Project Proposal Feasibility Study

Team 12: Automeated Solutions

The Smoke Sentry

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Engr339/340 Senior Design Project

Calvin College

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Executive Summary

The project that Team 12 decided to study, design, and build is a device that can be inserted into a gas grill to automate the smoking process of meat so someone can walk away from the grill. The team performed research on automated devices for alternative smoking methods such as charcoal and electric grills. The senior design group met with Smokehouse professionals and others with smoking expertise in order to learn about challenges and to gain perspectives for a gas grill, smoking device. The team then decided on methods to implement with the device to maintain gas flow, regulate and measure temperature, and provide the right amount of wood pellets and smoke. The team has begun the development of a prototype Smoke Sentry device.

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1.6 Introduction

Smoking of meat is a process that allows flavors to permeate meat and makes meat more tender. The person smoking the meat chooses a type of wood flavoring to imbue into the meat. The chips from this wood flavor are soaked in water to extend their life in the heat. The chips are gradually inserted into the smoker over time to keep a consistent smoke content. The smoke and heat in the smoking device cook and flavor the meat. When the meat reaches the desired internal temperature, the process is finished. This means that the process takes a large amount of time and careful attention to temperature and smoke fuel. Therefore, it is a good process to automate since it is intensive and time consuming. In addition to the nature of smoking to be arduous, it is also not easily available as a way of cooking meat for many people. Many of these people have gas grills and there is no readily available, automated way to smoke meat on a gas grill. With this in mind, the team decided to focus on automated gas grill smoking for the project.

Team 12 consists of two mechanical engineers, Jon Sager and Jordan Swets, and two electrical engineers, Ethan Oosterman and Dain Griffin. The goal of the senior design course is to apply the knowledge learned in engineering classes to a real-world project. It is a capstone course to highlight the skills of senior engineers through an open-ended project. The engineering department at Calvin College seeks to provide students with the ability to handle challenges and requirements that they face in real scenarios. Calvin College is a liberal arts college that aims to provide students with the skill set to face the work environment.

1.7 Project Management

1.7.1 Team Organization

The team is divided into two groups. The mechanical engineers are working on gas, heat, and wood pellet/smoke devices and how to keep these in balance thermodynamically. The electrical engineers are working on the control systems needed to adjust the devices used for the process and how to relay this to the user.

Team Advisor:	Professor Mark Michmerhuizen
Class Instructors:	Professor Leonard DeRooy
	Professor Renard Tubergen
	Professor Mark Michmerhuizen
	Professor Ned Nielsen
	Professor Jeremy VanAntwerp
Industrial Consultant:	Eric Walstra (Gentex Corp.)
Project Mentor:	Randy Newsome (Intralox LLC)

1.7.2 Schedule

Scheduling for the team is usually decided a week in advance. The tasks needed to be performed are discussed over the weekend. Each workday, the schedule is reviewed and edited on our team's whiteboard as deemed necessary. The project schedule can be seen in the Appendix as the work breakdown schedule. Each team member is expected to work at least eight hours outside of class-allotted time on the project.

1.7.3 Budget

The main use of the budget will be for electrical components needed for the device. Most mechanical components are available from the machine shop and will not need to be purchased. Donors (as seen in Acknowledgements) have provided meat for testing. A grill has been offered for use during testing as well (as seen in Acknowledgements). Each group member is expected to put in at least 8 hours of work each week to maintain the schedule.

1.7.4 Method of Approach

For this project, research was needed on alternative solutions, recipes, the smoking process in general, and electrical control devices. These research topics were split evenly. The team plans to design the device through test trial-and-error. The device will be designed based on our initial research, then modified as tests are performed in order to achieve better results.

1.8 Requirements

The proposed system will input chip-flavored smoke into the chamber and will be sealed in order to maintain constant smoke level throughout the chamber. Relative humidity may be monitored to within +/- 5% and will be output to the user within a timeframe of +/- 1 second.

The proposed system will regulate its own fuel. Warnings of low fuel and current fuel will be output to the user.

