ENSE 481 – Winter 2025
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Final Report

Project Description:

When burnination has forsaken the nation, my money is on one controller. This project is a controller for a hot plate that precisely manages the power delivered to achieve and maintain a user-specified temperature. The system leverages feedback from a temperature sensor and incorporates a user interface with a display and buttons. The software runs on an STM32 Nucleo board. The primary objective is to quickly reach the desired temperature while minimizing overshoot, and then maintain that temperature even when disturbances occur such as cooking food. The controller utilizes a single artificial neuron with a sigma function activation which is about as many neurons as engineering students have left after final exams.

Control Strategy:

The system is designed with a focus on high-performance temperature control. The design employs a artificial neural controller that uses a sigmoid activation function to compute the heater duty cycle.

Feedback Mechanism:

A thermocouple sensor provides the real-time temperature feedback essential for the control loop. This feedback is used to calculate the error between the target temperature and the current temperature, thereby adjusting the input to the neuron and thus output power delivered by the solid-state relay.

Controller Board:

The controller is based on the venerable STM32F103RB Nucleo board, which handles sensors, inputs, control algorithms, and output signalling.

User Interface:

The user interface comprises input buttons for setting the target temperature and an e-paper display to show real-time information such as current temperature, target temperature, duty, chip voltage, chip temperature and system uptime.

Power and Safety:

The power control to the hot plate is achieved using a solid-state relay, which ensures swift power changes and durability. The relay optically isolates the high-voltage from the low-voltage. The high-voltage outlet, box, and wiring are all CSA-approved. Notably the low-voltage wiring has 1000V rated insulation to safely integrate with the relay in the box. Wires are clamped or secured with a rubber grommet. If a control wire breaks then it will fail-safe.

Testing:
The testing has been very successful. I fried some eggs while keeping below the smoke point of butter.

Buttons: the left button lowers the target by 10C and the right button increases the target by 10C. The hardware debouncing seems to be tuned just perfect (1k/1uf) and it is using the internal pullups (47k).

Thermocouple: referenced with with an infrared sensor and camera, it is accurate to within a degree. The big aluminum plate is a bad idea because it takes a long time to change temperature and is awkward to work with. A better idea would be to mount into a small aluminum block underneath the burner.

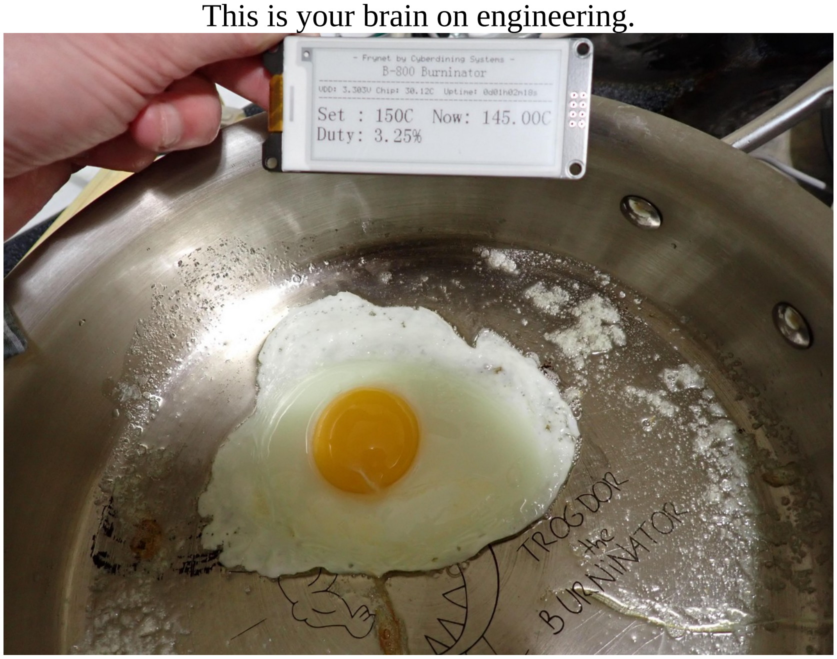
Display: the e-paper looks amazing but does have a slow ~0.5s delay. Note: did not test in the dark, don’t cook in the dark for obvious reasons.

Relay: varying duty is working perfectly and was verified with oscilloscope and display.

Microcontroller: I tried implementing sleep mode and it actually increased the power usage slightly?! It must be because it is very active and doesn’t have much time to sleep and there is overhead to enter and exit sleep mode. I also tested the watchdog timer at a lower value and it works to reset. The neuron works better in certain ranges depending on the fine-tuning. I could use different profiles or design a more complex neural network in the future.

Console: the console interface is working well. There was race conditions before when jumping around in the status window and other print operations would bump in. It was fixed with a semaphore. All the commands are working as expected and status reporting correctly.

This is your brain on engineering.



Block Diagram: