner and the last temperature sensor measures the temperature of the food product being cooked on the rotisserie.

We decided to use three Accuon ACU0235 temperature probes which each are wired to three 3/32" Panel mounted phone jacks. The three phone jacks are then soldered to the PCB board. In order for the temperature sensor circuit to work we also needed three 1MΩ resistors connected in parallel. The burner and ambient temperature probes are attached directly to the burner and inside of the grill respectively. The food temperature probe for the rotisserie feature is mounted inside the grill, but is designed for the user to manually insert the probe into the food product when measuring food for rotisserie cooking.

To have a reference temperature to compare the burner and food product temperature with we picked 75°F. This was chosen because this is considered room temperature. Our thermistor temperature probes have a resistance at 75°F of 1MΩ. Which is why 1MΩ resistors were used in our design. Having a resistance of 1MΩ at 75°F ends up being the baseline used in most thermistors in order to accurately measure the correct temperature. Figure 2 shows an example of how the temperature probes were utilized in the design of the Smart Grill.

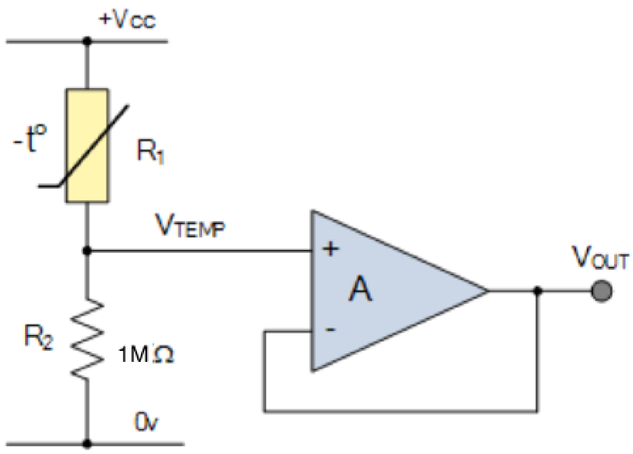


Fig. 2. In the case of the Smart Grill, +Vcc would be the 5V provided by the microcontroller and 0V would be its ground. R1 is the temperature probe itself and R2 is the 1MΩ resistor. Vtemp is read by an analog pin on the microcontroller. *Permission to use figure given by electronics-tutorials.ws.*

Thermistors are designed so resistance is dependent on temperature and they are directly related. For our Thermistors to accurately measure the temperature, as the temperature increased the resistance needed to decrease. We needed a large range of temperatures with greater accurate results. So we determined we needed the Steinhart-Hart equation in our code to give us the best result. This increased the accuracy by changing from a 1st order approximation (1) to a 3rd order approximation (2).

$$\Delta R = k\Delta T \qquad (1)$$

$$T^{-1} = a + b\, ln(R) + c(ln(R))^3 \qquad (2)$$

F. Burner and Motor Relays

Electromechanical relays are all around a good solution and much more robust than solid state relays are, however they are big in size and have a longer switching speed as well as shorter mechanical lifetime. Therefore solid-state relays are what we decided to go with. In order to automate the two stock grill features, rotisserie AC motor and AC burner temperature, two SSR's (Triac) will be used. The burner relay controls the temperature of the 1500W burner. The burner is rated at 15A and would need to be triggered with 5V DC and not much current. Since the burner relay will need to be triggered many times due to the code continuously checking if the burner temperature sensor has been read below the user defined target temperature. Not only will this relay be in operation the majority of the time Smart Grill is being used, a heat sink will be needed to dissipate the unwanted heat coming from all the burner's current needed to keep a constant temperature.

In order to allow the user to use the food sensor without the wire of the sensor getting wrapped around the rotisserie spit another relay is used to continuously loop a CW and CCW 360 degree rotation of the spit to prevent the wire from getting a chance to tangle. The Smart Grill's stock rotisserie feature is driven by a 4W 2RPM synchronous CW/CCW AC motor capable of rotating up to 10 lbs. Since its only a maximum of 4W load on the motor the relay did not need a heat sink, although since the relay would need to be in operation as long as the rotisserie is in operation, a SSR with an unlimited switching lifespan was what we needed.

