UNIVERSITY OF MAINE

ECE 403 DESIGN REPORT

Granny-Safe

A Smart Stove Top

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Abstract

This report describes the design, construction, and testing of a smart stove, that controls the temperature of a hot plate and includes an automatic shutoff feature. The project is powered by 120VAC mains which is stepped down to 5VDC. A full wave rectifier and DC-DC converter step down the supply to power to the rest of the project. The DC-DC converter was specified to output 5V $\pm5\%$ at 500mA with less than 100mV ripple, and exceeded the specification. A temperature sensor is used to read the temperature of the hot plate and outputs a voltage proportional to the temperature. The temperature sensor output is processed by a microcontroller and outputs a signal to the hotplate controller based on the user entered setpoint. The hotplate controller uses a triac to control the power supplied to the hot plate. Controlled triggering of the triac allows only a portion of each half sine wave of mains power to be supplied to the hot plate, which is adjusted by the microcontroller, to maintain the temperature within $\pm10°$F of the setpoint temperature. The microcontroller also outputs a signal to enable the alarm if the hot plate remains above 120°F for ten minutes. The project was able to meet all specifications and provided safe, precision temperature control of the hot plate.

Contents

List of Figures

List of Tables

1 Introduction

This document describes the design, simulation, and construction of the Granny-Safe project. The Granny-Safe is a smart stove top that allows precision temperature control of a hot plate burner, while incorporating safety features including an audible and visual alarm when the hotplate has been left on for ten minutes. Power to the hot plate is disconnected, if the alarm remains active for one minute, by means of an automatic shutoff feature. The Granny-Safe addresses the problem of hot plate dangers as well as accurate temperature control. Similar devices on the market today, such as the iGuardStove, are expensive and use motion sensors in the alarm process which can be unreliable. Granny-Safe is meant to be used for in home elderly care and for that reason the project was designed to be low cost, reliable, and easy to operate.

Project specifications are listed in the contract (Appendix A). The project had to meet the specifications in order to be successful. The contract requires a DC to DC voltage converter capable of supplying 5V$\pm$ 5% and at least 500mA with less than 100mV of ripple. The Granny-Safe must maintain a hot plate temperature within 10°F of the set temperature from 150°F to 400°F. Power to the hot plate must be controlled by a 5V input without the use of relays and must be capable of supplying 120VAC and a minimum of 5A. Lastly, the alarm timer is activated when the hotplate temperature exceeds 120°F and will sound if the reset button is not pressed within ten minutes.

In order to demonstrate that the Granny-Safe met specifications, A variety of methods were employed. Oscilloscopes from Barrows Hall were used to prove the power supply specifications, and a multimeter was used to prove the amperage supplied to the hotplate coil. An Adafruit temperature probe was used to confirm the temperature of the coil.

After the introduction of the project, the Granny-Safe is examined thoroughly in the sections below. Section 2 contains a high-level project overview, Section 3 contains an in-depth explanation on design choices. Section 4 details the results of the project, and Section 5 concludes the report.

2 Breakdown

The main goal of the Granny-Safe project was to provide precision temperature control with enhanced safety features for a hot plate burner. To best explain the functioning parts of the project, a high level block diagram is shown below in Figure 1. An explanation of the signal flow follows the diagram. Each block is then detailed with its inputs, outputs, and functionality in the system. The full schematic of the Granny-Safe is provided in Appendix B.

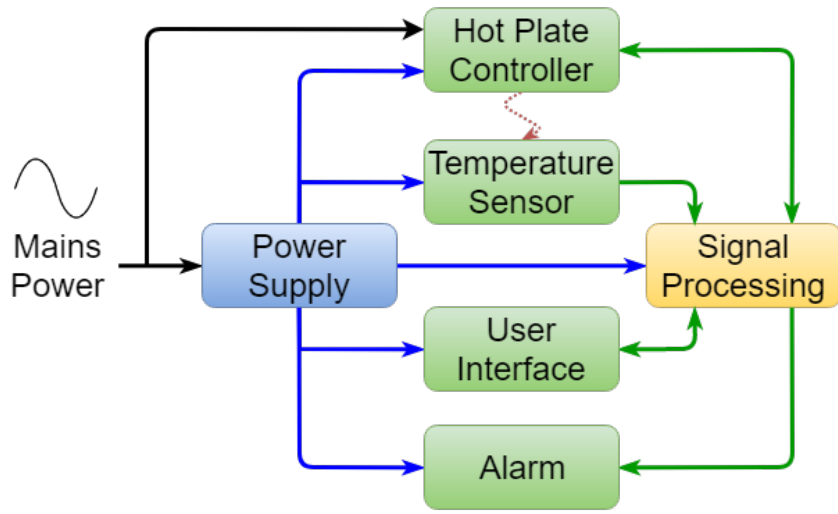

Figure 1: Functional block diagram of the Granny-Safe

As Figure 1 shows, the Granny-Safe is powered by mains power. The power supply then steps down the mains power to a level usable by the project. The hot plate controller is powered by mains and the power supply to regulate the power delivered to a hotplate. The temperature of the hot plate is measured by the temperature sensor and the output is sent to signal processing. Signal processing converts the signal into a temperature and compares it to the set-point entered through the user interface. A control signal is sent to the hot plate controller, based on the comparison, to properly regulate the temperature. The user interface allows the user to view the temperature and enter a desired set-point temperature. When certain conditions are exceeded the alarm is triggered and emits an audible and visual alarm. If the alarm is not reset through the user interface, the hot plate controller will disconnect power to the hot plate.

2.1 Power Supply

The power supply in the Granny-Safe is used to provide a 5VDC output capable of supplying at least 500mA, with no additional power sources other than 120VAC mains, to the rest of the project. The power supply uses a step down transformer and full wave rectifier to convert the AC source into a DC value. From there, a buck converter is used to reach the final specified voltage and amperage levels.

