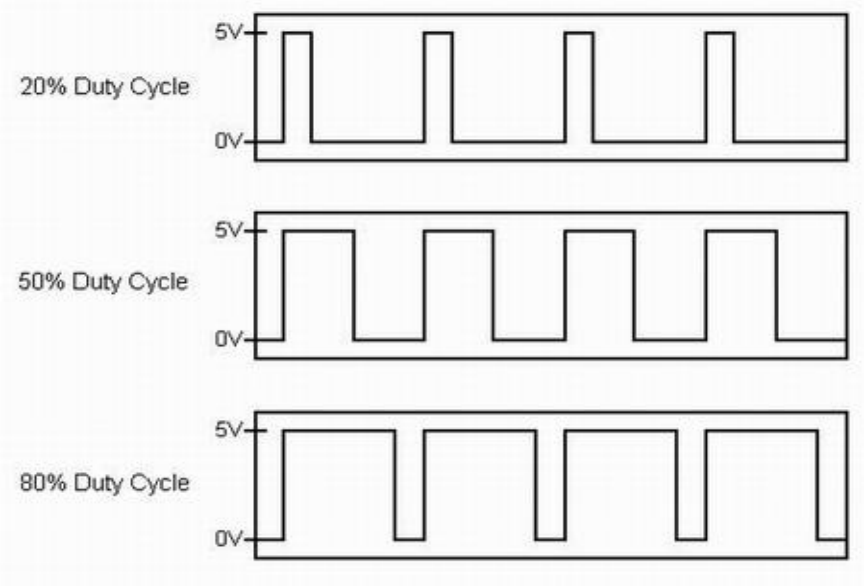
PID Temperature Controller

Arduino

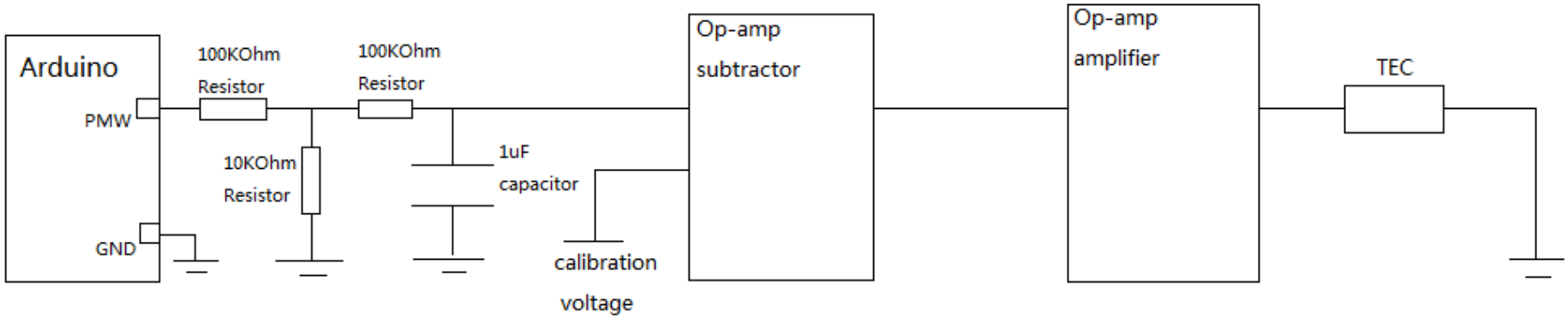
- Measures temperature using thermistor
- Controls power going to heating/cooling unit (Thermo-electric cooler, TEC)
- Only variable output from Arduino is PWM signal



- Duty cycle is controllable:
  - PWM:(0, 255) ⟶ Duty Cycle: (0,100)

Circuit

- Converts Arduino's PWM output to a DC-voltage with a positive and negative range



PID Algorithm

- Continuous:
  - $PWM = P * error + I * \int_0^t error\ dt + D * \frac{d\ error}{dt}$
- Discrete:
  - $PWM = P * error + I * \sum error * \Delta t + D * \frac{\Delta error}{\Delta t}$

- Improvements:
  - Handles integral windup
  - Handles on-the-fly parameter changes (I term)
  - Handles derivative-kick