The system will monitor both the internal temperature of the meat and the ambient chamber air in the system. Ambient chamber air will be made uniform within +/- 2 degrees Fahrenheit throughout the chamber. The surface of the grill will also be made uniform to within the same specified tolerance. These measurements will be output to the user within +/- 1 second.

In addition, the system will be programmable by the user. The user will set a target temperature that will be maintained at the temperature tolerance specified previously. The user will also be able to control the input of chips into the system.

The system should be adjustable to fit various grill sizes. It should fit any rectangular cross section from 360 square inches to 400 square inches.

1.9 Research

While investigating how to accomplish our proposed solution, we found other similar solutions. The “Big Green Egg” (biggreenegg.com) is its own device and grill combination that runs on charcoal. The CyberQ (bbqguru.com) is a device that monitors and regulates temperatures in a grill or smoker. The PitmasterIQ (pitmasterIQ.com) also monitors temperatures in grills while barbecuing.

These products solve similar, but different problems. The Big Green Egg does not address the smoking aspect that we will solve with our solution. It also is not attachable to any gas grill, which our solution should accomplish. Our solution strives to be more versatile and user friendly than this product.

The CyberQ and the PitmasterIQ are simply parts of the solution that we will create. Although our device will also monitor and regulate temperature, it will also transform a current gas grill that is used by the average consumer into an automated smoking experience. This is not in the scope of the CyberQ and the PitmasterIQ devices.

In addition, the team was able to tour a smokehouse in Portage called “Barrett’s Smokehouse”. The owner of the smokehouse, Tim Barrett, showed the team numerous methods of smoking different types of meats. The takeaway from this tour was the common method of “low and slow”. This refers to a timing and temperature controlling technique where the chef starts at the lowest temperature to increase the porosity of the meat. He then adds smoke to the system to fill the pores with the flavor of the wood. When the pores are filled, the temperature is increased again to further increase the porosity and smoke absorbed by the meat. The smoking process is finished when the meat can take no more smoke because it cannot increase its porosity and the appropriate core temperature has been reached.

See References in section 1.19.

1.10 Task Specifications and Schedule

The tasks were split up into their mechanical and electrical concentrations. For example, designing the structure of the proposed system is to be drawn in a 3D modeling package such as SolidWorks and is to be done by either of the Mechanical Engineers on the team. However, designing the circuit diagram for the proposed architecture is to be done by the electrical engineers.

After the system is modeled and the circuit diagram is created, the materials can be ordered, the prototype can be built and wired and testing, retesting, and debugging can begin. A more complete list of tasks and scheduling can be seen in Appendix A.

1.11 **System Architecture**

The system consists of two primary components: a specialized rack to be inserted into the grill, and a controller that would monitor the grill's conditions and adjust them as necessary. The controller would perform this function via a number of devices and sensors present in the rack. A diagram of the overall system is shown in Figure 1.11.1 below.

