Senior Design Interim Report

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Smart Stoves

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Executive summary:

Smart Stove is concept idea for developed for senior design project in combating fire hazards caused during unattended cooking. It also monitors dangerous level of harmful natural gas built up for added safety measure. Customers for a new method for fire safety device is widely available in many industries. Engineering requirements sets the parameters needed to be followed in designing and extending product’s lifespan. There were many design concepts developed for Smart Stoves. It is an ongoing process for product’s survivability. Design optimization will also need to be performed for betterment of features offer by Smart Stoves. It is possible to add more features and deflect common errors in system through design evolution. Concluding product will save precious lives and billions of dollars in property damage all over US.

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Background:

Internet of Things devices have many useful benefits in today's connected world. Smart home devices have the biggest market share in application of IoT. Home security is on of these sectors which provides secure living under busy eyes of technology. However, not all these smart devices can protect us from an event of house fire. In each year, house fire mounts to enormous property damages along with precious death tolls in US.

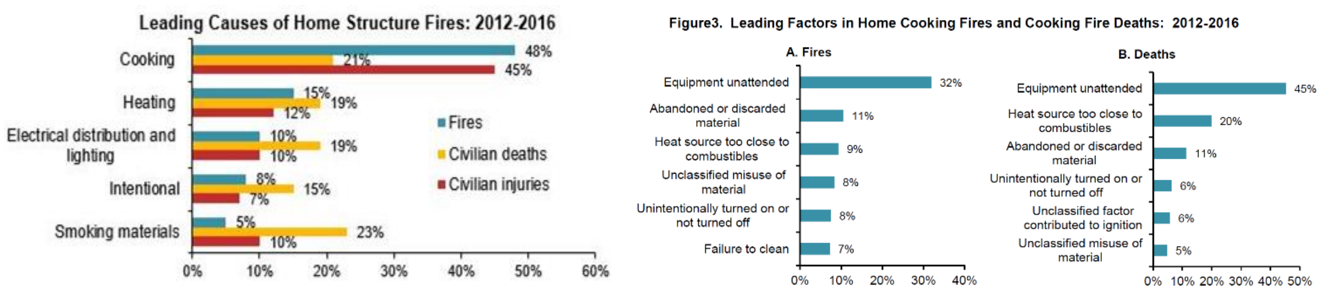

Figure 1 : a) Leading cause of house fire. b) Leading cause of home cooking fire.

According to data collected by National Fire Protection Association, leading cause of house fire is cooking related. Figure 1.b) explores the cause of fire, based on cooking setups in house. It is evident that the number one factor for house fire is unattended equipment uses. The highest percentage in death tolls, about 45%, are also caused by unattended stove fires while cooking.

One of the objectives for this senior design project is to prevent house fire caused by unattended cooking. The second goal is to detect build-up of cooking gas from a faulty cooking system and take fire hazard prevention protocol by notifying necessary personals. Both objectives of this project are integrated in an IoT system which has multiple components for data acquisitions and transmission capabilities. The only competition opposing our approach in house fire prevention comes from age old Smoke Detector. Smoke detectors has inherent problem of being reactive than proactive in cases such as gas leakage, an event of fire, or notifying people out of its audio range. This new IoT device will rectify all these issues and put forth a new standard for Home fire Safety.

Smart Stove is developed using few following principles. First of which is data acquisition. As for system requirements, we need to determine a presence of human in front of stoves at all time while cooking. Determining if stoves are in use or not proses another challenge for this project. Lastly, gas leakage around the supply line to stoves needs to be monitored all the time. This project uses multiple sensors for data acquisition part. MC105 is a gas detection module capable of sensing methane (CH_4), butane(C_4H_{10}) and propane (C_3H_8), which are part of natural gas used for cooking at home. For stove ON/OFF condition, pressure sensor in conjunction with humidity sensors are used. Pressure sensor detects weight of cooking equipment such as cooking pans while humidity sensor, situated near steam vents, detects concentration of water vapor caused by heating up food items. A motion detector is enough to detect presence of human Infront of stoves.

Second stage of this project requires input signal conditioning and data transmission. Each senor modules are accompanied by a robust Wi-Fi module. Therefore, data from input devices are acquired using an offsite main hub. This main hub is built with an MCU, Wi-Fi module and smoke detection unit. Incoming signals are conditioned to interface and processed with MCU unit. MCU unit acts as buffer between singles transmission route and provides additional compute logics in Realtime. Data from sensors then uploaded to a cloud services for end user.

Last stage of this project requires help of cloud services such as Amazon Web Services (AWS). Cloud services use input data to make decisions for cases such as whether stoves are on/off, current gas concertation level, and if stoves are unattended (when stove is on). The statues report is sent to user mobile devices. User can make informed decision based on option available them. A JAVA based application is used to relay GUI options to users.

Customers and their requirements:

Meeting customer demand requires current inside knowledge of market shares in Home Safety Industry. This product competes directly with Smoke Detectors. Therefore, shares the same market segment. According to “Smoke Detector Market”, by Power Source, “the total market is expected to grow from USD 1.31 Billion in 2015 to USD 2.52 Billion by 2022”. The rise in demand is fueled by two major factors in industry. The first being inherent development in construction industry where the second being expected rise of population in urban area. Additionally, rise in Home Fire safety awareness also help drive this market.

Smart Stove’s market share falls within consumer industry. The target customers for this type of product is anyone with a kitchen, government regulators and fire safely officials along with current Stove (appliance) market and natural gas delivery services. While the end users are general population, however, establishing a permanent standard through government official and training fire departments staffs in using these devices can lead to less fire hazards cases each year. Permanent link between appliance industry will help integrate this system efficiently, removing any unnecessary human errors during installation. Demography for targeted varies extensively. However, general target group is considered above 13 years of age and have access to kitchen at home. Senior citizen, especially with dementia, is considered a focused target group because the probability of leaving the stoves on is higher.

A large sample of survey data from varying range is needed to conclude customer’s requirements list. However, based on the trend in Smoke Detector industry, approximation of requirements can be made. Customers for Home Safety in Fire Prevention industry requires their system to be robust, reliable, informative, easy to use and lost cost enable. Additionally, these devices require low maintenance, change battery once every 12 months for Carbon Monoxide alarm. All the components used to design project is low cost and ultra-lower powered, such as ATMEGA4809 (MCU) can operate in sleep mode to conserve energy. Smart Stove fulfills all these requirements and offer additional features which were never used before in industry. The IoT device is capable of relaying Realtime safety statues to end users. For example, users will be immediately notified if there is gas leakage in their home, even in the case when user is away. User can interact with phone app to check status such as if their stoves is on/off, air quality, or if fire is being attended by someone in the vicinity. With the help of all this crucial information, user can take an informed decision.

Engineering specifications:

3.1) Overview:

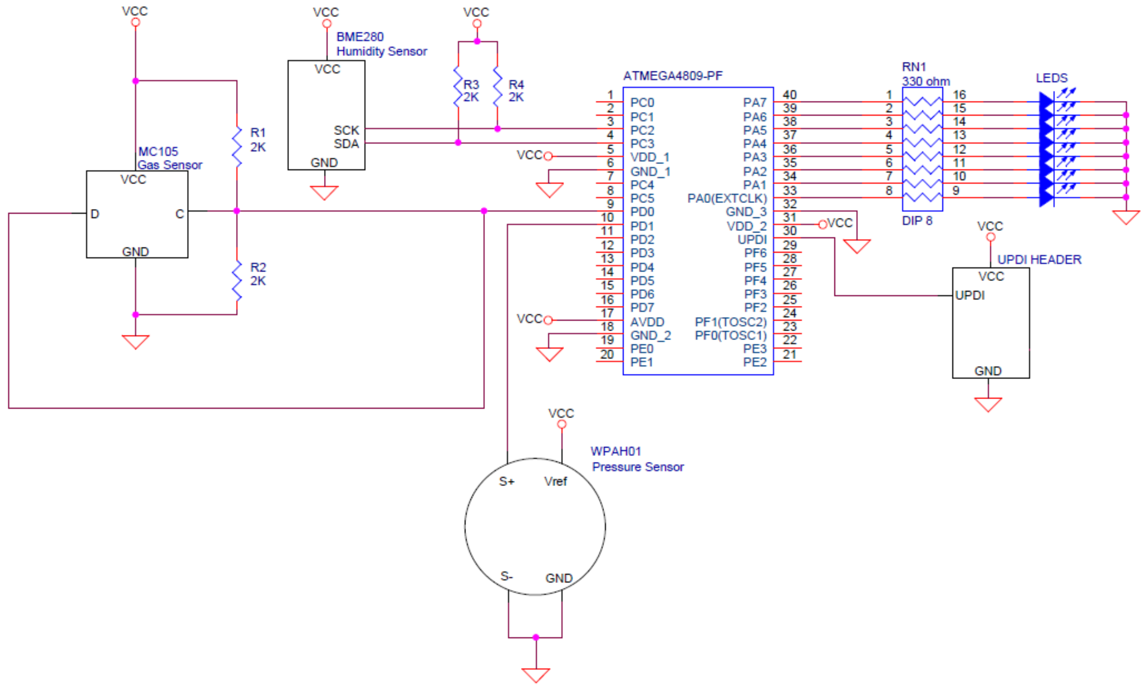

Figure 2: Top-Level Schematic for Smart Stoves at prototype stage.

There are many challenges to be considered when designing an IoT smart home device. In developing an engineering specifications list, which provides insight in how to tackle each challenge from a practical viewpoint. List below presents all the specification for this project.

1. ATmega 4809
2. MC105 Catalytic Flammable Gas Sensor
3. WPAH01 Ceramic Pressure Sensor
4. BME280 Combined Humidity and Pressure Sensor

3.2) Specification Details:

The ATmega 4809 is the 8-bit microcontroller with a processor speed of 20Mhz. It is a 40pin board mount unit. It can be programmed with embedded C. It is one of the latest MCU that has compatibility with Wi-Fi module making it the ideal choice for our project. Having 10 ADC pin is also a plus, although we are only using 2 of those pins. In general, the 4809 having the Wi-Fi compatibility is what caught our eyes.

The MC105 is a catalytic type gas sensor which detects combustible. It can detect methane, butane, propane etc. For a combustion to occur, the gas concentration must be within the Flammability Range. Meaning the gas concentration must be within the Lower Explosive Limit and Upper Explosive Limit. For example, the Flammability Range for Methane is 5%-15%. Mc105 output represents the LEL percent. Once it crosses the LEL, there is a chance of explosion. Our system will detect the gas and will alert the end user if the LEL is above 10%. The system output is analog. The internal ADC of the MCU is used to convert this value to digital data. The parameters of this sensor are shown below:

Model		MC105
Sensor Type		Catalytic Type
Standard Encapsulation		Plastic
Working voltage(V)		2.5±0.1
Working current(mA)		150±10
Sensitivity (mV)	1% CH4	20~50
	1% C3H8	30~70
Linearity		≤5%
Measuring range(%LEL)		0~100
Response Time (90%)		≤10s
Recovery Time (90%)		≤30s
Working Environment		-40~+70℃ <95%RH
Storage Environment		-20~+70℃ <95%RH

Figure 3: Parameters for Gas Sensor, MC105.