2.2 Temperature Sensor

The temperature sensor uses an resistance temperature detector (RTD) to measure the temperature of the hot plate coil. The temperature sensor is powered by the power supply and uses an instrumentation amplifier to output a voltage that is proportional to the temperature. The output signal is sent to signal processing, which converts the voltage into a temperature. The temperature is displayed to the user and used to adjust the hot plate temperature as needed.

2.3 Signal Processing

The signal processing for Granny-Safe is provided by an Atmega328P-PU microcontroller. The microcontroller is used to calculate the temperature based on the data received from the temperature sensor. It is also used to process and send data to the user I/O as well as send a control signal to the alarm circuitry to turn it on or off. The microprocessor takes the user entered setpoint, along with the temperature data and with the use of a proportional-integral-derivative (PID) contoller, regulates the signal sent to the hot plate controller to then regulate the temperature of the hot plate.

2.4 Hot Plate Controller

The hot plate controller regulates the hotplate temperature and uses connections from the 5V power supply, 120 VAC main, and the microcontroller. A zero sensing circuit is used to find the zero crossings of the AC power, at which, a pulse is sent to the microcontroller. The triac circuit has connections to the main power and microcontroller. At every zero crossing, the microcontroller can send controlled pulses to the triac which allows power to flow to the hot plate. The amount of power going to the hot plate can be manipulated by the microcontroller to adjust the temperature value.

2.5 User Interface

The user interface enables a user to interact with the hot plate controller. Through the user interface, the user can select what temperature the hot plate will maintain by utilizing a keypad. The keypad allows the user to enter a set-point which is then displayed above the actual temperature on the LCD screen. If the alarm is activated, the keypad can be used to reset the alarm. A green LED is used to indicate that a setpoint has been entered and a yellow LED is used to indicate that alarm conditions have been met.

2.6 Alarm

The alarm informs the user that the hotplate has remained on for over ten minutes. The alarm circuitry features a piezoelectric (PZ) speaker and red LED to serve as safety features for the Granny Safe project. The speaker and LED are connected to an input of the microcontroller. When the temperature sensor first records a temperature of 120 degrees Fahrenheit the alarm timer is enabled. After ten minutes the speaker and LED are activated. If the alarm is not reset within one minute, power will be disconnected to the hotplate, the alarm will turn off, and the setpoint will clear.

3 Details

The design, analysis, theory and simulations conducted to complete the Granny-Safe are discussed in this section. Decisions were made based on previous knowledge and testing, and resulted in continuous revisions of the project until it met all specifications. The Granny-Safe's high level components, shown in Figure 1 are discussed, with each broken down into important blocks and discussed at length. Included in Appendix C is a detailed parts list of all parts used in the Granny-Safe.

3.1 Power Supply

The purpose of the power supply is to convert mains power in a level usable by the project. Its consists of a step down transformer, a full wave rectifier, and a buck converter. The Granny-Safe needed a 5V power supply capable of providing at least 500mA of current. In order to reach this voltage level, a step down transformer was used to bring the 120VAC down to a more manageable 12VRMS. In order to convert this 12VRMS into a usable DC voltage, a bridge rectifier was used. To reach the 5V specification, a buck converter was used. Further details about the bridge rectifier and buck converter will be discussed below.

3.1.1 Bridge Rectifier

The purpose of a bridge rectifier is to convert an AC signal into a rectified AC signal. The rectified signal can then filtered by means of a capacitor to produce a DC voltage. To implement the bridge rectifier, schottky diodes were used. In this case, the rectified voltage of 12V was significantly higher than the necessary 5V required. This was a conscious design choice because small losses through the diodes can be ignored.

3.1.2 Buck Converter

Buck converters are a switching regulator used to control output voltages by switching on and off at a set duty cycle. They offer an efficient solution to voltage regulation.

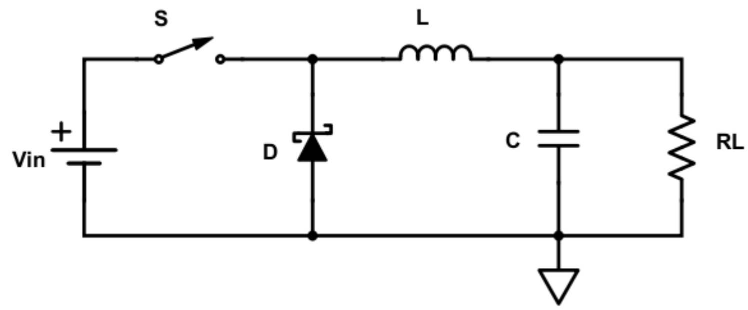

Figure 2: Buck converter topology

When the switch in a buck converter closes, current flows through an inductor, capacitor, and load. When the switch is closed, the capacitor discharges through the load while the inductor is used to maintain constant current. The diodes in a buck converter circuit provide a current path when the switch is closed. Schottky diodes were selected for this application due to their fast switching capabilities coupled with low forward bias voltages. Low forward voltages and fast switching capabilities help improve the efficiency of the circuit.

The TI simple switcher LM2576 was used as a buck converter chip. The LM2576 was selected due to its variable input range, adjustable voltage output, and smoothing qualities. The chip was capable of up to 2A of current, which is more than sufficient for the application.

The LM2576 switches at a set frequency of 52kHz. To find the necessary inductor values for the application, the duty cycle must be calculated first. The equation for the duty cycle of a buck converter is seen below in Equation 1.

$$D = \left(\frac{V_{\text{out}}}{V_{\text{in}}}\right) \tag{1}$$

With an input voltage of 17V and a desired output voltage of 5V, a duty cycle of 29 was chosen. With this value in mind, an inductor value is found by using Equation 2.

$$L_{\text{min}} = \left(\frac{T * V_{\text{out}}}{2 * I_{\text{out}}}\right)(1 - D) \tag{2}$$

Using the duty cycle calculated above, the minimum inductor was calculated to be 210uH. Due to available parts, a 330uH was deemed sufficient and functioned properly.

