PID-Controlled Hypothermia Blanket

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Introduction & Clinical Need

- Hypothermia - kills twice as many as heat in United States [1]
  - Mild = 32-35℃
  - Moderate = 28-32℃
  - Severe = below 28℃
- Body temperature set point = 37 ± 0.5℃
- Rewarming should be started ASAP, before emergency room arrival
- Active external rewarming (AER) approaches are used for all severities
- **PID blanket to monitor and control 2℃/hour rewarming rate [2]**

Existing Blankets

- Passive external rewarming (PER) blankets rely on remaining body heat [3]
  - Not helpful in moderate to severe cases
- AER techniques often employed only in hospital
  - Require equipment and can block other treatment [3]
- Used during time to emergency room
  - Longer trips in cold or rural areas would benefit from AER
- Have to recheck state of patient every 15 minutes
  - PID-controlled AER continuously checks state of patient

Typical PER blanket [4].

Design Constraints - Ideal

- Desired material properties:
  - Heat conductible to transfer heat throughout entire blanket
  - Heat reflective surface to reduce heat loss caused by thermal radiation
  - Flexible, able to be wrapped airtight around a patient to prevent heat loss caused by evaporation and convection
- Storage concerns:
  - Blanket, PID, and power supply (battery) should be able to be compacted into most first aid kits

Design Constraints - Ideal

- Usability
  - User friendly interface so anyone can set up device and insert desired temperature to perform first aid
  - Reusable aside from replacing power supply
- Safety and other guidelines
  - Electrical components insulated to prevent micro and macroshock
  - All first aid kits require clear labeling in all materials stored within

Specifications

- Desired weight and dimensions [5]
  - Size: minimum 34" x 48” to fit all body sizes
  - Weight: ideally less than 1.5 lbs
- Other performance aspects
  - 2℃/hour warming rate
  - Oscillation amplitude no greater than 0.5℃ from set temperature (37℃)
  - Low steady state error (within 0.5℃) so set temperature accurately reached [6]
  - Accurately responds to patient’s current temperature

Current Prototype

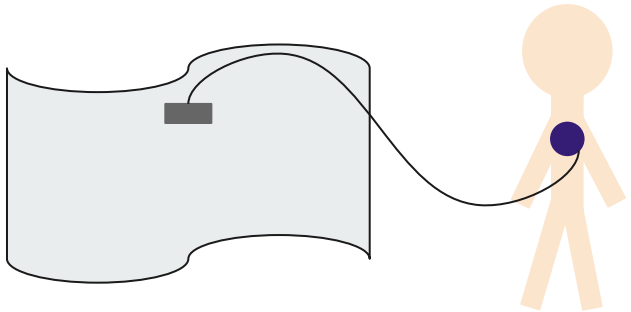
Proposed Design

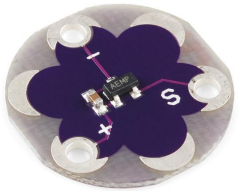
Heating Resistor → Electric Blanket System