The WPAH01 ceramic pressure sensor detects pressure from 0 to 10 bar. It is a piezoresistive sensor. The idea is to place the pressure sensor under the grill on the stove. Using the pressure, we can calculate the weight of an object. In our case, the weight of whatever is being cooked. And if the weight suddenly rises and slowly decreases afterwards, then we know that something is cooking. This sensors data will be compared to the Humidity sensors data to accurately detect if something is cooking on the stove. The output of this sensor analog.

Item	Parameter
Size	Φ18mm*6.35mm
Detection Range	2bar、5bar、10bar、20bar、50bar、100bar
Working voltage	2-20V
Sensitivity	1.5—4mv/V， typical value 2.5±1.0mv/V
Input, output resistance	10KΩ±30%
Temperature range	-40℃-125℃
Zero output	0—±0.4 mv/V，， typical value 0±0.25mv/V
Linearity, hysteresis, repeatability	typical value ±0.3 %FS
Temperature draft	Typical value ±0.05%FS/℃
Safe overload	two times of rated detection range (when sensitivity is typical value)
Stability	Better than ±0.5%FS / year（if it is used properly）

Figure 4: Specifications for Pressure Sensor, WPAH01.

The BME280 is a humidity sensor which detects the relative humidity of the area. It is a capacitive sensor. This will be installed above the stove. When something is cooking, there will be vapors. Using the humidity sensor, we will detect the vapor, and combined with the data from WPAH01, the system will determine if the stove is on or not and if something is cooking. Unlike the other two sensors, this sensor has digital output and programmable. It follows the I^2C protocol.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating range[3]	R_H	For temperatures < 0 °C and > 60 °C see Figure 1	-40	25	85	°C
			0		100	%RH
Supply current	$I_{DD,H}$	1 Hz forced mode, humidity and temperature		1.8	2.8	µA
Absolute accuracy tolerance	A_H	20…80 %RH, 25 °C, including hysteresis		±3		%RH
Hysteresis[4]	H_H	10→90→10 %RH, 25 °C		±1		%RH
Nonlinearity[5]	NL_H	10→90 %RH, 25 °C		1		%RH
Response time to complete 63% of step[6]	$\tau_{63\%}$	90→0 or 0→90 %RH, 25°C		1		s
Resolution	R_H			0.008		%RH
Noise in humidity (RMS)	N_H	Highest oversampling, see chapter 3.6		0.02		%RH
Long term stability	ΔH_{stab}	10…90 %RH, 25 °C		0.5		%RH/ year

Figure 5: Specifications for Humidity/Temperature Sensor, BME280.

Design concepts:

As with developing any new design concept, it is imperative to start from few possible vantage points within a given industry. Smart Stove's root start is given by Professor. Shterengas' description of the project, which states, "Develop a multiple sensor system capable of raising alarm if moving object poses chemical threat." This description gave us a baseline for target industry and initiated conceptualizations of various product ideas. Few parameters set by Prof. Shterengas' project proposal includes multi-sensor system, capable of raising alarms, battery operation, and uses of microprocessor to log events etc. These parameters served as guidelines in the brain storming process for this project.

Using the guidelines, few applications of chemical sensors were derived from combinations of brain storming and online research. These applications were categorized in their respective industry for more clarity on this subject matter. Industries which were considered includes Defense, Farming, Consumer Electronics, and Petroleum market. Applications of chemical sensors in Defense industry described Chemical weapons detections system, Illegal Drug Detection. In Farming, possible idea included detection of common harmful reagents for plants, pesticides etc. For Petroleum industry, the idea was to detect oil resources available around the world. In consumer market, Gas Stoves were discussed in conjunction with age old smoke detector.

Feasibility of this project along resources available for this project dictated evaluation process of possible applications of gas sensors. In discussion with Prof. Shterengas, we narrowed the application in two industries, Farming and Consumer market. The criteria for this project also expected a low powered, battery operated system. Upon more research in these industries and freshness of these ideas, Smart Stoves was conceived. There are few key factors which contributed in decision making process for Smart Stoves. Insightful discussions with Prof. Shterengas provided new approaches in making Smart Stoves viable. We conceptualized inputs required to make informed decision for stove's on/off status. Discussion included in utilizing pressure sensor in combination with humidity sensor, input data is enough to conclude where the stove is turn on or off. Evaluation criteria is fully realized and design concept for Smart Stoves was achieved.

Design optimization:

Smart Stoves requires low maintenance in working environment. It is low powered, hence battery operated and work in the principle of sleep/awake cycles periodically. Design decision for this device is also motivated by available budget and resources available to us. There are number of factors considered in design optimization for the top-level system.

5.1) Cost:

	Materials	**Purpose**	**Cost**	**Source**
Hardware	ATxmega 4809	CPU/ Data processing	10 @ 23.70	Mouser Electronics
	Winsen MC105	Combustible Gas Sensor	10 @ 22.70	Ebay
	WPAH01	Pressure Sensor	10 @ 22.00	Ebay
	BME 280	Humidity Sensor	2 @ 11.96	Ebay
	Atmel ICE	MCU Programmer	1 @ 150.00	Ebay
	HC-05 Wireless Bluetooth RF	Wireless Com.	3 @ 24.00	Amazon Inc
	RGB LEDS	Output/ Debugging	25 @ 6.05	Ebay
	Assorted Circuit Elements	Signal Conditioning	Free	Lab
Software	Capture CIS	Schematic Tools	Free	OrCad
	Java-Eclipse	App Development	Free	Oracle
	Android Studio	App Development	Free	Google
	Amazon Web Service	Cloud service	Free trial	Amazon
		Total :	$ 260.41	

Figure 6: Budget allocated at prototype stage.