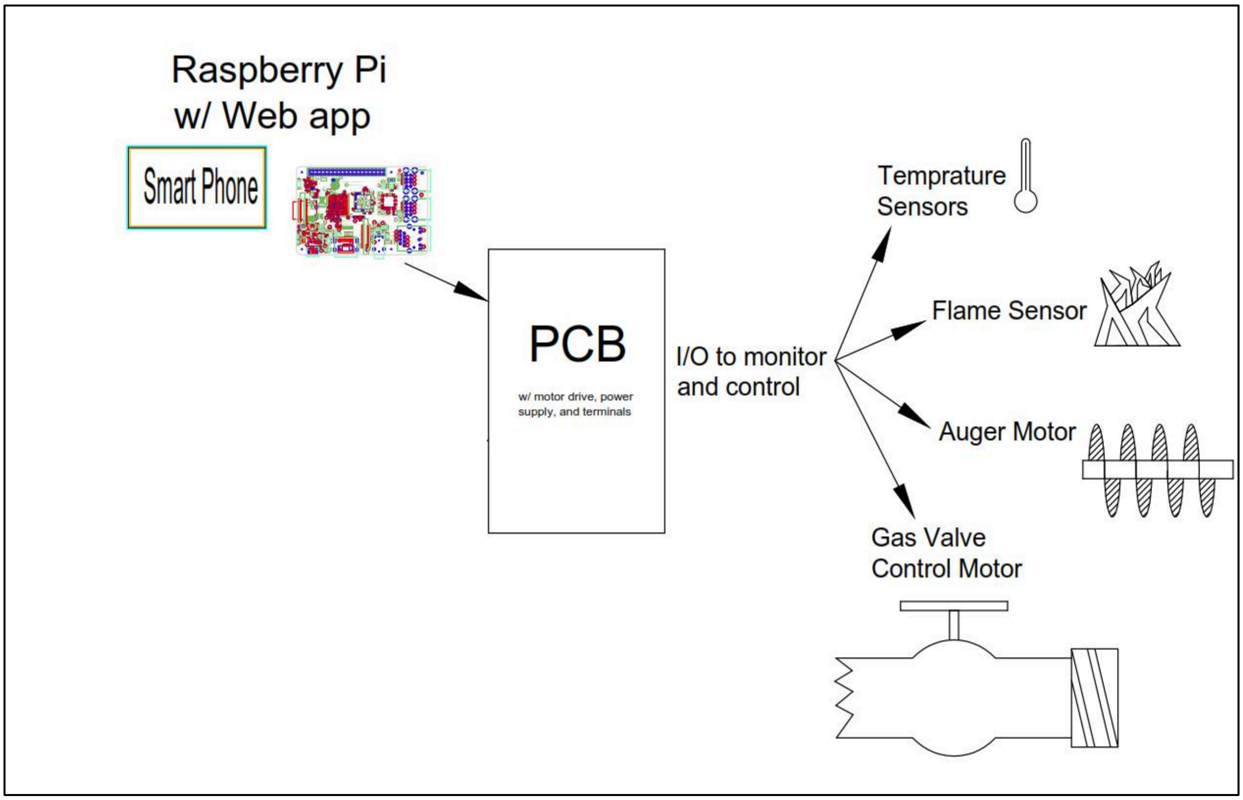

Figure 1.11.1: Overall system diagram

The rack must contain at least two thermocouples in order to measure both the ambient temperature inside the grill and the internal temperature of the food being smoked. A flame sensor is also included in the design to indicate to the user whether the grill's flame has gone out at any point in the smoking process.

In order to feed chips into the system for generating the smoke, the team decided to design an auger system. This system can be seen in 1.11.2. As seen in the figure, the auger is attached to a step motor. This motor will receive temperature data signals from the control system and twist the auger accordingly. The auger will then push the chips down the tube which will then fall into the chip tray. The chips will then burn and provide the smoke in the system.

