UNIVERSITY OF MAINE

ECE 403 DESIGN REPORT

Granny-Safe

A Smart Stove Top

Joshua Andrews, Electrical and Computer Engineer

Riley McKay, Electrical Engineer

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Abstract

Mention user input?

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 $\pm 5\%$ 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 $\pm 10°$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.

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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 removed 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 are expensive and use motion sensors in the alarm process which can be unreliable. Granny-Safe was 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.

disconnected?

Can you point to a specific brand?

Good. Design features.

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.

Again, should you mention user input?

After the introduction of the project, the Granny-Safe will be 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.

Good.

What a beautiful block diagram!

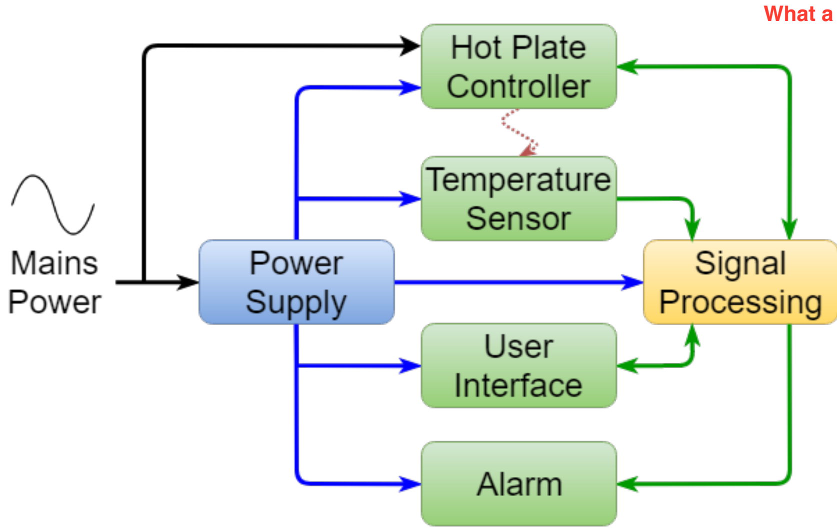

Figure 1: Functional block diagram of the Granny-Safe

As Figure 1 shows, the Granny-Safe is powered by mains power (black arrows). The power supply then steps down the mains power to a level usable by the rest of the circuit (blue arrows). The temperature of a hot plate is measured by the temperature sensor and then a data signal (green arrows) is sent to signal processing. The user interface allows the user to view the temperature and enter a desired set-point temperature. When a set-point is entered it is processed and a control signal is sent to the hot plate controller. The hot plate controller regulates the power delivered to the hot

Would it make sense to say exceeded rather than met?

plate in order to maintain the desired temperature. When certain conditions are met 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 shut off power to a hot plate.

2.1 Power Supply

Wording.

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

2.2 Temperature Sensor

Maybe spell out first time?

The temperature sensor uses an 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

You can introduce the brand and model.

The signal processing for Granny-Safe is provided by a 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 PID contoller, regulates the signal sent to the hot plate controller to then regulate the temperature of the hot plate.

Spell out PID?

Sentence needs reworking.

2.4 Hot Plate Controller

The purpose of the hot plate controller is to . . . .

The hot plate controller uses connections from the 5V power supply, 120 VAC main, and microprocessor. 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.

Something missing?

allows the user to enter a set-point which is then displayed above the actual temperature on the LCD screen. After ten minutes of being activated, the keypad can be used to reset the automatic shut off time.

2.6 Alarm

You might begin with an overview of function.

The alarm circuitry features an audio alarm and a series of LEDs to serve as safety features for the Granny Safe project. Both the audio and visual alarms take inputs from the microcontroller. The project features three LEDs; a green, yellow, and red. The green LED turns on when a setpoint is entered. The yellow is when the hot plate temperature exceeds 120 degrees. The red LED, as well as the audio alarm, are enabled when the ten minute timer expires.

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 hardware and software are discussed, with each of the two sections 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.

YOu might forecast subsections

3.1 Power Supply

The purpose of the power supply is to. . . . It consists of. . . . . The design goal. . . .

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

Show schematic?

designed?

A bridge rectifier was used to convert AC power into usable DC power. 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.

The power supply needed to do x. Considerations to meet this requirement included. . . . A Buck converter configuration was chosen because. . . . . The purpose of the buck converter is to xxxx.

3.1.2 Buck Converter

Do they lower voltage?

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 1 shows. . . .

A buck converter works as follows.

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 .

Equation $_{dutycycle}$.

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 .

Equation$_{inductor}$

For the capacitor values, the LM2576 datasheet recommended 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 470uH.

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 .

Equation .

The expected values were used, but the circuit proved to be extremely sensitive. To combat this, a 10K pot was used as a resistor ladder. The 10k 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

Purpose/design goal?

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. The voltage drop across the RTD and 100 resistor is sent to an instrumentation amplifier. 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 bridges are detailed below.

3.2.1 Wheatstone Bridge

The wheatstone bridge acts as a simple two-part voltage divider, which serve as the inputs to the instrumentation amplifier. At zero degeees Fahrenheit, the resistance of the RTD is 100Ω. As the temperature increases, the thermal properties of the RTD cause the resistance to increase at a relatively linear rate. The platinum RTD was chosen because of its linearity in the range specific to this application; ie 150°F to 400°F. When the resistance of the RTD increases, the voltages between the two output nodes varies.

3.2.2 Instrumentation Amplifier

The instrumentation amplifier

3.3 Signal Processing

The microcontroller the Granny-Safe is the ATMEGA328P-PU. Arduino uses this microcontroller in the Arduino Uno R3 which made programming the Granny-Safe easier.

3.3.1 Microcontroller

3.3.2 PID Controller

3.4 Hot Plate Controller

3.4.1 Hot Plate

3.4.2 Zero-Sensing and Triac Control

The power, and thus the temperature, to the hot plate needed to be regulated so that. . . . The circuit designed to control the temperature includes . . . . .

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 360kΩ 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.

3.5 User Interface and Alarm Activation

There are both audio and visual alarms used as safety features for the Granny-Safe hot plate

4 Results

4.1 Power Supply

4.2 Temperature Sensor

4.3 Temperature Control

4.4 Triac Current Conditions

5 Conclusion

References

A Project Contract

B Schematics

C Parts List

D Datasheets

E Operating Instructions