Control Flow

↓ Arduino measures temperature from thermistor

↓ PID algorithm determines PWM output value

↓PWM signal converted to DC-voltage signal

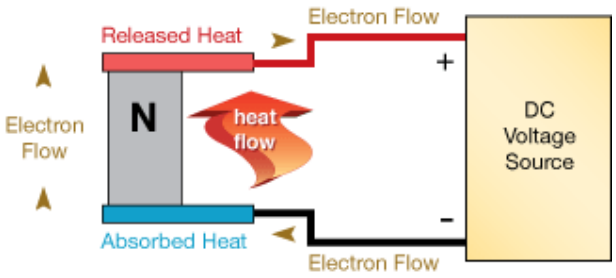
↓DC-voltage signal used to power TEC

Practical Issues

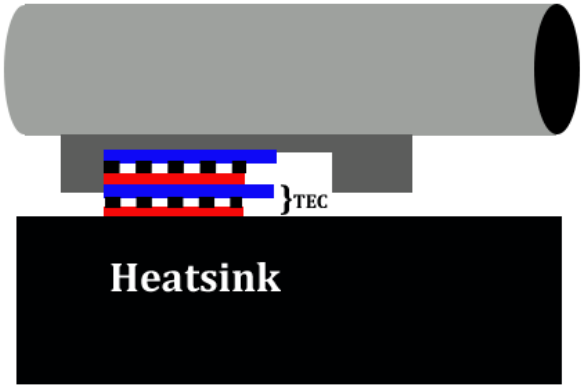
- Power provided to TEC is not exactly symmetric with Arduino's PWM output
  - The larger the range, the more asymmetric the output
  - Range must be large enough to properly power TEC
- Choosing a range:
  - Choose a PWM range, i.e. 80 to 120
  - Change calibration voltage until midpoint (PWM=100) gives 0 V output
  - Make sure DC-voltage signal is symmetric,
    - i.e. PWM=80 gives – 1.3 V, PWM = 120 gives 1.3 V
- Determined range: PWM: (80, 220)
- Low-end of range uses more power than high-end of range
  - i.e., PWM=80 draws 1.25 A from power supply, PWM=220 draws 0.93 A

Practical Issues (contd)

- TEC needs a good heatsink to efficiently heat and cool



- Solution:
  - Attach second TEC to open side of main TEC



Practical Issues (contd)

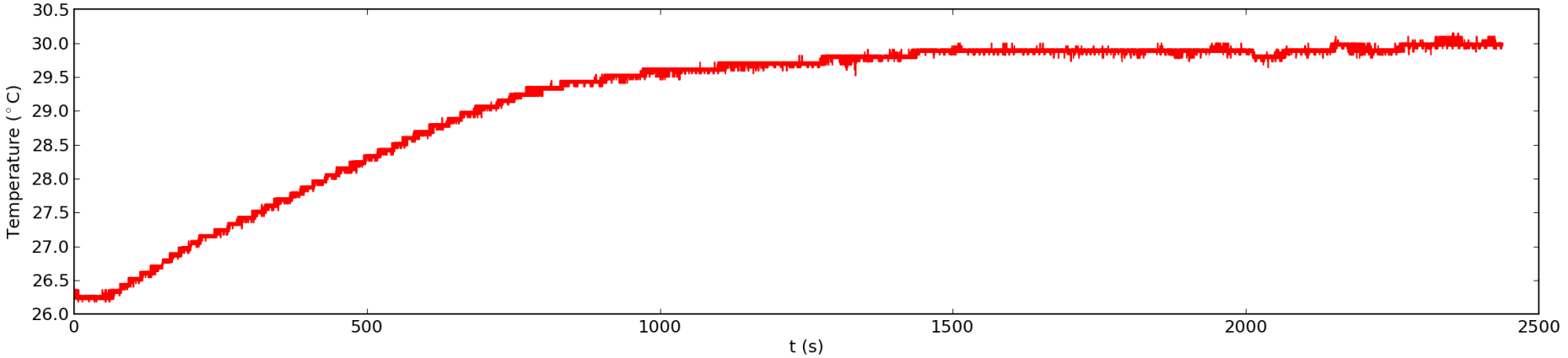
- Accuracy of Arduino gives error of temperature measurements: ± 0.02° C
  - Measurements fall into bins of width ~0.04° C

