

Team ST²

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Biomedical Engineering 400

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Abstract

To help diagnose neurological disorders, a portable thermal probe is needed to determine if a patient has a loss of temperature sensation in a specific area of the body. The probe itself is an aluminum surface that is heated with a resistive heating element to desired target temperatures. A microprocessor-based system controls heating of the probe surface. The physician will place the probe on the patient's skin, depress a button to begin testing, and an LED will signal when five seconds has elapsed. Safety is a primary concern; the device indicates circuit failure or abnormal operation by a flashing red LED. Ultimately, the device will attach to the Welch Allyn ophthalmoscope/otoscope handle which is already widely used in medical examining rooms. The first generation prototype, however, is powered by a 5V AC/DC converter that plugs into a wall outlet.

Problem Definition

Doctors are now finding it necessary to test for neurological damage in patients who experience pain or numbness with warm/heat sensitivity. Currently, there is no portable device that a physician can use to apply hot sensation to a patient's skin. Physicians investigating sensory loss could use a device that heats up to warm and hot target temperatures of 38°C and 45°C respectively as a prescreening process before a more rigorous quantitative sensory test is performed. This device should be convenient to use and safe to apply to patients.

Motivation Why Design such a Device?

- The need for a quick and easy-to-use method to preliminarily test for neuropathic disorders.
- Pre-screening to possibly avoid more complete and rigorous Quantitative Sensory Testing; saves the patient and clinician valuable time.
- A device that will be compatible with existing medical equipment (Welch Allyn power handle), thus reducing total cost for the client.
- A portable device can be moved between exam rooms or carried by a physician very easily.
- A safe, easy-to-use testing device that requires little training and will not cause any harm to the patient or the user.

Background

The peripheral nerves innervate the skin of the body allowing the skin to transmit stimuli along these nerves to the brain. The conscious perception of these stimuli is called sensation.

"Neurologists need to judge severity of neuropathy in order to:

- Ascertain the degree of neurological impairment.
- Decide on how comprehensive an evaluation for underlying cause is justified.
- Come to a conclusion about whether therapy should be begun, altered, or stopped.
- Make inferences about outlook
- Decide whether a given therapy is efficacious."

Peter J. Dyck, MD, Mayo Clinic, Rochester, Minn.

Quantitative Sensory Testing

Method used to assess degree of neurological disorder

- Uses hot, cold, and vibration stimuli to determine sensitivity thresholds
- Performed on different areas of the skin—six times at each location for each stimulus
 - Temperature never exceeds 50°C
 - Tests take 1-3 hours

Current devices are bulky and inconvenient to use!

Product Design Specifications

Client Requirements

The product should:

- Be safe and not burn patients; i.e. the temperature must never rise above 50°C
- Heat up to target temperatures of 38°C and 45°C (within 1°C) relatively quickly
- Maintain the target temperature through several successive tests on the same patient
- Have a probe surface with an area of 4.0 cm²
- Indicate when the probe surface has reached the target temperature
- Indicate when the probe has been applied to a patient's skin for five seconds

- Be convenient to use and easy to clean with alcohol and/or soap and water
- Attach to a Welch Allyn ophthalmoscope/otoscope handle or some other common clinical-setting power source.

Design Requirements

Performance: The device should be able to be used to test a maximum 10 patients on a single charge, each including up to 3-4 minutes of testing at 38°C and 3-4 minutes of testing at 45°C.

Safety: The probe temperature must not exceed 50°C in any event (including user abuse and circuit element failure).

A five-second timer should be used to alert physician to remove device from patient's skin.

Operating Environment: The device will be used under normal indoor hospital/clinical conditions (20-25°C, 1 atm pressure, less than 60% relative humidity, and very little dust) by trained physicians.

The probe will primarily be used on a patient's hands and feet. The skin may possibly be moist.

Ergonomics: Size of probe should allow for full contact to the skin of the various areas of the body tested.
Placement of operator controls should not cause undue strain in the hand, wrist, or fingers.

For more information see the ST² web site at:

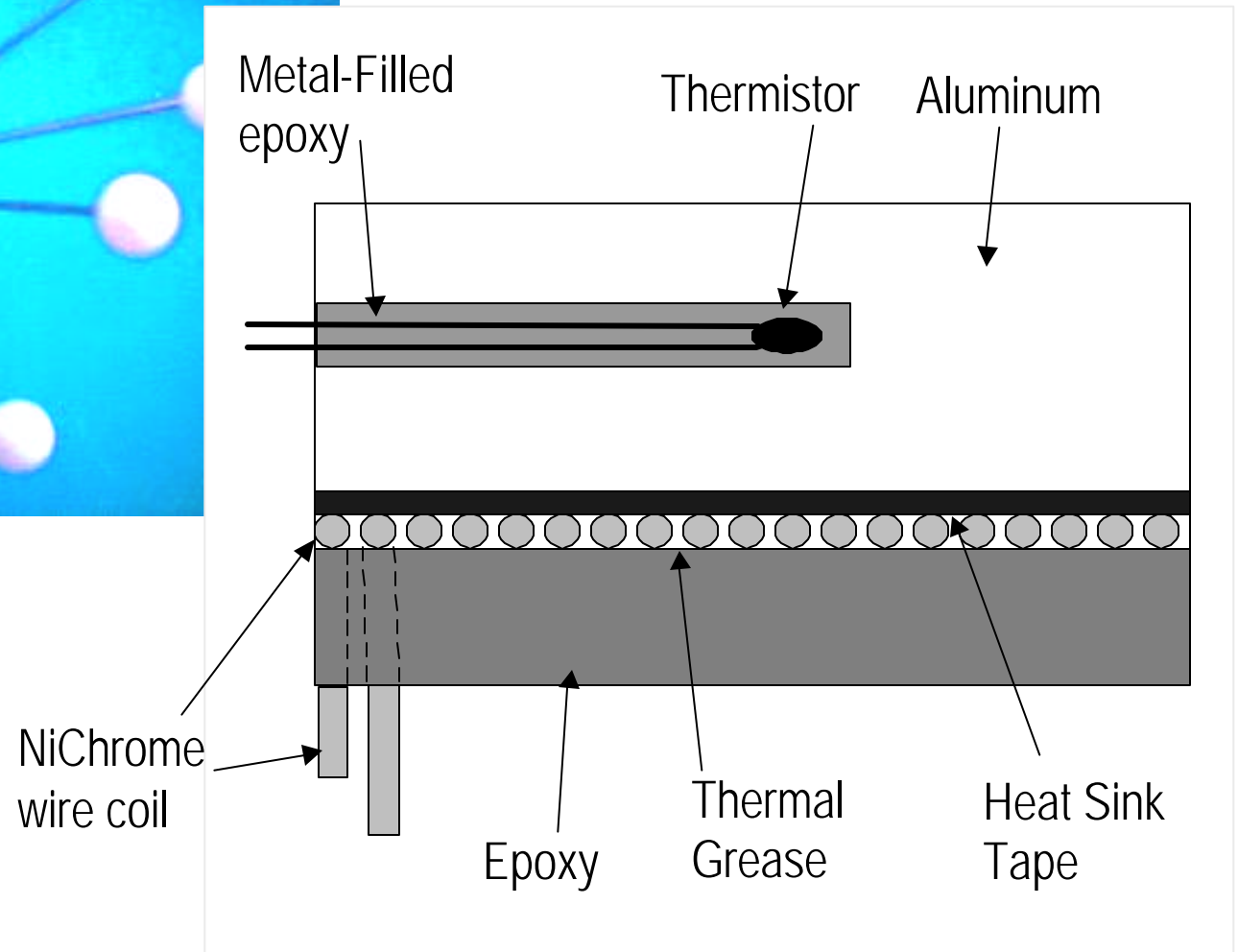
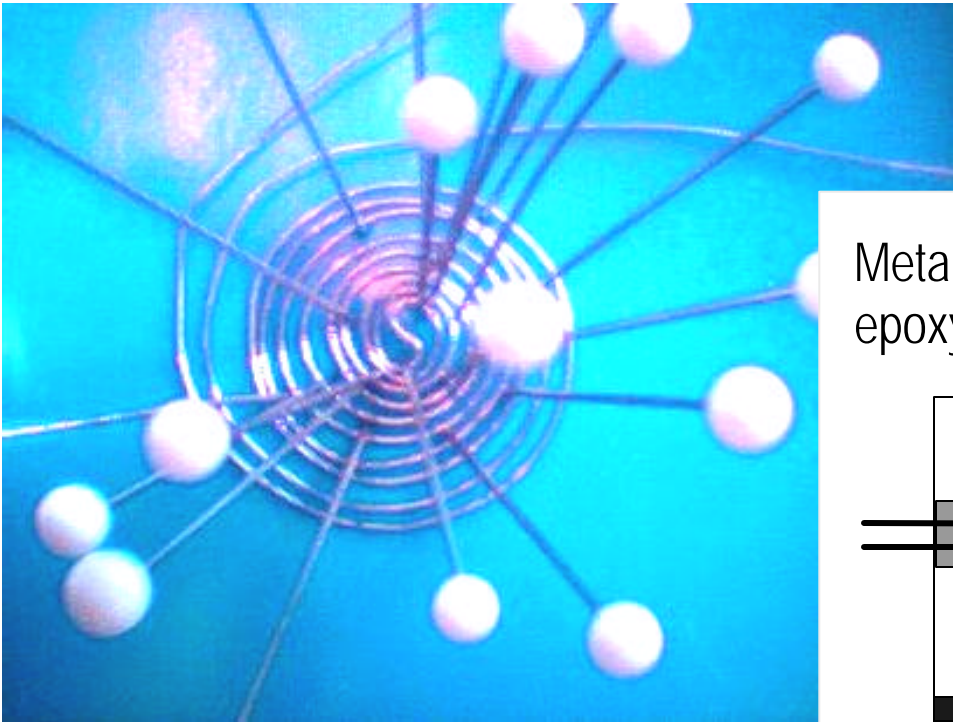
<http://www.cae.wisc.edu/~thermpro/>