For the capacitor values, the LM2576 datasheet [1] recommends a capacitor value of at least 470uF. Several capacitor values of both smaller and larger capacitance's were tested, and none proved to be better than the value of the 470uF.

One of the main advantages of the LM2576 is the adjustable output voltage set by two resistor values. The resistor values can be calculated by using the following Equation 3.

$$V_{\text{out}} = 1.23 * (1 + \frac{R_2}{R_1}) \tag{3}$$

Referencing the equation above, a output voltage of 5V was desired. With this in mind, the ratio of R_2 and R_1 was calculated to be 3.06. Using resistors in the 10kΩ range, R_2 was calculated to be 3kΩ and R_1 was calculated to be 1kΩ.

The expected values were used, but the circuit proved to be extremely sensitive. To combat this, a 10KΩ pot was used as a resistor ladder. The 10kΩ range seemed like a logical choice due to it being high enough resistance so any stray resistances are negligible, yet low enough as to be negligible when compared to the input impedance of the LM2576 which is in the 1 mega ohm range

3.2 Temperature Sensor

The purpose of the temperature sensor is to measure the temperature of the hot plate and supply the measured value to the microcontroller. A platinum 100Ω RTD was used in the temperature sensor circuit to respond to the temperature of the hotplate. A wheatstone bridge was used with the RTD to generate a voltage difference which is sent to an instrumentation amplifier. The instrumentation amplifier amplifies the small voltage difference to The RTD has to be capable of measuring 150°F to 400°F as well as be accurate in that range. The RTD was chosen due to its ability to operate in the specified range and is accurate to plus or minus 1.8°F up to 185°F. Further details about the instrumentation amplifiers and wheatstone bridge are detailed below.

3.2.1 Wheatstone Bridge

The purpose of the wheatstone bridge is to determine the value of an unknown resistance. The goal of the wheatstone bridge was to minimize power consumption while maintaining a high degree of accuracy in measurement. The wheatstone bridge, shown in Figure 3 acts as a simple two-part voltage divider, which serve as the inputs to the instrumentation amplifier.

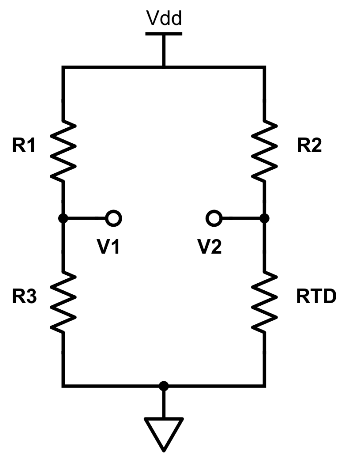

Figure 3: Wheatstone bridge topology

If the values for R1, R2, and R3 are known, the resistance of the RTD and therefore temperature, can be calculated. As the temperature increases, the thermal properties of the RTD cause the resistance to increase at a relatively linear rate. The increase in resistance causes the voltage at V2 to increase which also causes the difference between V2 and V1 (ΔV) to increase.

At thirty-two degrees Fahrenheit, the resistance of the RTD is 100Ω. The granny safe is not expected to operate below 32 degrees Fahrenheit and because of this a 100Ω resistor was used for R3. This ensures that ΔV always remains positive. A 1$\%$ tolerance resistor for R3 was chosen to limit the error in the voltage difference. R1 and R2 are used to limit current through each branch and are set equal to each other, at 2.4kΩ, for a maximum branch current of 2mA. The resistance of the RTD at a given temperature, in degrees Celsius, is found by using

$$R_{\text{t}} = R_0(1 + \alpha T) \tag{4}$$

where R_0 is the resistance of the RTD at 0 degrees Celsius and α is the resistance-temperature coefficient for the RTD. The listed α for the Adafruit RTD was 0.00385Ω/°C. While the contract specifies maintaining temperature up to 400 degrees Fahrenheit, in order to read temperatures above that range, T was set to 260 degrees Celsius (500°F). This resulted in a resistance of 200Ω and supplied the upper limit for this project. Using the resistance in the wheatstone bridge provided a maximum ΔV of 0.2V.

With the design of the wheatstone bridge complete, the ΔV must now be calculated and amplified to be used as an input to the microcontroller's analog to digital converter (ADC), which is discussed later in this section. To generate the desired input, an instrumentation amplifier is used and discussed in the next section.

3.2.2 Instrumentation Amplifier

The purpose of an instrumentation amplifier is to provide amplification to a test signal without the need for impedance matching. The design goal of the instrumentation amplifier is to utilize the full range of the microcontroller's ADC thus providing the most accurate temperature measurement. This is accomplished by use of input buffer amplifiers connected to the inputs of a difference amplifier. A basic, three op-amp, instrumentation amplifier configuration is shown in Figure 4.

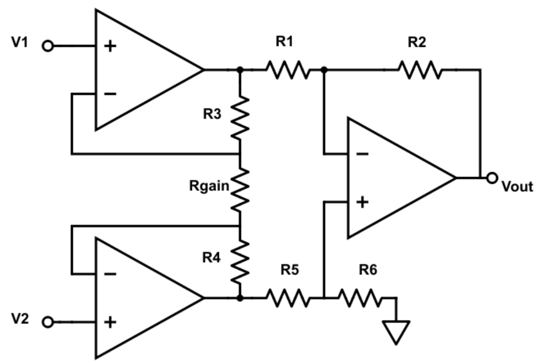

Figure 4: Op-Amp instrumentation amplifier

To utilize the full range of the ADC, the output voltage of the instrumentation amplifier is required to range from 0V to 5V. Because the op-amps are connected to the 5V supply, the output will never fully reach 5V, causing the temperature measurement to be inaccurate. To combat this the higher temperature range was chosen to ensure the Granny-Safe's operating range was always accurately measured. Setting R_3 equal to R_4, R_1 equal to R_5, and R_2 equal to R_6 yields the following gain equation, taken from [2],

$$V_{\text{out}} = (1 + \frac{2R_3}{R_{\text{gain}}})(\frac{R_2}{R_1})(V_2 - V_1) \tag{5}$$

and was used to find the resistor values. V_{out} is desired to be 5V when ΔV is 0.2V yielding a gain of 25. The values of R_2 and R_1 were chosen to be 15kΩ and 3kΩ respectfully, along with an R_3 value of 20kΩ and an R_{gain} of 10kΩ, to reach the desired gain.