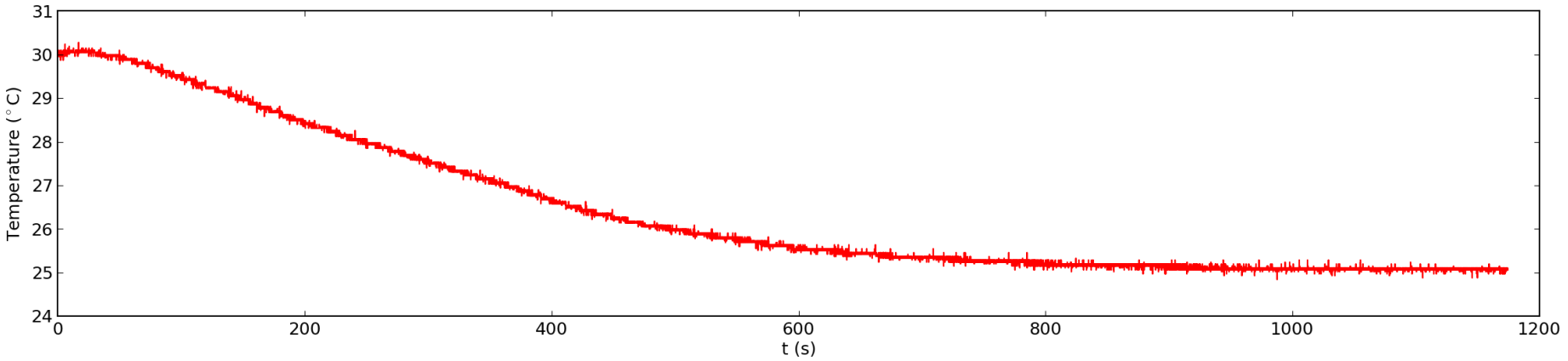
Temperature Controller User Interface

- Created in Pythics

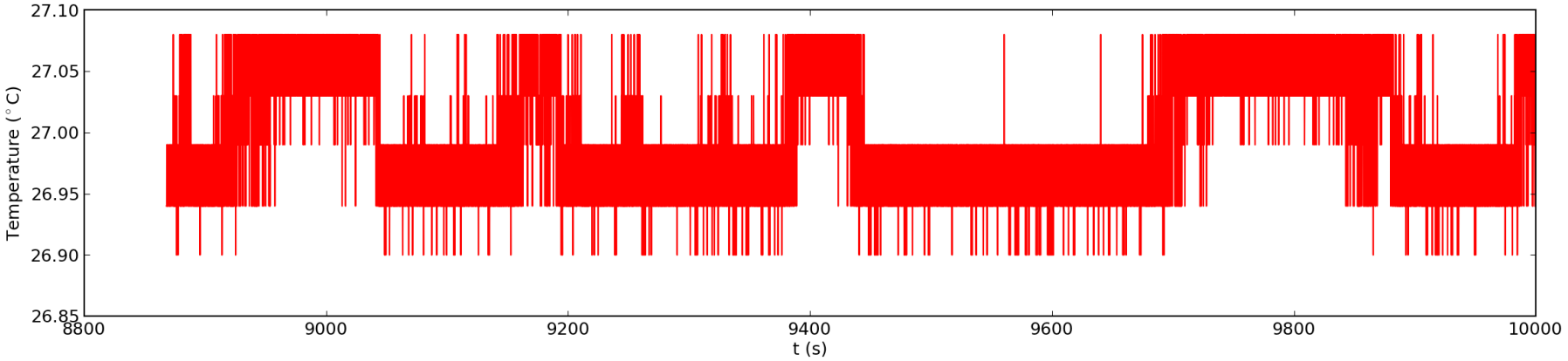
- Functionality:
  - Plot temperature over time
  - Change parameters: P, I, D, and set-temperature
  - Save parameters to Arduino's memory

Results





- Parameters: P = 60.0; I = 0.0001; D = 0;


27.10
27.05
27.00
26.95
26.90
26.85
Temperature (°C)
8800
9000
9200
9400
9600
9800
10000
t (s)