The Fotek SSR-25 DA (w/ attachable heat sink) was used for both Burner and Motor Relay Triacs. The SSR-25 is very popular for household applications as it has a wide output voltage range of 24-380VAC and max current capabilities of 25A. The operation junction temperature of the SSR-25 is an issue at about 180F however precautions were top concern by using a secure heat sink and metal enclosure to insure safety.

III. System Concept

The concept of Smart Grill is basically all systems (burner, motor, LCD and mobile app) working together to enable the user to cook dinner flawlessly and with more time to attend to more important matters. It is the primary goal of this project to ensure that grillers have the convenience and option to grill how they choose which remains unaffected by power receptacle convenience, grill proximity, cooking know-how, fuel source and flavor not to mention electric grills offer convenience, safety, and less pollution making this a great option.

With an investment for the Smart Grill, a grill can easily make their home into On-The-Go, set it and forget it flexible fuel, Indoor/Outdoor rotisserie Smart Grill. If you can not afford to buy our grill, then this technical paper serves as guidelines for the "average Joe" to recreate this project in his or her own way for a cost effective solution. It is up to the person utilizing the grill to decide what is in their budget and how much technology and functionality that their grill rig utilizes. One of the best features of our project is it gives the griller the freedom to choose the right part that will fit with their grilling needs.

When the Smart Grill is plugged into a standard sized 120V wall outlet, the LCD touchscreen will illuminate and show the main menu screen with the different menu options to choose from as seen in Figure 3. When a food item is selected the grill will automatically begin to preheat. The temperature sensors are continuously monitoring the burner temperature and will then alert the user once it reaches the desired level.

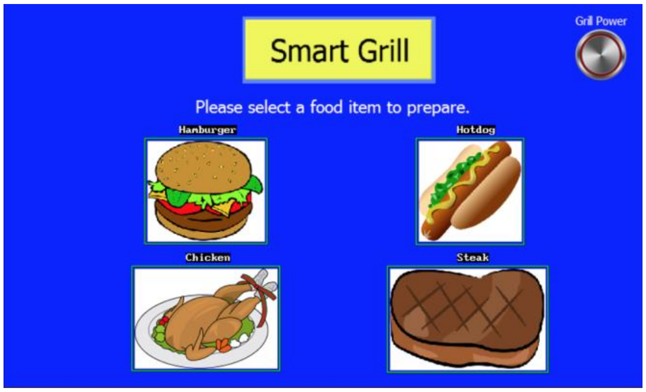


Fig. 3. Smart Grill LCD touchscreen displays this menu upon startup. The user can then select hamburger, chicken, steak or hotdog to begin grill preheating. The user will also be returned to this screen after cooking and can choose to cook something else to turn the grill back off with the power button on the top right hand corner.

Once the grill is finished preheating, the LCD touchscreen will display the food prep screen, which will prompt the user to place their food item on the grill. During this step, the user can choose the temperature they would like their food cooked to and also decide if they would like to rotisserie their food or use the grill burner. Figure 4 shows an example of the food prep screen for cooking chicken.

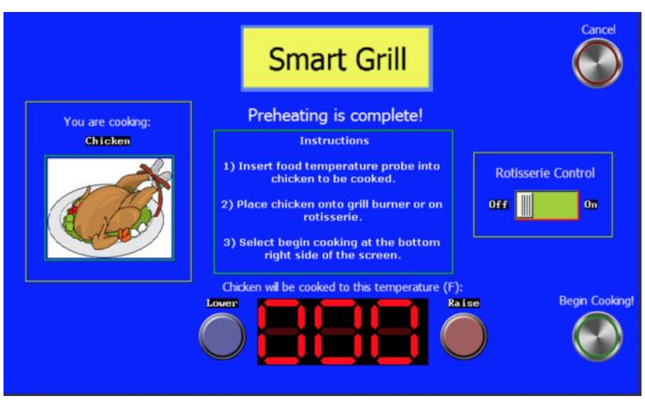


Fig. 4. Smart Grill LCD touchscreen displays the food prep screen for cooking chicken. User can set the desired cooking temperature, choose to use the rotisserie feature, begin cooking, or cancel and return to the main menu.