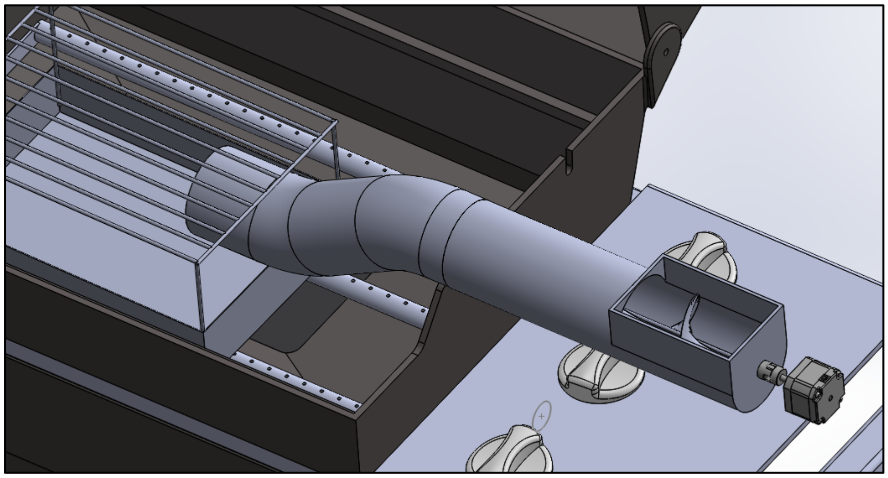

Figure 1.11.2: Basic auger design showing feed, tray, and motor

The rack also contains devices for controlling various aspects of the process. First, the rate of propane flow must be controlled in order to adjust the temperature inside the grill. Second, the rate at which wooden chips are added to the flame must be regulated to ensure that the food receives the proper amount of smoke.

Temperature regulation is directly related to the gas input into the system. The team designed a method of controlling the gas input into the system that can be seen in Figure 1.11.3. As seen in the figure, there are two pulleys attached by a synchronous belt. One of the pulleys is attached to a valve on the propane tank. The other pulley is attached to a step motor. The step motor will receive temperature data signals from the control system and twist the pulley accordingly. When the pulley attached to the step motor is twisted it will then twist the pulley on the gas valve which will either increase or decrease the amount of gas into the system.

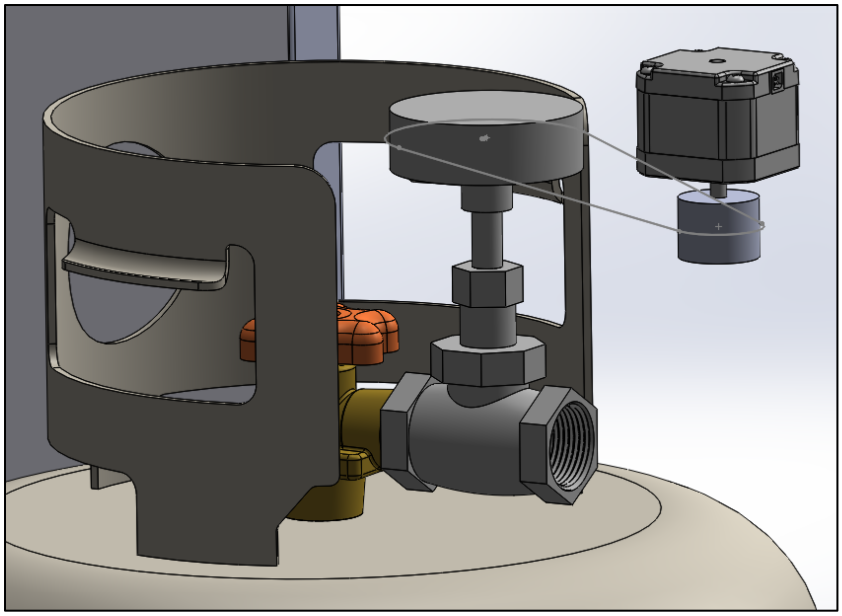

Figure 1.11.3: Design of gas flow valve with motor (line indicates belt path and hose is not shown)

The controller must be connected to a device (such as a touchscreen) that would allow a user to input certain parameters into the system. These parameters would define the conditions at which the controller should hold the system.

1.12 **Design Criteria**

Two main components of the system have presented opportunities for unique alternatives: the controller and the method of temperature measurement.

The controller should ideally be low-cost, low-latency, and easy to program.

The temperature measuring system should be low-cost, safe to put in and around food, and reliable in environments filled with smoke.

1.12.1 Design Norms

This design focuses primarily on three design norms: transparency, integrity, and caring. The system will be transparent in that it will communicate the temperature to the user in a clear and concise way to ensure awareness of the smoking process. Additionally, integrity is to be shown through honest communication of the data displayed to the user. All information sent shall be accurate and honest. Finally, the idea of caring for the user is essentially the entire basis for this design. This product is intended to make the smoking process easier and less stressful for the user, improving the user's quality of life.