Thermistor → Temperature Sensor on Body

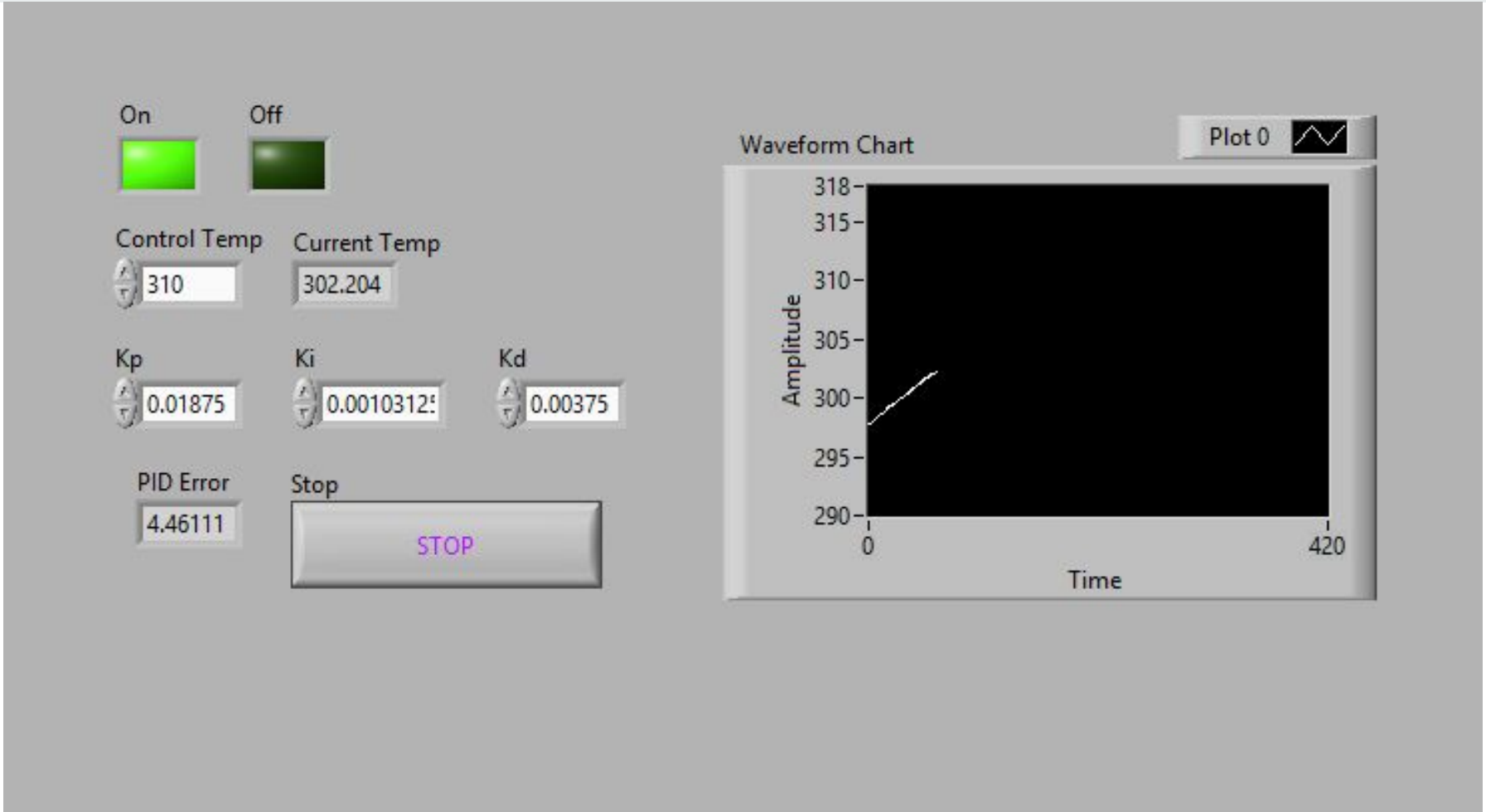
PID tuned to 2℃/min → PID tuned to 2℃/hour

Power Source → Battery Powered





LilyPad temperature sensor [7].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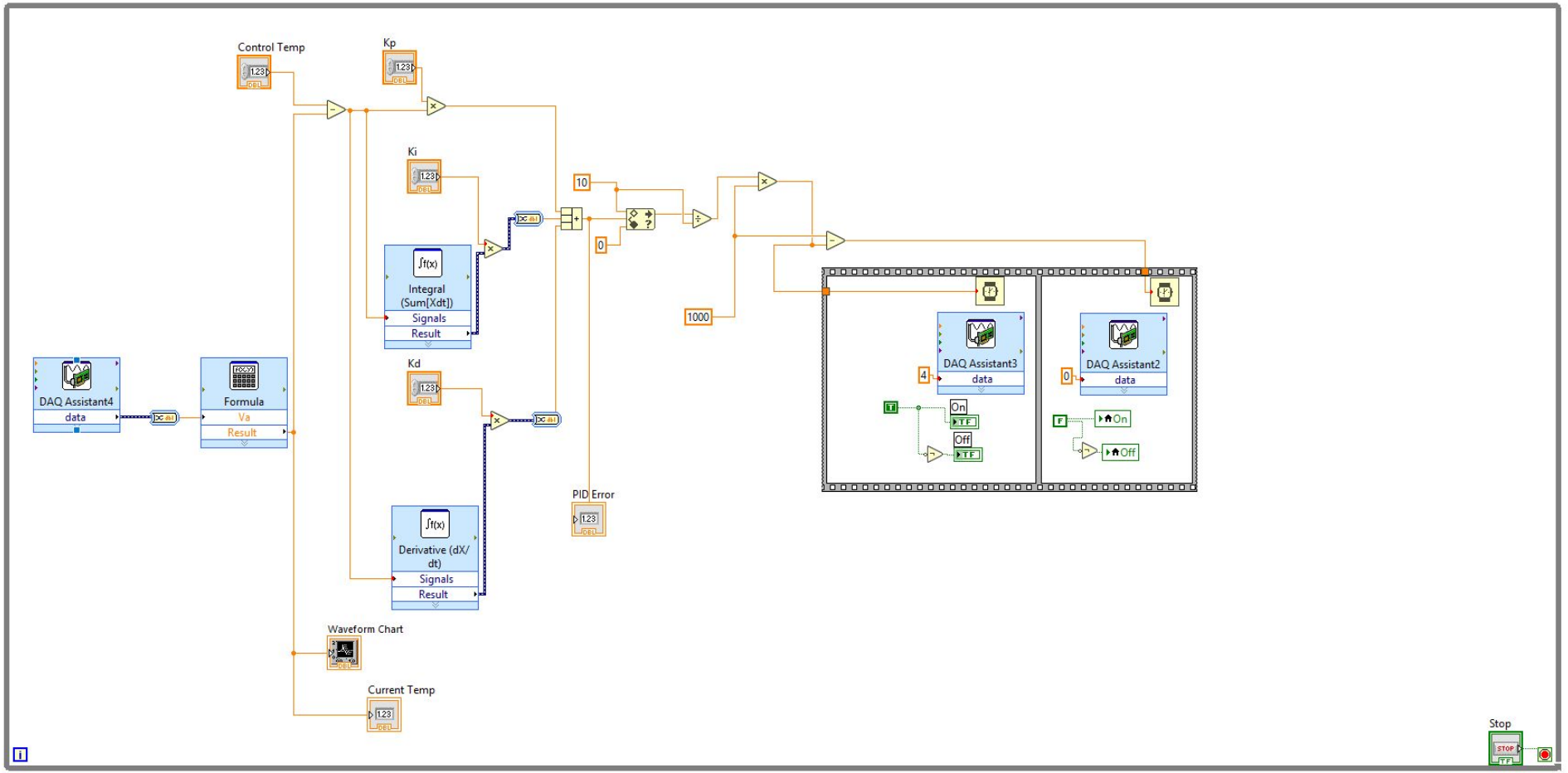
Off
Control Temp
310
Current Temp
302.204
Kp
0.01875
Ki
0.0010312
Kd
0.00375
PID Error
4.46111
Stop
STOP
Waveform Chart
Plot 0
318
315
310
305
300
295
290
Amplitude
0
420
Time