During the entire prep phase, the burner will continue to be regulated to stay at the proper temperature throughout this period so the user can take as long as needed to place the food on the grill. Before the user can begin cooking, it is important that the food temperature sensor is properly inserted into the meat.

When cooking begins the user will be able to monitor the status of the food being cooked on the main cooking screen. This screen will display the temperature values for the ambient air temperature, burner, and food being cooked. Figure 5 displays an example of the cooking screen for cooking steak.

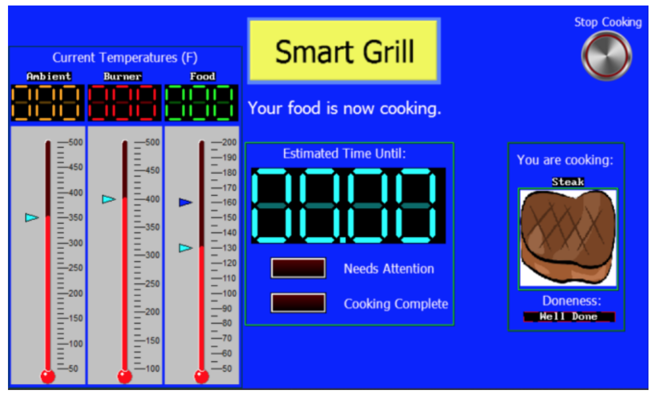


Fig. 5. Smart Grill LCD touchscreen displays the cooking screen for cooking steak. Temperature values are visible on the LED digits and thermometers. The estimated time until the meat needs to be turned over or is completed cooking is indicated in the center by the LED digits and virtual LEDs.

While the food is cooking the food temperature probe is constantly being monitored for the food to be approaching its doneness temperature. The burner also continues to be regulated at the appropriate temperature. If the food is a steak or hamburger and is being cooked using the burner instead of the rotisserie, the “needs attention” LED will be illuminated with an estimated time until the food needs to be flipped over. A screen on the LCD will prompt the user that their food needs to be flipped as seen in Figure 6. Once the food has been flipped the screen will return to the cooking screen with a time remaining until cooking is complete and the appropriate virtual LED illuminated. If instead the rotisserie feature is being utilized, upon beginning the cooking process an estimated time until cooking is complete is displayed immediately as the rotisserie does not require the user to flip the food.

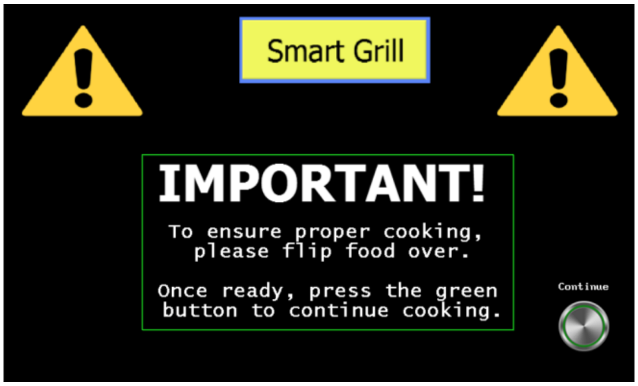


Fig. 6. Smart Grill LCD touchscreen prompts the user to flip the food being cooked to ensure proper cooking throughout.

The food will continue cooking until the temperature probe detects that the food has reach the correct temperature which was previously specified by the user on the prep screen. At this point, the LCD touchscreen will make an audible beeping sound and display a cooking complete screen as seen in Figure 7. The user will also be notified on the mobile application and the beeping will continue until the user returns to the main menu. From the main menu, the user can choose to cook something else or power down the grill.