1.13 **Design Alternatives**

The system's controller offers a great deal of design alternatives. For the purposes of this project, the choice has been narrowed down to a Raspberry Pi or an Allen-Bradley Micrologix 820 PLC. Both offer their own unique advantages and disadvantages.

The Raspberry Pi is advantageous in that it is cheaper and it offers more freedom of choice in software development for the system. A Raspberry Pi can be programmed in a number of different languages, while a MicroLogix 820 has a much more limited selection. The Raspberry Pi also offers more in the way of connectivity to external devices through Bluetooth or Wi-Fi. Nevertheless, the MicroLogix PLC has advantages of its own. While the PLC must be programmed with proprietary software, this software greatly simplifies the process and allows for easier development of complicated control system functions than does a coding language. The Raspberry Pi would require a far greater amount of work to achieve the same results as a PLC. Additionally, the MicroLogix PLC has native support for analog signals, which would be required for the system's inputs and outputs. A Raspberry Pi does not, and would require converters from analog to digital and vice-versa.

The temperature sensor also offers two alternatives. One is a thermocouple, while the other is an infrared sensor.

The thermocouple must be connected by a wire to the area at which the temperature must be measured, while the infrared sensor allows for temperature detection from a distance. On the other hand, since a thermocouple does not rely on light for its temperature reading, it is unhindered by the presence of heavy smoke in the grill. A thermocouple is also less expensive than an infrared sensor.

1.14 Design Decisions

Based on the aforementioned design criteria, the Raspberry Pi is the better choice for the system controller. While it is more difficult to program for this type of controller over a PLC, the lower price and added connectivity features make it the more suitable candidate for the job.

The thermocouple is the better choice for the system's temperature sensor. The lower price combined with the reliability in smoke-filled environments make this option more effective than the relatively expensive infrared sensor.

1.15 Integration, Test, Debug

With the Smoke Sentry being an attachment to a generic gas grill, a gas grill will be required to test the system. This has already been acquired and is ready for use once the Smoke Sentry prototype is far enough along for us to begin testing. Electrical systems have been studied and tested, and it has been determined that a Raspberry Pi microcontroller will be better suited for the system than a PLC. Once there is a working prototype there will be extensive tests in temperature regulation, gas regulation, and airflow. The tests will start out simple with meats that only take one to two hours to smoke, and then slowly increase to longer recipes and meats to make sure that the system can withstand a longer smoke period. The goal is to have a working system that can easily maintain temperature for up to 15 to 20 hours of operating time.

1.16 Business Plan

1.16.1 Marketing Study

When looking at what is on the market when it comes to different types of smoking apparatuses, there are multiple variations to choose from. Charcoal smokers, full wood-burning smokers, combination electric and wood smokers, and even gas smokers are all potential options depending on what type of resources a consumer would like to use. With the market being so diverse, it could be thought that an automated system would have been developed for each of these. Nevertheless, research indicates that automated temperature control systems seem to have only been created for charcoal grills to turn them into smoker systems. There are complete automated systems for each variation, but most systems are expensive and not aimed towards the do-it-yourself customer.

For this reason, the design's focus was narrowed down to an apparatus that will fit a generic gas grill and convert it into an automated smoker system.

1.16.1.1 Competition

As competitors go, there are not many automated temperature regulating systems designed for gas smoking for the everyday consumer. Companies like Charbroil and the Big Green Egg have automated systems that focus on charcoal smoking and have created full systems for purchase, but not something that can attach to an already owned grill. This allows for the development of a system that can attach to a gas grill without too much competition and allows for price variability as long as there is a demand for the product.

1.16.1.2 Market Survey

With the market being devoid of any particular smoking system that can attach to a gas grill, a survey of the do-it-yourself smoking community was required. After talking to multiple smoker enthusiasts, the conclusion was reached that an attachment to a gas grill would be desirable. Beyond just the idea of simply creating an attachment, more research is needed in variables like cost and functionality to make sure that this product is a success.