Simulations confirmed the design and further details on processing the instrumentation amplifier output is found in the following section.

3.3 Signal Processing

The signal processing in the Granny Safe is performed by an Atmega328P-PU microcontroller. It is responsible for computing the temperature, handling the user interface, and controlling the hot plate temperature by means of a PID controller. Arduino uses this microcontroller in the Arduino Uno R3 and was used to make programming the Granny-Safe easier. The two main components of the signal processing of the Granny-Safe are the microcontroller and the PID controller. The microcontroller processes user inputs and

3.3.1 Microcontroller

The microcontroller supplies the ”brains” to the Granny-Safe. It is responsible for processing all of the signals through the project. The microcontroller receives inputs from the user interface, as well as the zero-sensing circuit. The microcontroller also supplies power to the LED’s and audio alarms when necessary.

The micrcontroller used was the Atmega328P-PU, chosen due to its ample documentation, 10-bit ADC, and due to its many GPIO ports. The 10-bit ADC allows for accurate conversion of the voltage from the temperature sensor. The microconntroller also features i2c connections which are utilized by the LCD and, by using the Arduino Uno R3, an easy IDE environment to develop code for and flash the microcontroller.

The 10-bit ADC allows for 1024 digital levels between 0 and 5V. This results in a 0.5 degree Fahrenheit resolution of the temperature reading.

3.3.2 PID Controller

The purpose of the proportional integral derivative controller, otherwise known as the PID controller, is to regulate when the triac gate is open, and therefore controlling the amount of power going to the hotplate. The amount of power going to the hotplate is directly related to the temperature of the coils. The PID controller works by adjusting the input based on how the output compares to the desired values. For example, if the actual temperature is below the desired temperature, the PID controller will change the input to the triac to allow more power to flow to the hot plate. To make the system more stable, A PID controller also takes the derivative and integral of the error and adds the three terms together. The input of the PID controller is the signal of the zero sensing circuit in the form of a pulse. Other inputs into the controller include the setpoint, which serves as the desired value, and the actual temperature.

3.4 Hot Plate Controller

The purpose of the hot plate controller is to regulate the amount of power delivered to the hot plate. Regulating the power of the hot plate provides a means of controlling the temperature of the hot plate and to disconnect power completely.

3.4.1 Zero-Sensing

The purpose of the zero-sensing circuit is to provide a pulse to the microcontroller for every half sine wave. The zero-sensing circuit is connected to mains power. Every time there is a zero crossing in the sinusoidal AC signal, a pulse is sent out. The zero-sensing circuit is operated like a comparator, with one signal constantly being zero volts and the other being the sinusoidal AC source. The sine wave changes polarity twice every period, and with a frequency of 60Hz, there are 120 pulses per second, being sent to the microcontroller. These pulses, approximately one every 8.33ms, can be seen in Figure 5.

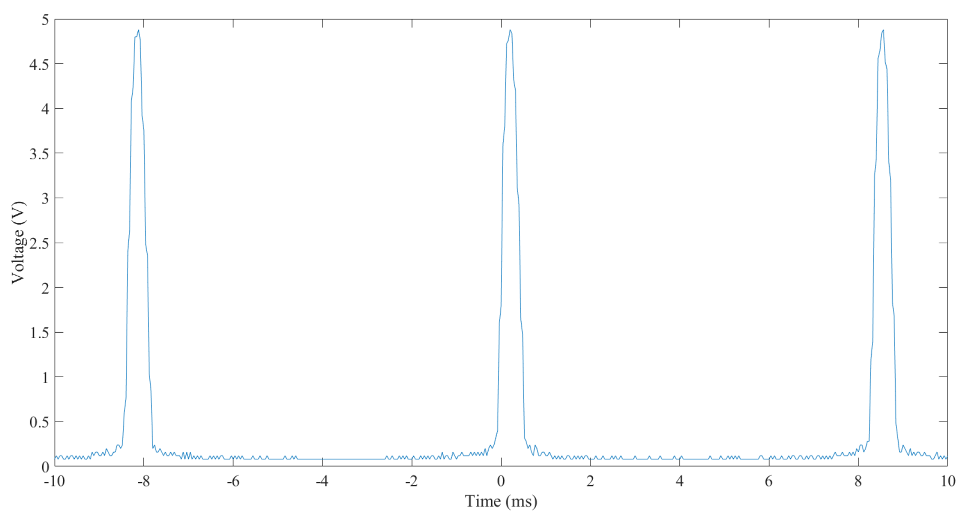

Figure 5: Zero-sensing circuit output

This pulse was sent as an input to the microcontroller to be used in the PID controller discussed earlier in this report.

3.4.2 Triac Control

The purpose of the triode for altering current, or triac, is to control the flow of AC power to the hotplate. A zero sensing circuit paired with a triac current gate was used to control the power to the hot plate, and thus the temperature. The zero sensing circuit receives a signal from the 12VRMS side of the transformer. Every time that the AC sine wave changes polarity, a zero crossing occurs. At this zero crossing, the zero sensing circuit sends a signal to the microcontroller. Since a sinusoidal wave has a zero crossing twice every period and AC power operates at a frequency of 60 Hz, there is approximately 120 pulses sent to the microcontroller per minute. For every pulse sent to the microcontroller, a signal can be manipulated by the PID control and sent to the BJT gate of the Triac. A 2kΩ resistor was placed in front of the BJT to limit current to the gate. When current is sent to the gate of the BJT, the gate allows current to flow through the 360k resistor and enable the triac, which in turn allows current to flow to the hotplate. The pulses sent to the triac can be manipulated by the microcontroller to control the amount of heat generated by the hotplate. A triac can be thought of as a PNP and BJT with the gate of the NPN tied to the drain of the PNP, and the gate of the PNP tied to the base of the NPN. When a signal is applied to the gate of the NPN BJT, it allows power to flow through both transistors and into the hotplate.