In developing a new product cost per device varies drastically at different stage of development cycle. At prototype stage, budget for Smart Stoves are shown in Fig.2. Initial cost at this stage is high and do not reflect accurate final cost of device when mass produced. From Fig.2 , it is apparent that most if the cost is associated in programming the microcontroller using Atmel ICE rather than components used for final design. All software used in the project adds no additional cost, since all are freely available to use.

5.2) Safety:

There is no inherent risk of using any components used in this project. All the parts use ultra-low power and draws relatively low current. Design shapes and sizes of individuals items concurrently poses no health risk to its user, since its small and contains no sharp angles. Final design contains housing for top-level and individual units, which translate to safe handling of this product. During maintenance period, replacing battery pack, design elements can be handled without taking any safety precautions.

At prototype stage of Smart Stoves, however, certain precautions need to be taken in testing of Natural Gas Detection Module. In ensuring reliability for this module, overdriven methane gas needs to be feed into MC105 to monitor its sensitivity and outputs. This is done using a lighter gas fluid under an enclosed glass doom facing down. The relative size of enclosure is small, therefore small amount gas trapped inside materialized to a high concentration. This small amount of gas leaked poses no threat, however, precautions are taken by removing any forms of items which can cause a first to start.

Similarly, humidity sensor used in design doesn’t actively requires for safety precaution. However, delivery method to sensor requires careful handling. Boiling water is used to drive the output of humidity sensor to its saturation point. In reducing the risk of mishandling, only a small portion water is boiled in a large open kettle and senor is placed above it. Therefore, risk involved in designing is minimal.

5.3) Sustainability:

Smart Stoves is designed having low-powered and efficiently requirements as foremost parameter. There are many factors to considered when using battery powered device such as current draw, temperature, humidity, surface mount devices (SMD) etc. Accurate estimation on lifespan for each component will take a large sample data over many years. All the parts at prototype stage were chosen based on its low current draw (Engineering Specification) and cost. When mass produced as SMD, this current draw will be less which will extend the lifespan of Smart Stove even more. The goal when used as battery powered system is to follow set and forget rule. End-user will need to change battery every 12 months for proper operation, as they do for Smoke Detector. This reflects on sustainability of this project such that it requires less effort and maintenance in upkeeping this product. Although, when used as hardwired system, energy used to operate the product will have negligible effect on end-users billing. Overall system performs as highly suitability device without the need to frequently use external resources such as additional energy or maintenance.

5.4) Social/Environment Effect:

As engineers we are tasks to solve problems in ethical manners which do not impact society in negative way. On positive note, our system will compensate for human errors in kitchen and help prevent house fire. The use of such technology will help us prevent billions of dollars' worth in property damage and save precious lives; which is priceless. It will help evolve current home safety equipment and make it smarter. The system connects to our mobile devices which enables instant notification deliveries. The system is low powered, small and can be manufactured in on a single PCB, which has low to nonenvironmental effect. There are only positive social effects, since app for this system will always keep you connected with fire hazards drills. The app can also alarm the authorities in the case of emergencies, resulting in effective quick evacuation procedures.

Potential negative effects also need to be under consideration in designing this project. Although, smartness of this device makes our lives safer, it also allows 3rd party members an opportunity to interfere with ongoing communication between subsystems. Underlying structure for this system is to gather information from physical sensors and send notification to user phone. If signal is intercepted in mid-communication, potentially hackers can alter the transmitted message leading to no alarm or false alarms. This problem will be solved using software solution to encode the messages between active channels. User’s data acquisition poses another ethical dilemma for full functionalities of product, where user’s data is collected through various sensors. User have necessary options in agreeing to give system adequate permission in collecting data for flawless operations of the system. This concern can be address by being transparent about how the total system works and communicating it to end user. Overall the negative societal impact of this design project is minimal and will be continually be revised in predicting future problems.

Design evaluation:

6.1) Overview/Data :

Smart Stove’s design decisions are ongoing processes at each stages of the project. Upon conceiving project concept various design ideas were discussed. Following stage references from Gannt chart, design elements are updated. Overall this project referenced to 4-stages, which are pipelined. These stages are research, prototype, adjustment, bells and whistle. All these stages are motivated by budget, time and resources available to complete the project.

The goal is to gather accurate and reliable data from physical world in making concept of Smart Stove possible. There are multiple sensors which plays a specific role in data acquisition for this reason. Pressure sensors and humidity sensor work concurrently in decision if stoves are on or off while Methane (CH_4) Gas Detector is actively monitors combustible gas leakage from gas stoves. These sensors are required to be place in specific locations around gas stoves in serving their purposes. The sensor, MC105, gas detector, was thought to be placed close to stoves at the beginning of the concept idea. However, later it is changed to house in with the microcontroller few feet away from stoves. This is because while stoves are on, it will produce a small amount of natural gas around it. This unwanted input varies based on stoves brand, kitchen size and dimensions. By placing the sensor, a distance away where ideally no gas should be present, allow us to calibrate the system accurately and only detect valid inputs (buildup of gas). Similar decision is also made for central unit of this system, by relocating it from the celling to human accessible wall with an outlet. Although, individual system can be powered using battery, central unit will benefit from a main power source, since it will pack an LCD display to convey Realtime information. Pressure sensors are placed on/under grill rack of stoves to measure weight of cooking equipment along with its food content. Humidity sensor is placed next to steam vent to gather maximum range in inputs caused by process of cooking food.