1.16.2 Cost Estimate

In looking at what the Smoke Sentry may cost there is still quite a bit of research needed to come to a final conclusion. There are still quite a few things that need to be decided upon within the project. Some aspects that still need consideration are how the system is going to be controlled, whether it be by PLC or a Raspberry Pi microcontroller. Research is still being done at this time before we make the decision on what is the best course of action. However, testing and research into ease of use and cost is pointing to the Raspberry Pi as the microcontroller to use. With the ability to use a Web app to display the Smoke Sentry GUI (Graphical User Interface), this allows us to utilize the customer's devices as the main GUI controller and use a cheaper one for the system. Other things need to be taken into account as well along with cost of sensors and material in building internal workings of the system.

1.16.2.1 Development

Within the development process of the Smoke Sentry there have been variable changes after new research has been brought to the table. With this being a system that relies on temperature variation depending on recipes, a prototype needs to be constructed in the near future to allow for rigorous testing as seen in the Appendix. With different meats needing different temperatures and times at those temperatures testing will be crucial in the development of the system having an accurate automated program.

1.16.2.2 Production

1.16.2.2.1 Fixed Costs

With looking at the amount of time put into research the estimate so far is about 50 to 70 hours. Finding the proper components and sensors for the system took some time along with assembling a system that will work in theory. The development time for the Web app and control program will be where most of the fixed cost will go. So far 20 hours have gone into R&D for the code and programming, and there is a lot of development needed to complete the main program infrastructure. It is estimated there will be an additional 120 hours of development time needed to complete the programming side of the system. With an engineer roughly costing $60 per hour on the low end, in a real world situation the overhead of this project would be somewhere in the $15,000 range. As production of the prototype continues this cost with need to be taken into consideration.

1.16.2.2.2 Variable Costs

The components that will be used to construct the Smoke Sentry; the microcontroller, temperature sensors, fan and motor, gas regulator and assorted metal hardware to create the inner box; will all be considered variable cost. With the cost of materials for the prototype being around the $500 budget, having an affordable product for customers is looking attainable with the product being manufacture on a larger scale. The possible starting target is 10,000 units produced in the first manufacturing term. Cost of materials still need to be reviewed to get a concept price per unit to sell to the customer.

1.16.2.2.3 Summary Financials

As seen in Figure 1.16.1, the total cost of parts for the prototype are estimated to be under $250. With other possible small component prices added in, this number can be safely estimated to finish around $300. With a budget from Calvin of $500, this is substantial evidence the project is viable and will be moving forward with the build of the prototype.

With this feasibility in mind, the Smoke Sentry will be further analyzed for production quantity price for the final report for senior design. The team's goal is to estimate costs on a basis of 10,000 units.

Electrical Part Description	Qty	Cost per Unit	Total Cost
Adafruit DC & Stepper Motor HAT for Raspberry Pi - Mini Kit	1	$ 22.50	$ 22.50
Raspberry Pi 3 - Model B - ARMv8 with 1G RAM	1	$ 39.95	$ 39.95
Stepper Motor - 125 oz.in (200 steps/rev, 600mm Wire)	2	$ 21.56	$ 43.12
Thermocouple Type-K - Glass Braid Insulated (Bare Wire)	2	$ 12.56	$ 25.12
IR Flame Sensor Module Detector Smartsense For Temperature Detecting Compatible With Arduino	1	$ 7.00	$ 7.00
			$ 137.69
Metal Part Description	**Qty**	**Cost per Unit**	**Total Cost**
Auger	1	$ 35.00	$ 35.00
Grill Grate and Tray*	1	$ 8.35	$ 8.35
Chip Feeder*	1	$ 12.81	$ 12.81
Metal Tubing*	1	$ 11.47	$ 11.47
Gas Valve	1	$ 12.99	$ 12.99
			$ 80.62
*cost is estimated from material weight and operations done			

Figure 1.16.1: Part costs and totals for Smoke Sentry prototype

1.17 Conclusion

The study of this product's design, management, and cost all indicate that the project is feasible. While there are obstacles that still need to be overcome before the system can be fully realized, the research and planning undergone thus far have shown that the Smoke Sentry has the potential to be a success. The team has discovered a number of ways to improve upon the initial design since the idea's inception, from simplifying the set of variables controlled within the grill to developing an internet-based method of interfacing with the system.