Heating Element

The complete probe assembly consists of:

- The wire coil, a resistive heating element
- Heat sink compound to maximize heat transfer to probe surface
- Thermally conductive tape to couple the heating element the surface that requires heating, and electrically isolate the coil
- The aluminum "probe head", which is warmed to a desired temperature and is the point of application of the probe
- A thermistor that measures the temperature of the aluminum
- Clear epoxy layer to seal and insulate the heating element

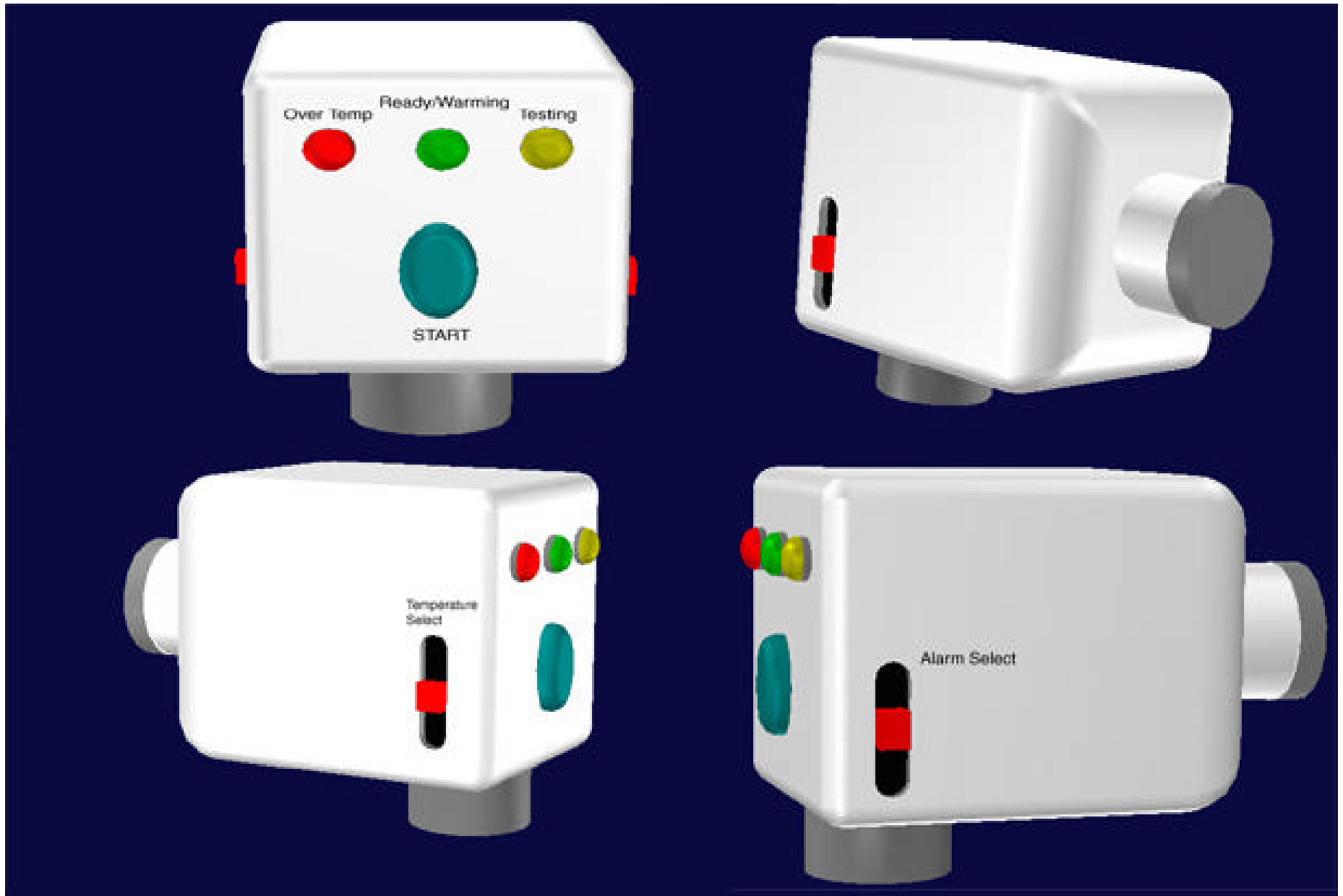
Heating Element



Welch Allyn Handle



Concept of Final Design



Circuitry

The circuit consists of analog and digital circuitry to perform temperature control of the probe surface. The analog section performs temperature measurement and prepares a voltage equivalent to temperature for being digitally processed. The digital section makes an analog-to-digital conversion and determines the probe heating and user outputs based on the temperature level and the user inputs.

Analog Circuitry

- Thermistor whose resistance decreases exponentially with temperature
- Wheatstone Bridge containing thermistor provides differential input to...

- Op amp with feedback resistor has a linear output with temperature
- Low-Pass filter to cancel high-frequency noise and to prevent aliasing of that noise when sampled at 20 Hz by the analog-to-digital converter (ADC)

Digital Circuitry

- Serial 8-Bit ADC reads voltage equivalent to temperature is read by...
- Basic STAMP II microcontroller which has:
 - EEPROM to store program, programmable thru PC serial port
 - 16 programmable I/O pins
 - Internal 5.0 V regulator supplying up to 50 mA to STAMP II and the other control circuitry
- LEDs to alert user to state of the device
 - Green to tell normal operation

- Red to tell too hot or that an error has occurred
- Yellow to tell that 5 s timer has expired
- Switches allowing user input
 - Temperature selection: 38 or 45°C
 - Timer start, held down while performing a test
 - Sound on timer-end enable switch
 - Reset switch, to allow operation after an error has been reported (hard to reach)
- N-channel MOSFET as switch to allow power to reach heating element