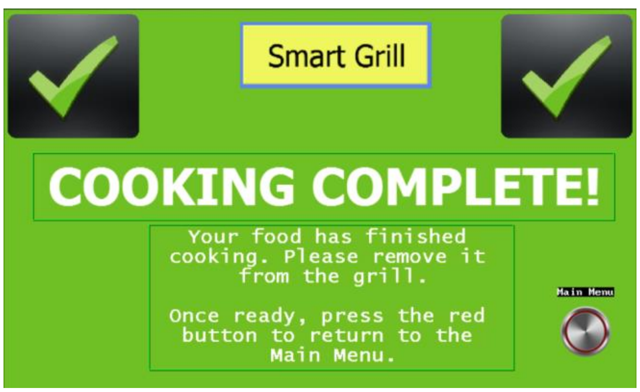


Fig. 7. Smart Grill LCD touchscreen alerts the user that cooking is completed for their food. The user can now remove the food from the grill and return to the main menu.

IV. Hardware Detail

Smart Grill was designed and retrofitted from all stock components with the exception to the burner thermostat that was just limiting the amount of current to the burner. The chassis of the grill was purchased for approximately $180 and we worked around the grills constraints to accommodate all subsystem peripherals. The only thing done to the current stock rotisserie motor and burner electric controls was taking the power wire of the single phase power cord into one side of our switch and on the other side of the switch completes the circuit to the power input of the burner or motor system on the grill. In order to isolate the potentially harmful electrical contacts and junction temperatures of the relays a metal enclosure was designed to with the both the LCD display area, burner, sensor and wire locations.

The system components detailed in Section II are all connected as seen in the flow chart in Figure 8.

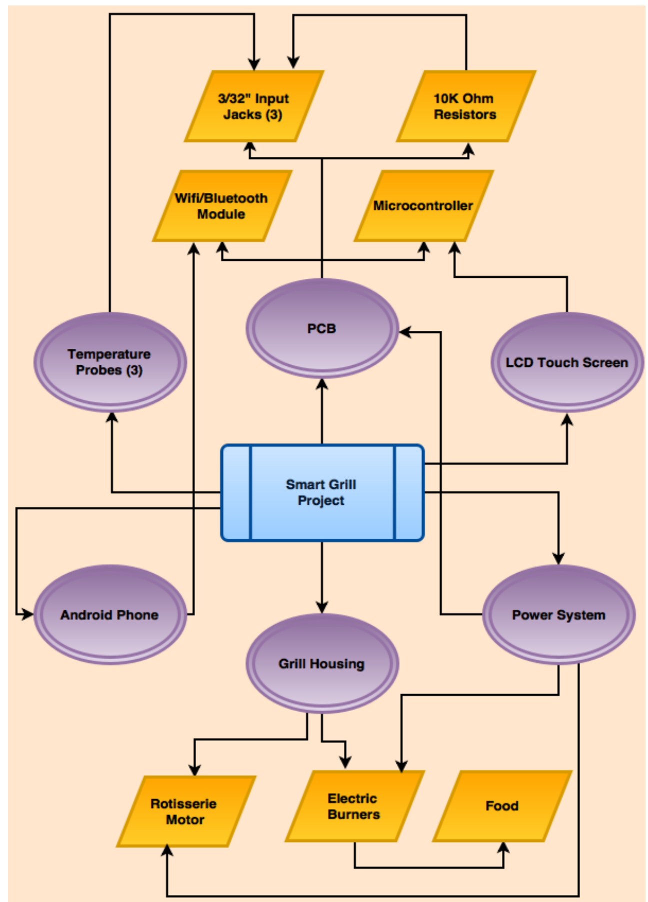


Fig. 8. Flow chart detailing how the different hardware components of the project interact with one another. Major components are displayed in ovals and their individual subparts are displayed as rhombuses.