Design decisions for top-level at prototype stage is influenced by engineering specifications for this system. The goal at this stage is to test individual component used in this project and verify the outputs. This process also serves as learning opportunity in common pitfalls. Design decision is constrained to each component's referenced circuit diagram. This is due to the fact; we need to only verify sensor's functionality and output.

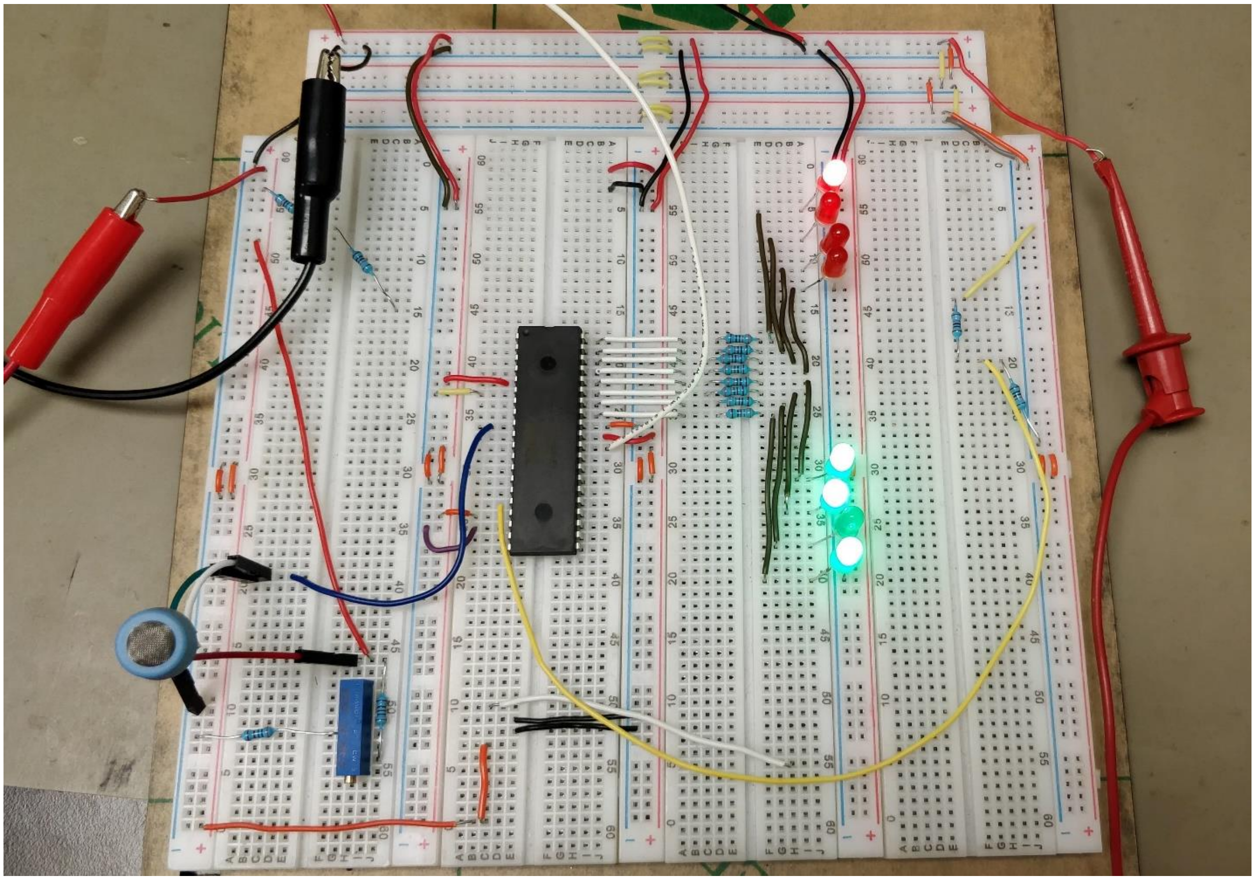

Figure 7: Prototype of MC105, Gas Sensor.

Prototyping of Methane Gas Sensor is shown in Figure 7. On left hand side in round shape is MC105. It is powered using 2.5 V from power rail while the MCU is using 5V operating voltage. Pin D0, of MCU Atmega4809 is used to input analog voltage of Gas sensor. This analog voltage is converted to digital value using MCU's built in Analog-to-Digital (ADC) converter. On the right-hand side, number of LEDs display this results in binary. Top banks of red LEDs represent most significant bits while the lower green LEDs contains least significant bits. The number shown in figure reads, "1000 1101", which converts to 141 in decimal. This is normal state output for gas detector, MC105, since it has initial offset voltage of 1.2V at its output. Voltage referenced used here is 2.2V. We know,

$$D_{output} = 255 * {}^{Vin}/_{Vref} \text{ , for 8-bit resolution ADC}$$

Using above equations, the ideal value we should have as decimal is 139. However, due to rounding error we received 141. This can easily be solved using a high-resolution ADC and oversampling of input data. Asif Iqbal derived the Embedded C codes necessary to program microcontroller. Required input to gas sensor was delivered using regular gas lighter.