3.5 User Interface and Alarm Activation

There are both audio and visual alarms used as safety features for the Granny-Safe hot plate, as well as user inputs. The user input is a 3 x 4 keypad. When the user inputs a setpoint, the setpoint is displayed on the LCD along with the current temperature of the hotplate. Once a setpoint is entered, the green LED is turned on. When the temperature exceeds 120 degrees, the yellow LED turns on. This warns that the hot plate is hot to the touch. After the hot plate has been on for 10 minutes, the red LED and audio alarm turns on. If the user doesn't press the reset button within one minute, power will be cut off to the hot plate. Debouncing capacitors are used for each key of the keypad.

4 Results

Once the hardware and software had been developed, testing confirmed that that all contract specifications were met. Mains AC power was used as the power input to the circuit. The buck converter achieved the 5V specification, and provided 500mA of current with less than 100mV ripple voltage. The temperature sensor was able to be accurate within 10 degrees of the temperature setpoint between 150 and 400 degrees. The Granny Safe was able to control 120 VAC and was capable of supplying 5A to the hotplate. A Rigol DS1102E oscilloscope was used to confirm the results. The power supply results will be discussed first, followed by the temperature sensor and temperature control. Finally, the results of the triac current conditions will be discussed.

4.1 Power Supply

The goal of the power supply was to create a 5V DC output from 120VAC. The testing of the power supply consisted of ensuring that the buck converter was able to supply the 5V with at least 500mA of current while keeping the ripple within the 100mA specification. The power supply was implemented with both solder board and PCB implementations. The solder board implementation worked well and was within all specifications. The PCB version kept blowing fuses for an unknown reason. During design review, it was discovered that a flaw in the PCB layout caused the full wave rectifier to work incorrectly, and therefore providing a current spike. The problem was soon corrected after design review by reorienting one diode. The results of measuring the voltage output of the buck converter was a DC voltage of 5.02V.

Based on the contract, the range of voltages could have been between 4.75 and 5.25V. As seen in the figure above, the project is well within spec with a measured voltage of 4.98V. In order to prove that the buck converter was capable of supplying the specified 500mA, the voltage was measured across a 10 Watt, 9.1 Ω power resistor. Ohm's law was applied by dividing the measured voltage by the resistor value to depict the current. Since the voltage across the 9.1Ω resistor was 4.98V, the buck converter was supplying 549mA, which exceeds the specification

The final power supply result was the ripple on the 5V output. The ripple was measured by taking the AC value of the signal. The results are seen below in Figure 6.

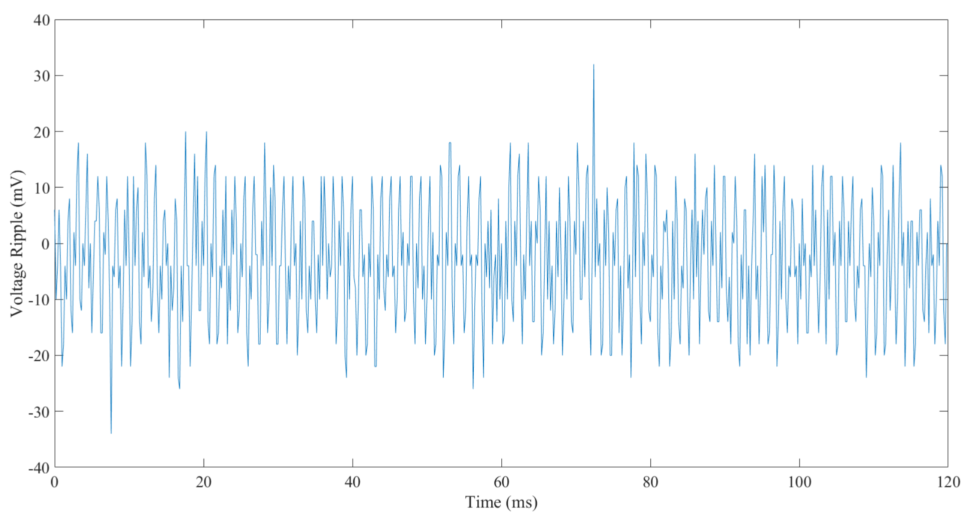

Figure 6: Voltage ripple measured across 9.1Ω resistor

As proved by the test measurements and figure above, the Granny-Safe met or exceeded all specifications for the power supply.

4.2 Temperature Sensor

The temperature sensor was specified to maintain temperature within 10 degrees of a setpoint between 150 and 400 degrees. To verify this specification, an Adafruit temperature sensor was used. The purpose of the Adafruit temperature sensor was to verify that the designed temperature sensor was reading the correct temperatures