The Smart Grill looks like an ordinary electric grill at first glance, with two tray tables on both sides of the grill. The left tray table is for holding cooking utensils while the right tray houses a black enclosure with an LCD touchscreen. This LCD touchscreen is the primary was the user can interact with the grill. Behind the enclosure is a black box that houses two relays for regulating power to the grill burner and the rotisserie motor. A power cord connects 120V to the grill burner and the rotisserie motor and this power is then regulated by the relays located in the black box behind the enclosure. A third plug runs into the LCD touchscreen enclosure. These three plugs are all connected on one power strip, which can be plugged directly into a 120V wall outlet to power the Smart Grill.

Inside the enclosure housing there is a PCB and the Bluetooth module. The Bluetooth module is powered from the 5V rail on the PCB and is essentially the middleman between the microcontroller and the mobile application. Data such as current temperature of the food and burner is pushed from the microcontroller to the Bluetooth module. From here the module sends it to the mobile application to display to the user. The PCB connects directly to the LCD touchscreen through five jumper cables giving it power and allowing it to transmit data when buttons are pressed on the screen and receive data such as temperature information to display to the user. The LCD touchscreen is built into the lid of the enclosure that houses the PCB and Bluetooth module so all of the wiring is not visible to the user.

The three temperature sensors run from the grill into the black LCD enclosure where they plug into the PCB via 3/32" mono audio jacks. The three temperature sensors are used to independently measure the temperature of the grill burner, the food being cooked, and the ambient air temperature inside of the grill. The ambient temperature probe is mounted inside the grill lid on the hinges to open and close the lid. This positioning keeps it out of the way when opening and closing grill, however still offers an accurate reading of the ambient air temperature during the cooking process. The burner temperature probe is located underneath the grating that the food is cooked on and directly measures the temperature of the burner coil. Finally, the food temperature probe that will be inside of the food during the cooking process has a cook inside of the grill for storage purposes. When being used the wire runs from the food and back into the LCD enclosure to connect to the PCB. The wire does not get tangled up in the rotisserie rod due to the motor's ability to change directions every 360 degrees.

The rotisserie motor is a defining feature of Smart Grill so we decided to enable the user to use the temperature sensor with the rotisserie feature. In order to make this practical we had to design a mechanism for the sensor wire to not become entangled or wrapped on the spit of the rotisserie. We decided to utilize the CW/CCW feature of our stock motor. We discovered that every time you switch the motor ON/OFF it will reverse direction. With a little bit of testing we found that the optimal time to keep the motor OFF in order for it to reverse direction every time was about five seconds. We used a simple code to turn the motor OFF for 5 seconds and ON for the required time (about 30 seconds at 2 RPM to make a 360 degree rotation), which will effectively and thoroughly cook the food over the entire surface area. If the rotisserie never actually rotates more than 360 degrees thus the food temperature sensor never actually wraps around the spit to the point that it hinders the users experience.

At the end of Senior Design 1 we had a number of power features that needed to be modified. However the more we worked on Smart Grill the more we all realized that not only were most of our power features were not practical but they were going to cost a majority of the budget. In order for Smart Grill to be a user friendly and DIY possible we removed the battery for all our subsystems, charging IC, the DC to AC converter for the burner, and all the circuits to regulate the on board power supply. This made us utilize the OEM wall outlet power supply and allowed us to save $500 and focus on a better user experience via the mobile app and LCD display and safety.

VI. Software Detail

The software for the smart grill is composed of three main parts, the code for the ATmega328, the LCD touch screen programming, and the mobile application. All three components need to work together and communicate between each other seamlessly. The LCD touchscreen and ATmega328 communicate between each other at 152,000 baud, which allows for quick response to user inputs and displays information to the user quickly. The LCD utilizes the microcontroller's hardware serial port for the fastest communication. The Bluetooth module, which sends information to the mobile application, is on a software serial port, which is a little slower but works for the purposes of the grill as the LCD is the user's primary way of interacting with the grill.

The ATmega328 was programmed using the Arduino software. This was used because there were already libraries available that assisted with communication between the microcontroller and the LCD touchscreen. The code was written to continuously loop updating the values of the temperature probes as the temperature readings are what drive the entire cooking process. From here, close integration between the LCD and microcontroller was needed to ensure they were always in sync. At the beginning of the program the two devices are started in unison and the microcontroller code tracks what page is being displayed on the LCD through multiple variables.