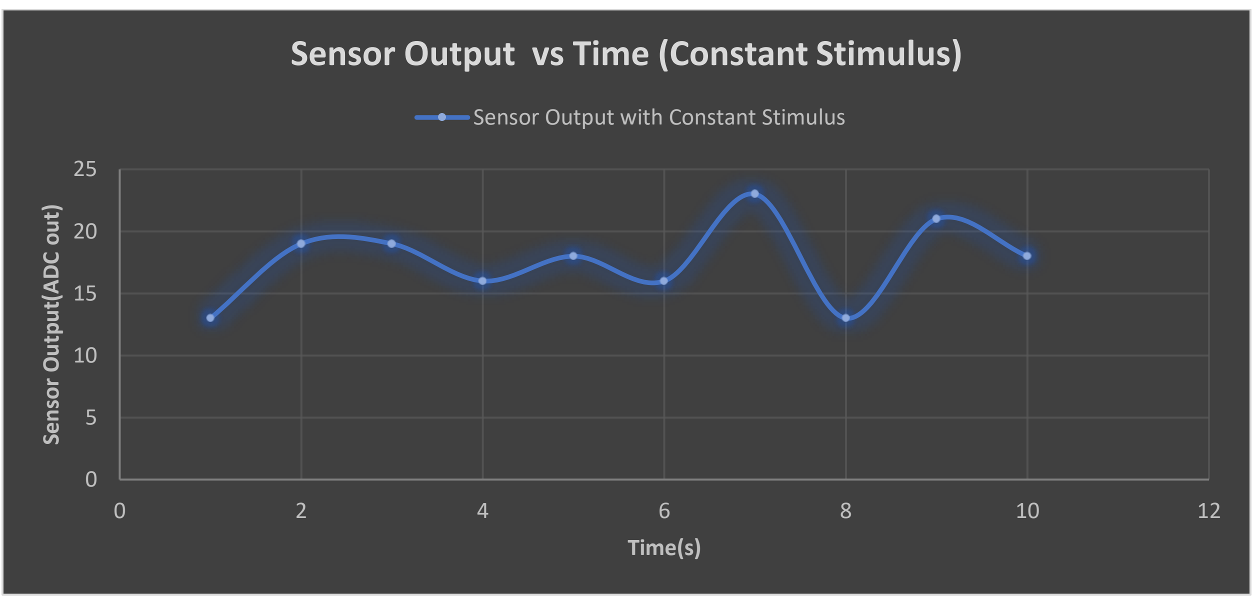

Figure 8: Gas Sensor, MC105, output using stimulus.

The quality of gas sensor was measured using stimulus and it's outputs observed. Fig. 8, depicts constant stimulus to Gas Sensor over a period. The values represented on Y-asix has offset of 140 because of constant 1.2V output of Gas sensor without stimulus. As shown in Fig.8, output is stable between 15 and 20 decimal value. In slow responsive system this is expected.

MC105 serves our application well. Bluetooth's functionalities will be tested and verified during next semester. The purpose at this stage is to supply input to each sensor and monitor it's output.

Temperature / Humidity Sensor:

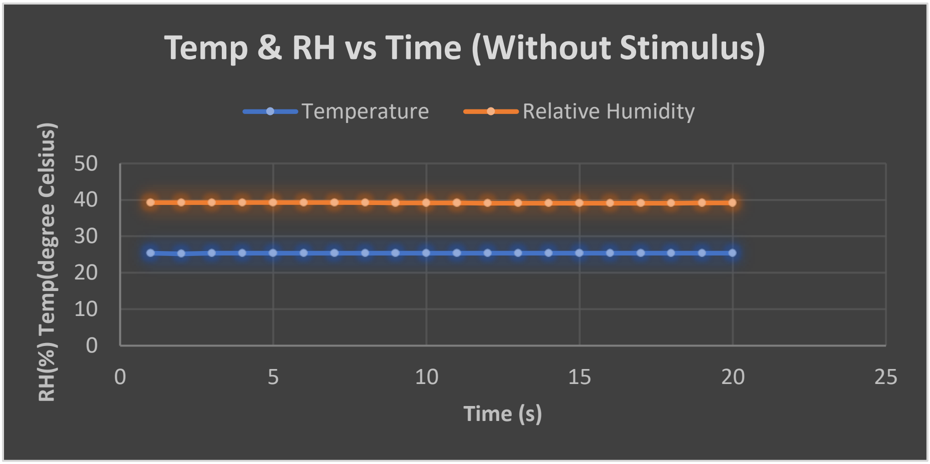

Figure 9: Temperature and Humidity readings without stimulus.

BME280, Humidity with built in Temperature sensor is needed to determine stove's on or off functionality. This part is a low-cost solution for testing overall system functionality. As shown in Fig.9 , readings for temperature and humidity is constant without any external stimulus to provided. The testing environment has thermostat set to 76° F, which translate to 24.44° C and humidity constant at 40%RH. The testing scheme and codes needed to program BME280 using I^2C protocol was derived by Roni Das.