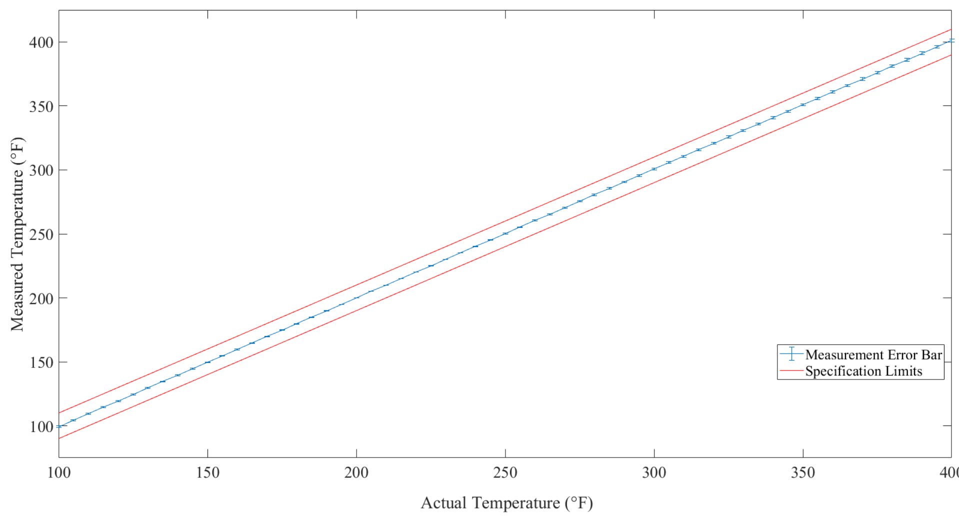

Figure 7: Comparison of measured temperature versus actual temperature

As seen in the figure above, the measured temperature was very close to the actual temperature, well within the limits of ± 10 degrees. The temperature sensor was often within a few degrees of the actual temperature for the whole measurement span. Variations between the two temperatures can be explained by physical variations of the placement of the hotplate probes. Although the probes are as close as possible to each other, there's no guarantee that the actual coil maintains a constant temperature along its length, and it was reasonable to assume a one or two degree variance. Despite this possible variance, it was determined that the method of measurement was the most accurate method available.

4.3 Temperature Control

The contract states that the Granny-Safe must maintain temperature within 10 degrees of a setpoint between 150 and 400 degrees. To prove that this specification was met, the graph below recorded the highest and lowest temperatures recorded throughout the measurement span. The results of this measurement can be seen below in Figure 8.

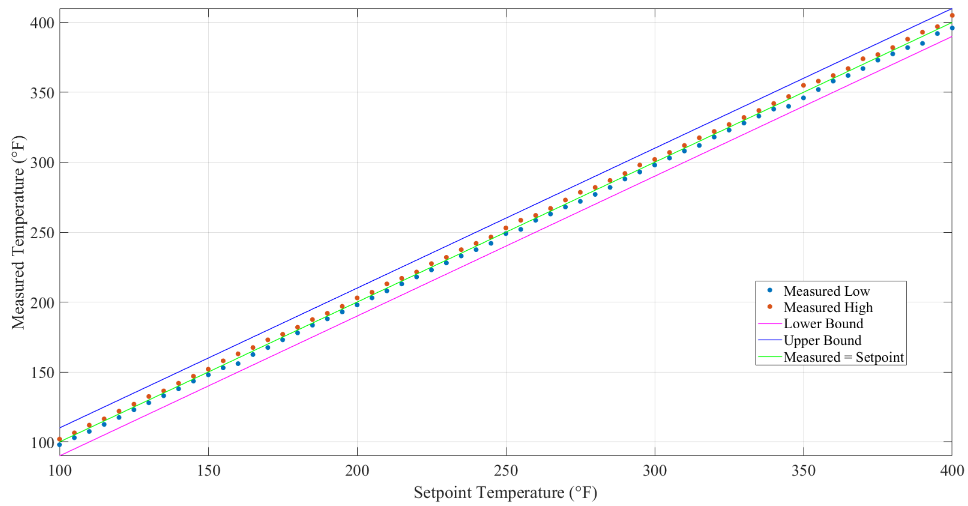

Figure 8: Minimum and maximum measured steady state temperature

As seen above in Figure 8, the Granny-Safe remains within specification throughout the range of temperatures. The measured temperatures are very close to the setpoint within the first 250 degrees. After that, there is more variance in the temperature, although the measured values are still well within spec. This variance can be explained in two ways. The first possible reason for the variance in the higher temperatures can be explained by the performance of the RTD. For this project is presumed that the resistance of the RTD functions linearly with temperature. However, the RTD is not completely linear for the higher temperatures, which can account for some fluctuation. The second possible explanation for the high end variance can be explained by the PID controller not being as precise when the temperature increases rapidly due to the properties of derivation and integration.

4.4 Triac Current Conditions

The contract stated that the project must be able to supply at least 5A of current at 120VAC to the hotplate. To prove that the project meets the specification, a Klein CL1000 multimeter was used. After several tests, the triac routinely provided 5.86A to the hotplate at max output.

5 Conclusion

In conclusion, the project was successful and met all specifications listed in the project contract. The design, testing, and results of the Granny-Safe were discussed. The complete project consisted of a PCB, keypad, LCD, RTD, and a hot plate. Various changes were made throughout the design process in order to meet specifications while still ensuring safety. Operating instructions are provided in Appendix E. The Granny-Safe provides a low cost and safe solution to maintaining the temperature of a hot plate. It excels due to its use of a triac to regulate power and its consistent alarm condition.

References

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[2] A.S. Sedra, K.C. Smith, Microelectronic Circuits, Oxford University Press, New York, New York, pp. 76-80, 2010.

[3] "SFH620A, SFH6206 Data Sheet" 2015 - Vishay Electronics. [Online]. Available:
http://www.vishay.com/docs/83675/sfh620a.pdf

Appendices

A Project Contract

Smart Stove Project "Granny-Safe"

Members
Josh Andrews, Electrical Engineering
Riley McKay, Electrical Engineering

Description
This device is designed to create a product which uses a temperature sensor to monitor and control a hot plate burner. The product will feature time and temperature settings, where the user will be able to control the temperature of the hot plate within ±10°F of a set temperature . Also featured would be a setting that turns the power to the burner off if the burner was left on for a set period of time. The device will also include the exclusion of relays, instead opting to use discrete components to control the hot plate burner. The project will also be comprised of a micro-controller and alarm circuitry. The main components will be powered by 5VDC, which will be obtained by utilizing an AC-DC and DC-DC converter from the wall outlet.