The LCD touch screen programming is mainly visually based as most of the code side comes from the microcontroller itself. Each screen that the user can see on the LCD touchscreen had to be created and laid out. Each object that appears throughout the entire project has an index number and an object type. This type and index can be referenced from the microcontroller to send commands to the LCD screen. Figure 9 displays an example of a table created to keep track of screen and index numbers for the entire program. This could be easily referenced while writing the code and be able to avoid referring back to the programming software for the LCD touchscreen.

Description	Form	Object Description	Type	Index
Start Up Screen	0	Grill Power	4Dbutton	0
		Hamburger Button	Userbutton	0
		Hotdog Button	Userbutton	1
		Chicken Button	Userbutton	2
		Steak Button	Userbutton	3
Preheat - Hotdog	1	Cancel PH Button	4Dbutton	1
		Burner Temp Digits	Leddigits	0
		Time Digits	Leddigits	1
		Burner Therm	Thermometer	0
Prep - Hotdog	4	Cancel Button	4Dbutton	7
		Begin Cook Button	4Dbutton	8
		Cook Temp Digits	Leddigits	7
		Lower Heat Button	4Dbutton	9
		Raise Heat Button	4Dbutton	10
		Rotisserie Switch	Dipswitch	0
Cooking - Hotdog	5	Stop Cook Button	4Dbutton	11
		Amb Temp Digits	Leddigits	8
		Burner Temp Digits	Leddigits	9
		Food Temp Digits	Leddigits	10
		Time Digits	Leddigits	11
		Amb Therm	Thermometer	4
		Burner Therm	Thermometer	5
		Food Therm	Thermometer	6
		Need Att LED	Userled	2
		Complete LED	Userled	3
Preheat - Hamburger	6	Cancel PH Button	4Dbutton	12
		Burner Temp Digits	Leddigits	12
		Time Digits	Leddigits	13
		Burner Therm	Thermometer	7

Fig. 9. Part of the indexing table used to keep track of different LCD display forms and what objects were located on them.

The microcontroller knows what screen is currently being displayed and what objects are on that screen. This allows it to look for button presses and react accordingly. For example, when the “begin cooking” button is pressed on the touch screen, the microcontroller knows what page it was pressed on and what new page should be displayed. Essentially all of the graphics processing and graphics storage are done on the LCD end, while the actual calculations and commands are given from the microcontroller side.

The next important feature is the mobile application. The mobile application communicate with the ATmega328 via Bluetooth technology and just like the LCD touch screen, its code will be based on the microcontroller. The goal of the app is to be a highly user-friendly by being intuitive on how the app should work. Although the app won’t send any information to the grill, it will share some key features as the LCD screen such as displaying the ambient temperature, burner temperature, the grill temperature, and the timer. The app was developed for Android mobile devices.

VI. Board Design

The PCB design was originally created using a program called Fritzing. This program allowed all of the required components for the board to be laid out on a virtual breadboard, which was beneficial because things were easily changed as the prototype became more developed. Once the breadboard layout was finalized, Fritzing allowed the PCB layout to be developed easily as all electrical connections were maintained as the components were laid out on the board. Figure 10 shows our PCB layout in the Fritzing program.