Program

- Checks for abnormal modes of operation
 - Temperature changing too quickly
 - Temperature not rising upon startup
 - Reset button being depressed upon startup
- Maintains probe temperature
- Notifies user of thermal probe status
- Alerts the user after 5 seconds of skin contact time
- Shuts the device down after 5 minutes of inactivity

Future Work

Future developments include both short-term and long-term goals. The plans for the coming weeks and months are outlined below, listing the major obstacles in the progression of our design. Many of our short-term goals may be realized soon. We have the necessary parts, just not enough time to put everything together before the semester is over. Once these short-term goals are reached, we can begin work on our long-term future plans.

Short-term Goals

- Implement new parts into analog circuit, including the 5V regulator and terminal block to connect the NiCr wire of the probe to the circuit.

- Implement new switches and LED's to the digital circuit for additional user interface.
- Test the printed circuit board (PCB) to make sure the program and the circuitry still work correctly.
- Place the PCB, switches, LED's, and the actual probe into a project box for a more complete and compact prototype.

Long-Term Goals

- Continue testing the program to make sure it detects all possible failures in the circuit.
- Begin and finish the process for the Human Subjects Protocol so we can test our project box prototype on human subjects.
- Test the project box prototype on actual human subject.
- Revise project box prototype design according to client's recommendations after actually using the device. This may

include revising the actual probe construction, control algorithm, user notification, and circuitry.

- Test the revised prototype using the actual Welch Allyn battery to make sure it can completely power the device for the needed amount of time.
- Construct a new prototype to fit the Welch Allyn handle. This would entail making the components more compact and constructing a connection piece that would connect the actual thermal probe head to the handle.

References

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