The team is already in the process of building the prototype Smoke Sentry so that the device can be optimized throughout the next semester of senior design. As the next stage of the project commences and plans are formed to assemble and program a functional product, the months ahead look promising for Automeated Solutions.

1.18 Acknowledgements

Professor Mark Michmerhuizen:

Faculty advisor

Randy Newsome:

Employee at Intralox LLC

Randy is a former professor at West Michigan University and enjoys helping student groups. He was instrumental in narrowing our focus of device design. He also helped set up a tour of Barrett's Smokehouse.

Barrett's Smokehouse:

Restaurant in Portage, MI.

Helped the group understand first-hand the smoking process and what it entails

Phil Jasperse

Machine Shop Technician

Helped the group with welding on the device and other machine shop needs

Bob DeKraker

Engineering Lab Manager

Helped with various technical and location problems and needs

Louise Earl Butcher

Butcher shop on Wealthy Street in Grand Rapids

Provided Team 12 with meat for test runs

The Swets Family

Donated a gas grill for use on Team 12's project

1.19 References/Bibliography

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PitmasterIQ Automatic Barbecue Controllers – pitmasterIQ https://pitmasteriq.com/. Accessed 12 Dec. 2016.

Schaenzle, Jordan. Personal interview. Atomic Object. 1 Dec. 2016

1.20 Appendix

GANTT CHART

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Research	2 days	Mon 10/10/16	Wed 10/12/16	
2		Find Current Recipes	1 day	Wed 10/12/16	Thu 10/13/16	1
3		Look At Alternatives	1 day	Wed 10/12/16	Thu 10/13/16	1
4		Decide Scope	1 day	Wed 10/12/16	Thu 10/13/16	1
5		Relevant Thermodynamic Principles	1 day	Wed 10/12/16	Thu 10/13/16	1
6		Relevant Control System Principles	2 days	Wed 10/12/16	Fri 10/14/16	1
7		Features Needed	2 days	Wed 10/12/16	Fri 10/14/16	1
8		Determine Requirements (interface, functional, performance)	20 days	Mon 10/17/16	Fri 11/18/16	2,3,4,5,6,7
9		Design System Architecture	3 days	Mon 10/17/16	Thu 10/20/16	2,3,4,5,6,7
10		Develop Design Norms	2 days	Mon 10/17/16	Wed 10/19/16	2,3,4,5,6,7
11		List design alternatives	1 day	Mon 10/17/16	Tue 10/18/16	2,3,4,5,6,7
12		List design decisions	2 days	Tue 10/18/16	Thu 10/20/16	11,2,3,4,5,6,7
13		Write PPFS Draft	16 days	Thu 10/20/16	Thu 11/17/16	12,11,2,3,4,5,6,7
14		Write PPFS	16 days	Thu 11/17/16	Thu 12/15/16	13
15		3D model	1 day	Thu 12/15/16	Fri 12/16/16	14
16		Circuit Design	1 day	Thu 12/15/16	Fri 12/16/16	14
17		Material selection	1 day	Mon 12/19/16	Tue 12/20/16	15
18		Component selection	1 day	Mon 12/19/16	Tue 12/20/16	16
19		Order materials	2 days	Tue 12/20/16	Thu 12/22/16	17,18
20		Build	15 days	Thu 12/22/16	Wed 1/18/17	19
21		Wire	6 days	Thu 12/22/16	Tue 1/3/17	19
22		Prototype	3 days	Wed 1/18/17	Tue 1/24/17	20,21
23		Test	10 days	Tue 1/24/17	Thu 2/9/17	22
24		Debug	5 days	Thu 2/9/17	Fri 2/17/17	23
25		Retest	5 days	Mon 2/20/17	Tue 2/28/17	24

Figure A1. Gantt Chart Task List

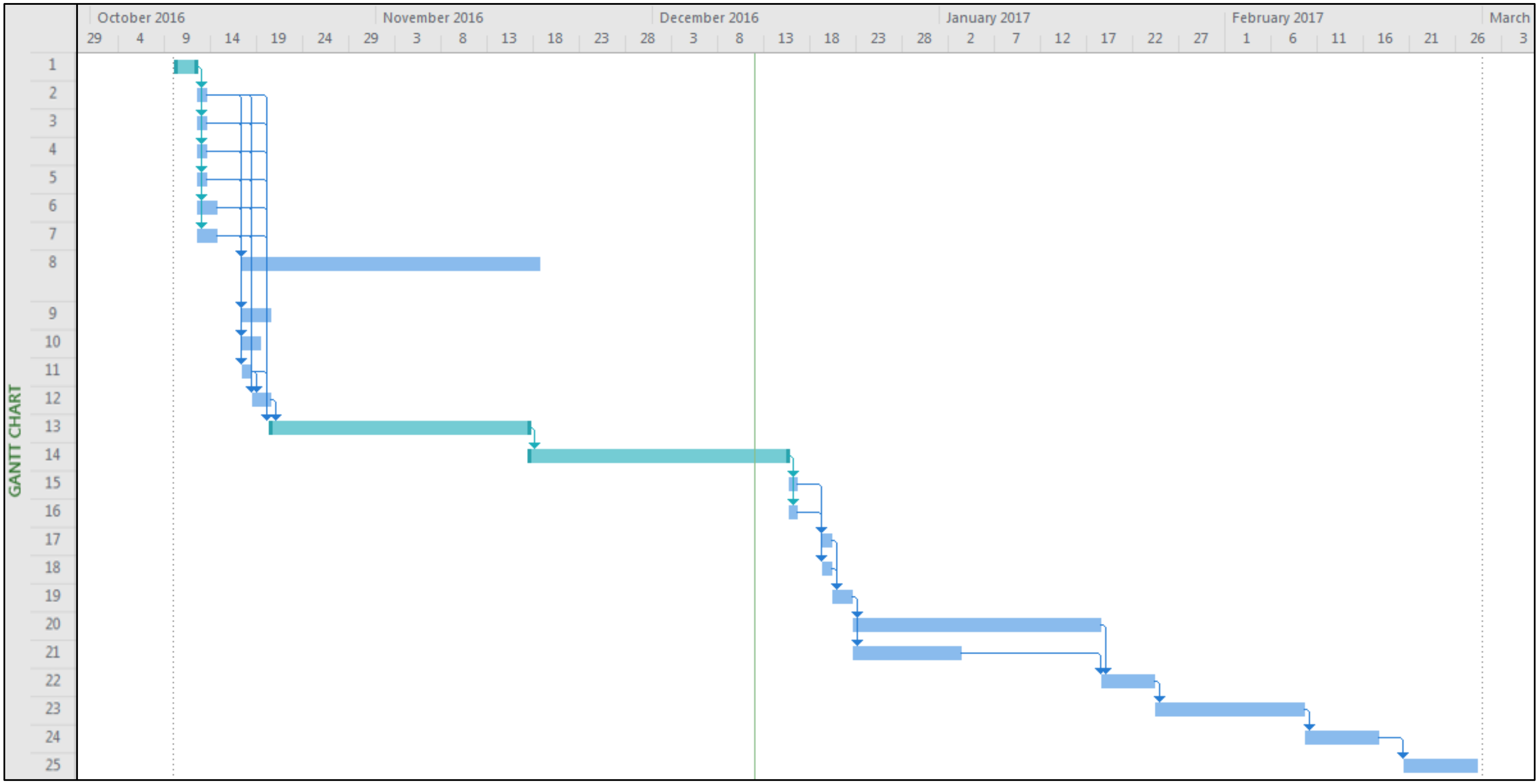

Figure A2. Gantt Chart Task Schedule