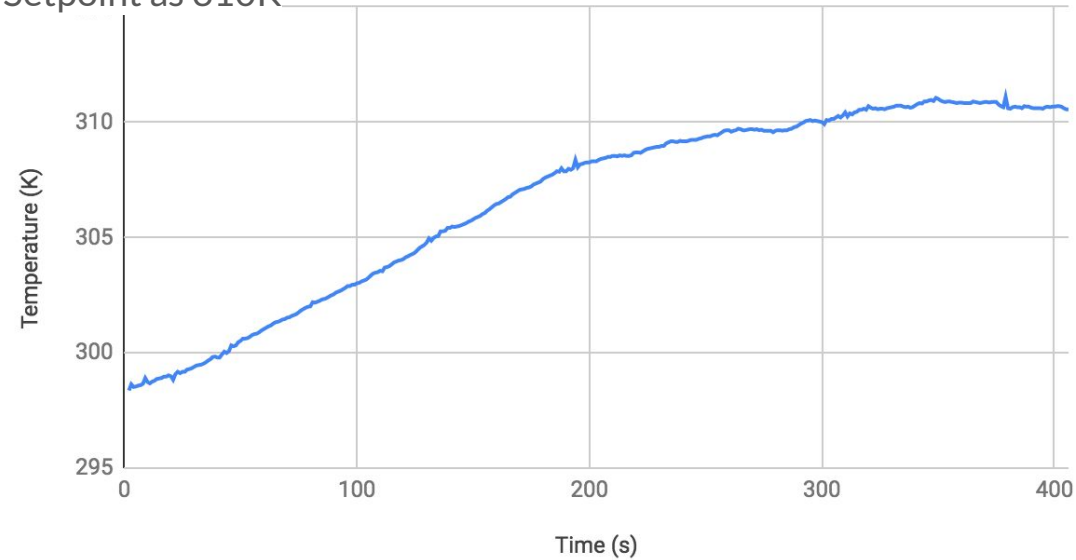

Control Temp
Kp
Ki
Kd
10
0
1000
Integral (Sum[Xdt])
Signals
Result
Derivative (dX/dt)
Signals
Result
DAQ Assistant4
data
Formula
Va
Result
PID Error
Waveform Chart
Current Temp
DAQ Assistant3
data
DAQ Assistant2
data
4
0
On
Off
Stop

PID Tuning

Kp	Ki	Kd	Behavior	Tset (K)	Ti (K)	Tf (K)	Time (s)	Rate (K/min)
0.1	0.001	1	Steady increase, rate too quick	297	276.7	285	66	7.55
0.05	0.0005	0.01	2K/min at first, then decays	310	298.7	306.6	293	1.61
0.05	0.003	0.007	Increase Ki reduce steady state error, see if overshoot okay with lower Kd	310	300.1	311.5	n/a	n/a
0.01875	0.00103125	0.00375	Intermediate Ki, lowered all equally	310	298.6	310.9	406	1.98

Final PID Control

Thermistor Temperature Over Time with Setpoint as 310K



	Temperature (K)	Rate (K/min)
Whole	298.6-310.9 (77.81-99.95 F)	1.98
Q1	298.6-303.1	2.837
Q2	303.1-308.3	3.126
Q3	308.3-310.1	1.061
Q4	310.1-310.9	Overshoot

Conclusions and Future Work

- Conclusions
  - Demonstrated proof of concept for hypothermia blanket
  - Gained understanding in PID controllers and LabView development
- Future work
  - Implement PID controller with corresponding specifications on blanket
  - Integrate body temperature sensor into device
  - Compact and mobilize device with battery as power supply

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References

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