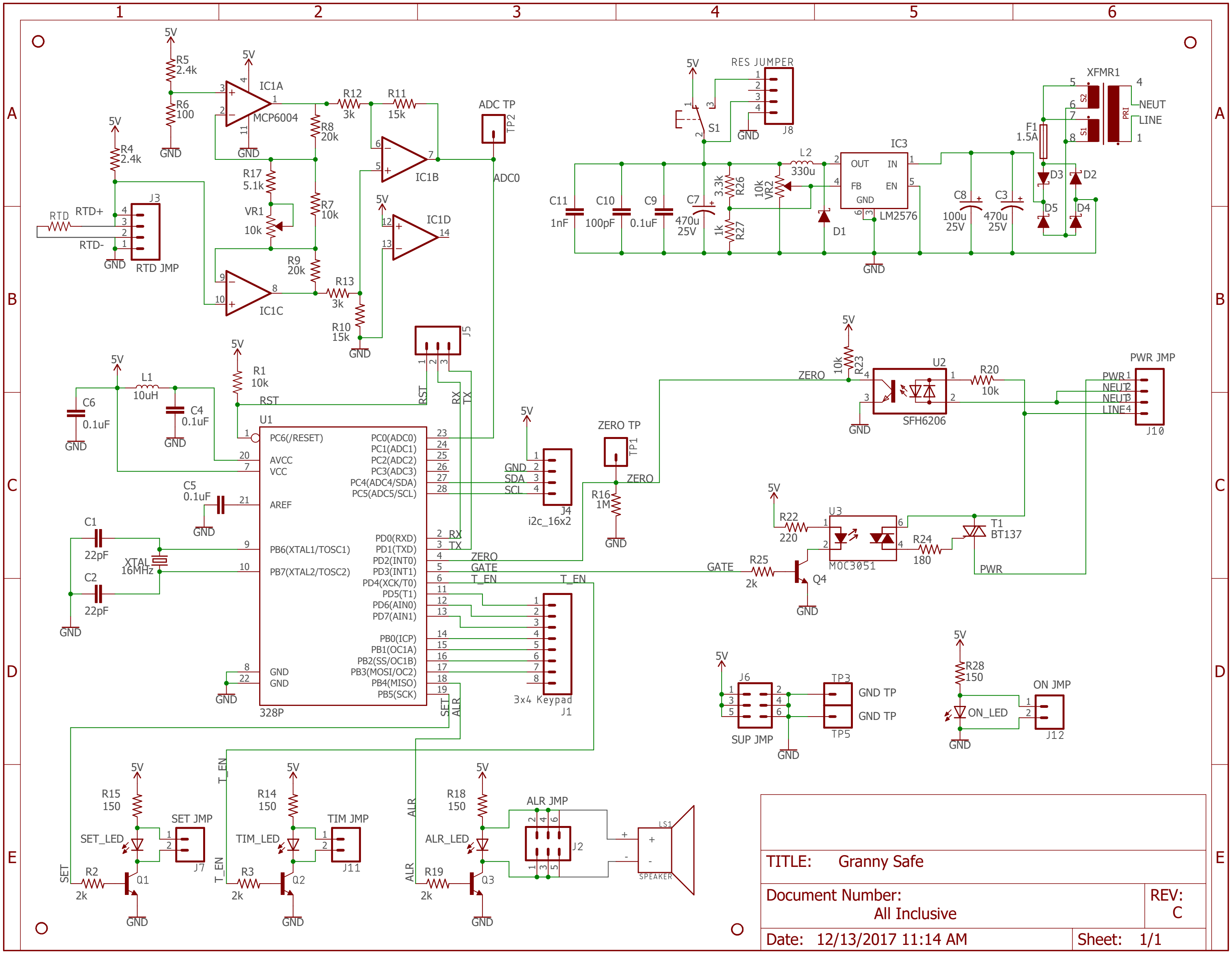
Inputs
- Temperature sensor data
- Temperature control knob/keypad
- DC voltage
- Pushbutton

Outputs
- LCD display
- Hotplate controller signal
- Alarm (speaker and LED)

Specifications
-DC to DC voltage converter 5V ± 5% with less than 100mV ripple supplying at least 500mA.
-No relays, 5V DC input controlling 120V AC and at least 5A.
-Alarm timer enabled when temperature exceeds 120°F, Alarm sounds after 10 minutes, and alarm deactivates if hotplate is turned off or reset if reset button pressed.
-Maintain hot plate temperature within ±10°F of set temperature between 150℉ and 400℉, measured in middle of second hotplate coil.

Name: ________________________ ________________________
Signature: ________________________ ________________________
Date: ________________________ ________________________

B Schematic



TITLE: Granny Safe
Document Number: All Inclusive
REV: C
Date: 12/13/2017 11:14 AM
Sheet: 1/1
U1
328P
PC6(/RESET)
AVCC
VCC
AREF
PB6(XTAL1/TOSC1)
PB7(XTAL2/TOSC2)
GND
PC0(ADC0)
PC1(ADC1)
PC2(ADC2)
PC3(ADC3)
PC4(ADC4/SDA)
PC5(ADC5/SCL)
PD0(RXD)
PD1(TXD)
PD2(INT0)
PD3(INT1)
PD4(XCK/T0)
PD5(T1)
PD6(AIN0)
PD7(AIN1)
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PB1(OC1A)
PB2(SS/OC1B)
PB3(MOSI/OC2)
PB4(MISO)
PB5(SCK)
IC1A
MCP6004
IC1B
IC1C
IC1D
ADC TP
ADC0
RTD JMP
RTD
RTD+
RTD-
XTAL
16MHz
i2c_16x2
3x4 Keypad
ZERO TP
RES JUMPER
IC3
LM2576
OUT
IN
FB
EN
GND
XFMR1
NEUT
LINE
F1
1.5A
U2
SFH6206
PWR JMP
U3
MOC3051
T1
BT137
SUP JMP
GND TP
ON JMP
ON_LED
SET JMP
SET_LED
TIM JMP
TIM_LED
ALR JMP
ALR_LED
SPEAKER