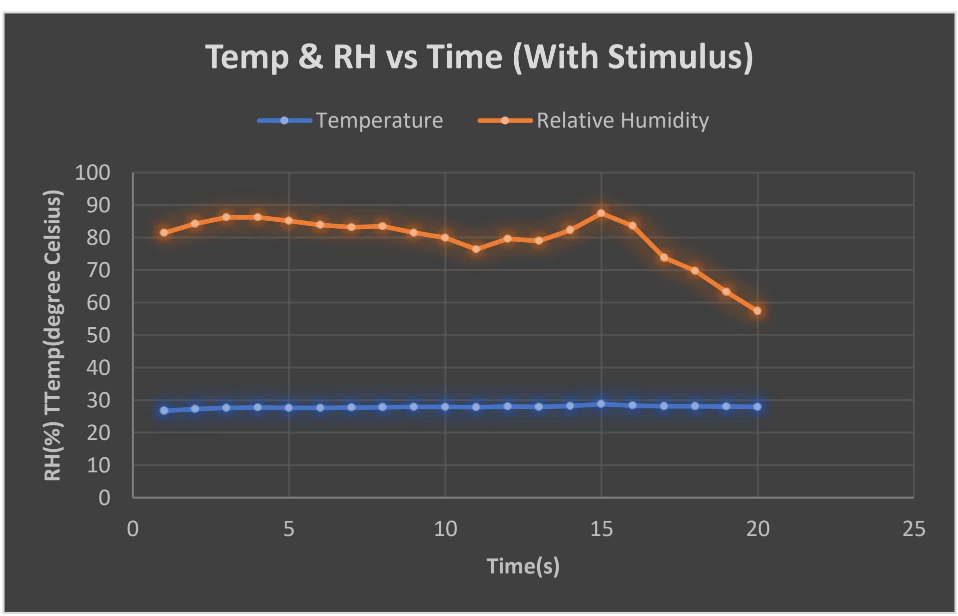

Figure 10: Temperature and Humidity readings with external stimulus.

In checking sensor's capabilities, an external arrangement was made to provided stimulus to system. A pot of boiling water was placed in the same temperature-controlled room and sensor placed directly above. Steam produced by hot water served as stimulus to BME280. Fig.10, shows data collected from this experiment. Temperature sensor shows slight rise from 24.44° C to 29° C whereas humidity reflects on greater change from 40%RH to around 80%RH. The delivery of steam to sensor's input is never constant, and due to the fact air is never a good conductor of heat reflects on minor change in built in temperature reading. However, even a small quantity change in water content in air shows during humidity reading. The output for this device is functional and applicable at prototype stage for this project.

6.2) Trade-Off:

When employing new engineering solution to real world problems, there are always trade-offs to consider. This project is mostly constrained by time and budget. In taking cost cutting measure, we only considered cheap parts during research and development. For example, BME280, is a humidity sensor used to measure water vapor from food steam. It is a low-cost sensor; however, it has maximum operating temperature of 85°C. The required location for this sensor is around air vent above stoves, therefore it can guarantee so sample any water vapor caused by heating food content. The temperature in this vicinity could rise well above 85°C when cooking process is ongoing. This can cause the sensor to malfunction, or even destroy is completely. However, this trade off is made during prototype stage given working environment for BME280 never exceed this range. By prototyping using low cost system, enable us to assemble all parts for this project at low cost, yet simulating real life capabilities of Smart Stoves. Not all low-cost items lead to big trade-offs in this project. Gas Sensor, MC105, is a low-cost solution, yet measuring parameters for this sensor is well within real world application. Software solution can also be trade-off, because there is newer suitable design language than Java which can accelerate design process much more efficiently. However, time allocate for this project poses another constraint of learning new language for app development. The outcome of this design decision by both team member is to develop only in Android environment, leaving iOS for future upgradability.

6.3) Learning Experience:

Roni: There is big learning curve when tackling a big project such as senior design. There were so many good ideas, which needed to be excluded from the project, to make it concise and applicable. I learned to code in Embedded C, which was not planned at the beginning of this project. Reading datasheet for various components became a daily routine, which accelerate the debugging process. Although this project is not close to finish, it became apparent that a surface mount device with all components will be tremendous beneficial in real world application. Lastly, there is always room for improvement and optimization for this design, for which we constantly brainstorm daily for newer and better ideas.

Asif: The learning experience so far was huge and there are more to come. I have gotten to work with breadboard and wiring it down. The most crucial thing to learn this semester was Embedded C. Our Atmega4809 microcontroller was programmed with embedded C and I had no knowledge of it prior. Another important part was learning about sensor. I learned how to work with sensors and more importantly how to interface them with microcontroller to process the data. This was a big learning experience.

Conclusion and discussion:

Smart Stoves is a work in progress. This senior design project challenged us in utilizing our accumulated engineering knowledge over past years from various courses. For example, Modern Sensors course taught us to identify and chose suitable components for data acquisition for this project. Embedded System Design course prepared us well for microcontroller programing; which enables us to process acquired data quickly and at a low cost. Signal processing is a major side quest for this project, which requires adequate understanding of inputs vs outputs and what they represent. Research regarding concept idea at the beginning of this project required us to brainstorm new solutions for a product that does not yet exist in market. Solutions which can be employed in making fire hazard less probable. At prototype stage, we learned how to code in Embedded C, as a team, in order to efficiently test system components. Although methods used in engineering Smart Stoves were not always easy and straight forward, it taught us to be patient and try a different approach in solving problems.

Program management:

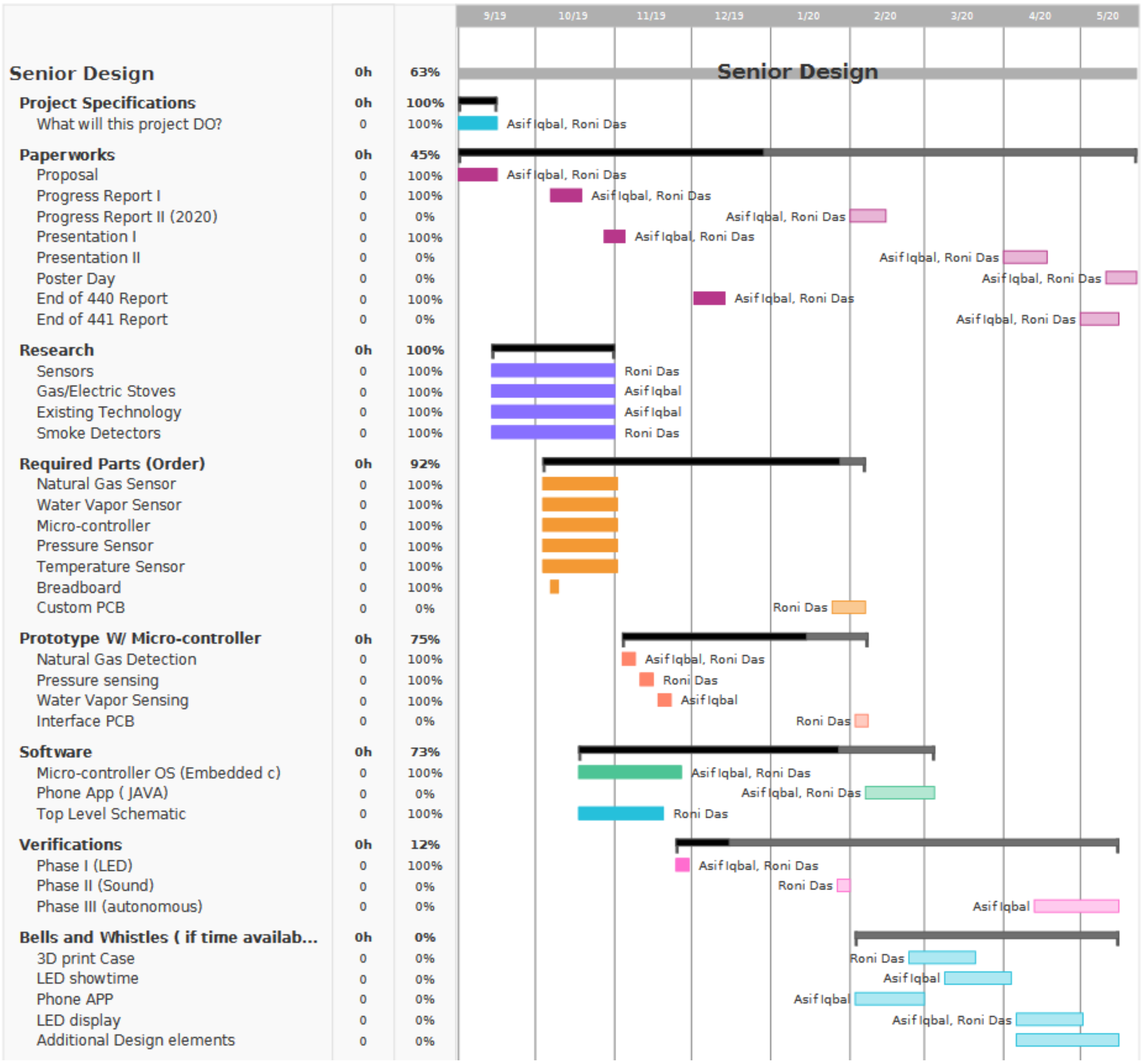

Figure : Gannt chart showing updated task.

Gannt chart above shows completed tasks in bold colors from respective section. Research phase for all components is completed. Required parameters found in datasheet is presented in Engineering Specification. Both team members worked in Research phase during this project in order to accumulate maximum knowledge and understanding common pitfalls.

Asif Iqbal derived coding base for MC105, gas sensor, while Roni Das worked on BME280, temperature/humidity sensor during first phase of prototype stage. Output results from microcontroller is verified using LEDS. Next phase of prototype will begin during beginning of next semester. Project conclusion will be made through working SMD version of porotype design.

Appendix A:

Team meeting is held with Professor. Leon Shterengas on every Friday at noon during the fall semester. There will be weekly meeting held in the spring semester too. Time and days for that will be determined in the beginning of Spring semester.

References:

[1] “MC105 Catalytic CH4 Sensor/Flammable Gas Sensor.” *Winsen*, https://www.winsen-sensor.com/sensors/combustible-sensor/mc105.html.

[2] “WPAH01 Ceramic Pressure Sensor.” *Winsen*, https://www.winsen-sensor.com/sensors/pressure-sensor/wpah01.html.

[3] “Piezoresistive Pressure Sensors: The Design Engineer's Guide: Avnet Abacus.” *Piezoresistive Pressure Sensors | The Design Engineer's Guide | Avnet Abacus*, https://www.avnet.com/wps/portal/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/piezoresistive-strain-gauge/.

[4] “Humidity Sensor”. (n.d.). Retrieved from https://www.sciencedirect.com/topics/materials- science/humidity-sensor.

[5] *Home Cooking Fires*, Ahrens, Marty. “PDF.” National Fire Protection Association. Nov. 2018.

[6] “Smart chemical sensor/alarm system.” Leon Shterengas. Electrical and Computer Engineering Senior Design Project Proposal Form - Faculty (2019/20), https://blackboard.stonybrook.edu/bbcswebdav/pid-5090723-dt-content-rid-36563269_1/courses/1198-ESE-440-SEC01-88901/Senior%20design%20project%20descriptions.pdf

[7] Rohan. “Smoke Detector Market.” *Market Research Firm*, 2019, www.marketsandmarkets.com/PressReleases/smoke-detector.asp.

[8] “Home Structure Fires.” *NFPA Report - Home Structure Fires*, https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Home-Structure-Fires.

[9] “Humidity Sensor Market Size, Share: Global Industry Report, 2019-2025.” *Humidity Sensor Market Size, Share | Global Industry Report, 2019-2025*,