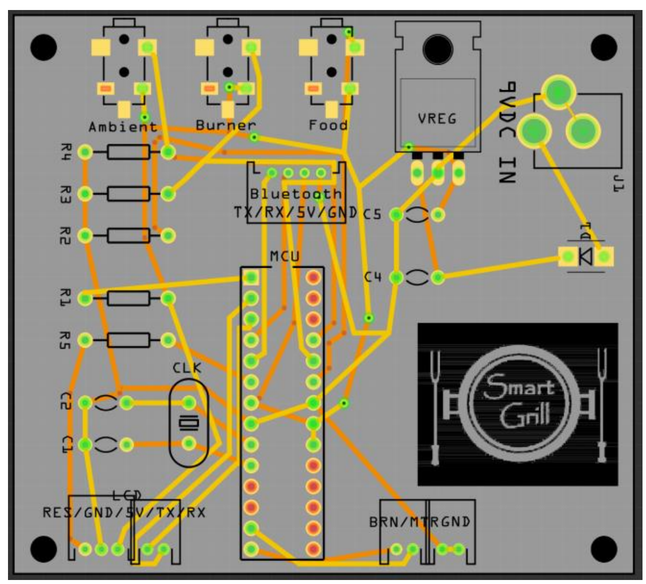


Fig. 10. Final PCB design for the Smart Grill

The PCB needed five pin connections to the LCD touchscreen, two for the motor and burner relays with a common ground pin, and four pins for the Bluetooth module. Attaching headers to the PCB in these locations and using jumper wires to accomplished connecting these hardware components. The PCB also houses the ATmega328 microcontroller, a 16MHz crystal, and several resistors and capacitors to serve as the barebones for the microcontroller to function on the board.

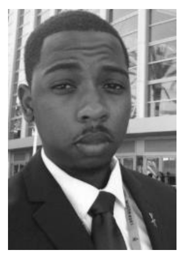
Another important element to the board are the temperature sensor jacks that the temperature probes plug into. These require the jacks themselves, which are soldered onto pads on the PCB, and 1M-ohm resistors, which are through-hole components on the board. The PCB was originally designed to be able to take a 7-12V DC voltage input from a AC-DC wall jack and use a 7805 voltage regulator to step the voltage down to 5V. This was the ideal solution when the board was first being developed as the power system was supposed to be battery based. However, the final design bypasses the regulator and just uses a 5V AC-DC wall jack input, which makes the product more efficient by not wasting energy to heat with the voltage regulator.

From Figure 10, the top left hand side of the board is where the three temperature probes plug into the 3/32" mono audio jacks. Underneath the temperature jacks, there are the four pins for the Bluetooth Module, which is above the microcontroller. On the bottom of the board, to the left of the microcontroller are the five pins for the LCD touchscreen and above them is the 16 MHz crystal and two 22pf capacitors needed to support its oscillation. Above the crystal, R1 is a 10K ohm resistor to keep the reset pin on the microcontroller high and R2 through R4 are the 1 mega ohm resistors for the temperature circuit. R5 is 1 1K ohm resistor needed for the LCD touchscreen reset pin which keeps it in sync with the microcontroller upon start up. To the right of the microcontroller on the bottom side of the board are the digital I/O pins to control the motor and burner relays. At the top right hand side of the board, is the input barrel jack, a diode to keep current from flowing back into the jack. There is also a 7805-voltage regulator with two smoothing capacitors to ensure a steady 5V is supplied to the microcontroller and other PCB components. The completed PCB can be seen in Figure 11 with all of the components attached except for the temperature jacks for ambient and burner.

Fig. 11. Physical PCB for the Smart Grill

THE ENGINEERS

Jeff Mueller is a 26-year old graduating Electrical Engineering student who is taking a job with "Texas Instruments" as an Applications Engineer. It is not currently known exactly where or what he will be doing for TI but has a start date of August 15th, 2016.



Jonathon Graff is a 37-year old graduating Electrical Engineer who is also a USAF Veteran and current member of the United States Air Force Reserve as an Aerospace Ground Equipment Technician. He is actively seeking employment as an Electrical Engineer in either in the Electrical circuit design or the Power and Energy industry. His other interests include travel, physical fitness and real estate.

Thierry Alerte is a 23-year old graduating Computer Engineering student who looks forward to working as a software developer at a company like Intel or Dell and then eventually getting a masters in Electrical Engineering.

Jonathan Schooley is a 24-year old graduating Electrical Engineering student who is taking a job with "exp Global Inc." in Orlando, FL, as an electrical designer. At exp he will focus on designing the electrical systems of ride and show buildings for the Disney and Universal theme parks.

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