C Parts List

Part	Vendor	Quantity	Part Number	Description	Price	Extended
Alarm Speaker	DigiKey	1	102-1554-ND	SPEAKER 8OHM 100MW TOP PORT 89DB	$3.14	$3.14
Temperatre Sensor	DigiKey	1	1528-2090-ND	PLATINUM RTD SENSOR - PT100 - 3	$11.95	$11.95
Transformer	DigiKey	1	595-1180-ND	XFRMR LAMINATED 20VA THRU HOLE	$11.99	$11.99
Currernt Limiting Fuse	DigiKey	10	507-1849-1-ND	FUSE 2A 350V RADIAL	$0.32	$3.15
Clock Crystal	DigiKey	6	X1104-ND	CRYSTAL 16.000312MHZ 18PF T/H	$0.69	$4.14
Zero Sensing	DigiKey	3	MOC3051M-ND	OPTOISOLATOR 4.17KV TRIAC 6DIP	$1.07	$3.21
Zero Sensing Surface	DigiKey	3	MOC3051SR2MCT	OPTOISOLATOR 4.17KV TRIAC 6SMD	$1.35	$4.05
Triac	DigiKey	5	1740-1028-ND	TRIAC SENS GATE 600V 8A TO220AB	$0.66	$3.30
Triac Surface	DigiKey	5	1740-1034-1-ND	TRIAC SENS GATE 600V 8A DPAK	$0.68	$3.40
Buck Chip	DigiKey	5	576-1045-ND	IC REG BUCK ADJ 3A TO220-5	$1.88	$9.40
Buck Chip Surface	DigiKey	2	576-1539-1-ND	IC REG BUCK ADJ 3A TO263-5	$1.96	$3.92
Opto Isolator	DigiKey	5	SFH620A-3-ND	OPTOISOLATOR 5.3KV TRANS 4-DIP	$0.92	$4.60
Op Amp	DigiKey	10	MCP6004-I/SL-ND	IC OPAMP GP 1MHZ RRO 14SOIC	$0.46	$4.60
Resistor	DigiKey	20	311-100HRCT-ND	RES SMD 100 OHM 1% 1/10W 0603	$0.02	$0.30
Terminal Connector	DigiKey	5	732-10955-ND	TERM BLOCK 2POS SIDE ENTRY 5MM	$0.38	$1.90
Slotted Terminal Connector	DigiKey	20	36-1040-ND	TERM TEST POINT SLOTTED .118"	$0.18	$3.60
Surface Mount Inductor	DigiKey	10	535-11587-1-ND	FIXED IND 10UH 3MA 2.55 OHM SMD	$0.10	$0.96
Capacitor	DigiKey	25	311-1088-1-ND	CAP CER 0.1UF 16V X7R 0603	$0.02	$0.53
Capacitor	DigiKey	10	1276-2096-1-ND	CAP CER 0.056UF 50V X7R 0603	$0.08	$0.79
Capacitor	DigiKey	10	490-6421-1-ND	CAP CER 0.56UF 10V X7R 0603	$0.15	$1.47
Diode Surface Mount	DigiKey	10	1655-1360-1-ND	DIODE GEN PURP 75V 250MA SOD123	$0.13	$1.25
Diode Through hole	DigiKey	10	SR306-TPMSCT-N	Diode Schottky 60V 3A Through Hole DO-201AD	$0.42	$4.20
Buck Chip surface mount	DigiKey	2	296-46303-1-ND	IC REG BUCK ADJ 2A SYNC 16HTSSOP	$4.30	$8.60
Inductor	DigiKey	2	732-7149-ND	FIXED IND 10UH 4.6A 23 MOHM TH	$1.87	$3.74
Schottky Diode Surface Mount	DigiKey	10	SK36A-LTPMSCT-	Diode Schottky 60V 3A Surface Mount DO-214AC (SMA)	$0.60	$6.00
Surface Mount Inductor	DigiKey	5	SRR1280-331K	FIXED IND 330UH 1.1A 600 MOHM	$1.06	$5.30
Power Resistor	DigiKey	2	SQP10AJB-9R1	RES 9.1 OHM 10W 5% AXIAL	$0.64	$1.28
Capacitor Through Hole	DigiKey	10	25YXJ220M6.3X1	CAP ALUM 220UF 20% 25V RADIAL	$0.19	$1.93
Potentiometer Surface Mount	DigiKey	10	TC33X-2-103E	TRIMMER 10K OHM 0.1W SMD	$0.12	$1.20
Potentiometer Through Hole	DigiKey	10	1-1623849-0	TRIMMER 10K OHM 0.5W TH	$0.27	$2.70
Ceramic Capacitors	DigiKey	20	MR045A682EAA	Various capacitors for buck converter	$0.03	$0.67
Atmel ATmega328p	DigiKey	1	ATMEGA328PB-A	Microcontroller	$1.38	$1.38
LCD Display	DigiKey	1	NHD-12232KZ-N	Information display	$12.50	$12.50
Solid State Relay	DigiKey	1	CLA233CT-ND	Test purposes only	$1.20	$1.20
Triac	DigiKey	1	F7290-ND	Hotplate controller component	$3.13	$3.13
Arduino Uno R3	In possession	1	\\\	Used to program microcontroller	$3.95	$3.95
Hot Plate	In possession	1	\\\	Main Part	$12.95	$12.95
Temperature Sensor	In possession	1	\\\	Temperature sensor	$4.99	$4.99
PCB Board	In possession	1	\\\	Implementing project	$1.20	$1.20
Keypad	In possession	1	\\\	User interface	$4.59	$4.59

D Operating Instructions

To operate device

1.) Ensure the RTD is attached to hot plate and both are plugged into device.

2.) Plug device into 120V wall outlet, the blue LED should illuminate.

3.) Enter a setpoint temperature between 100°F and 400°F and press button to enter. The green LED should illuminate.

4.) When temperature exceeds 120°F, the yellow LED will illuminate, indicating the alarm timer is activated.

5.) After ten minutes the alarm with activate. To reset the timer and silence the alarm, press the * button.

7.) If the alarm is not reset within one minute, the hot plate will turn off, the setpoint will clear, and the screen will display ”ALARM”.