# Improving the Speed of Shape Memory Alloy (SMA) Actuators by Faster Electrical Heating

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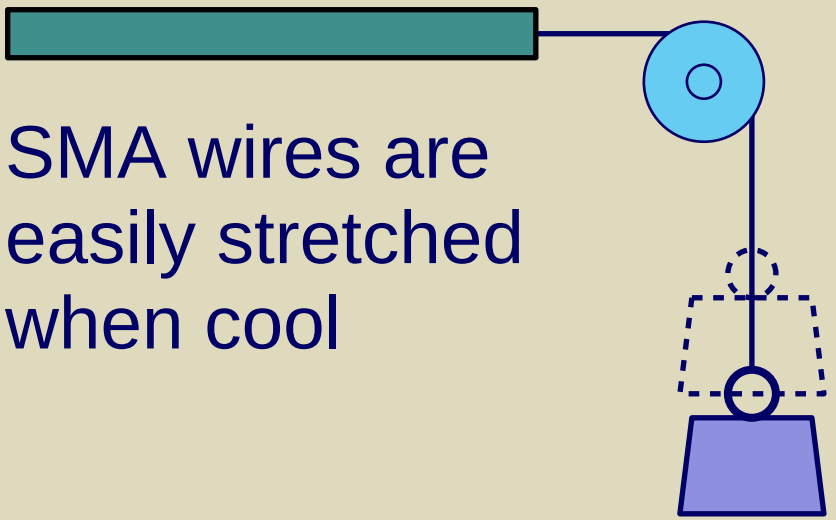
# Long Term Objective:

- to obtain fast, accurate, controlled motions and forces from SMA actuators, so that we can build and experiment with low−inertia robots.

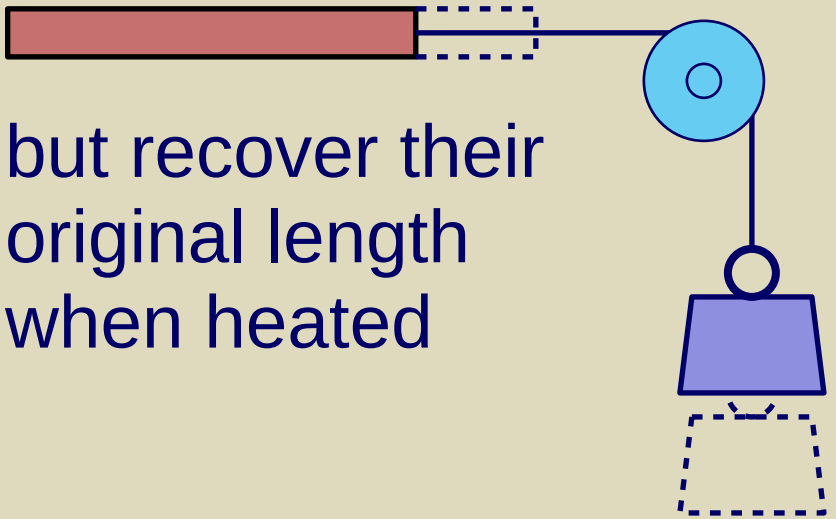
This work takes us one step in that direction, with a simple method for rapid heating of SMA.

# SMA Actuators

- Convert heat into mechanical work
- Usually heated electrically
- Problems:
  - slow
  - inefficient
  - hysteresis



SMA wires are easily stretched when cool



but recover their original length when heated

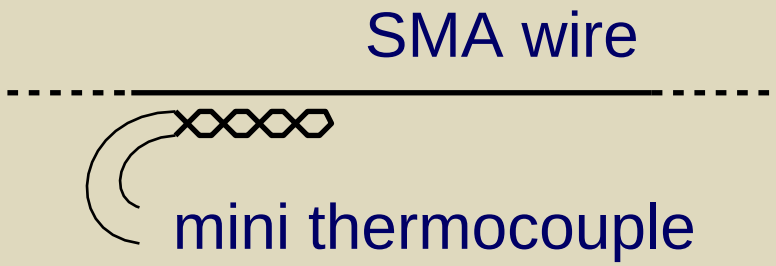
# Why Focus on Heating?

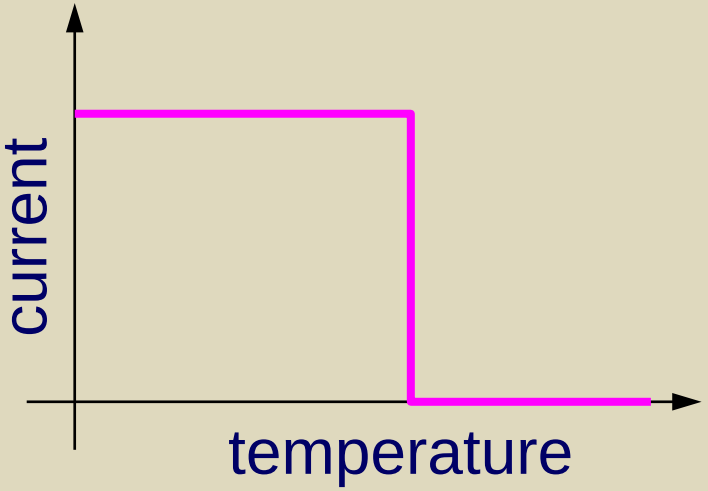
Excerpt from Flexinol (tm) data sheet:

| Diameter (mm) | Current (mA) | Contraction Time (sec) | Off Time 70C | Off Time 90C |
|---|---|---|---|---|
| 0.050 | 50 | 1 | 0.3 | 0.1 |
| 0.075 | 100 | 1 | 0.5 | 0.2 |
| 0.100 | 180 | 1 | 0.8 | 0.4 |

If we use the recommended safe heating currents then, for a thin wire, heating takes longer than cooling.

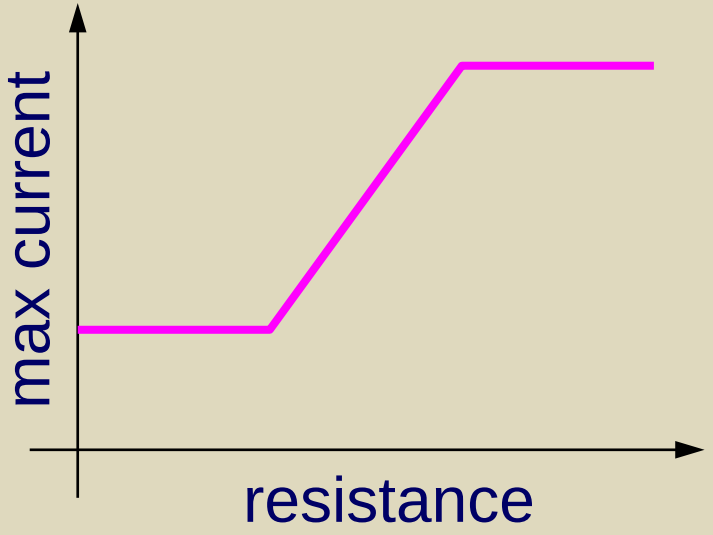
# Kuribayashi's Method



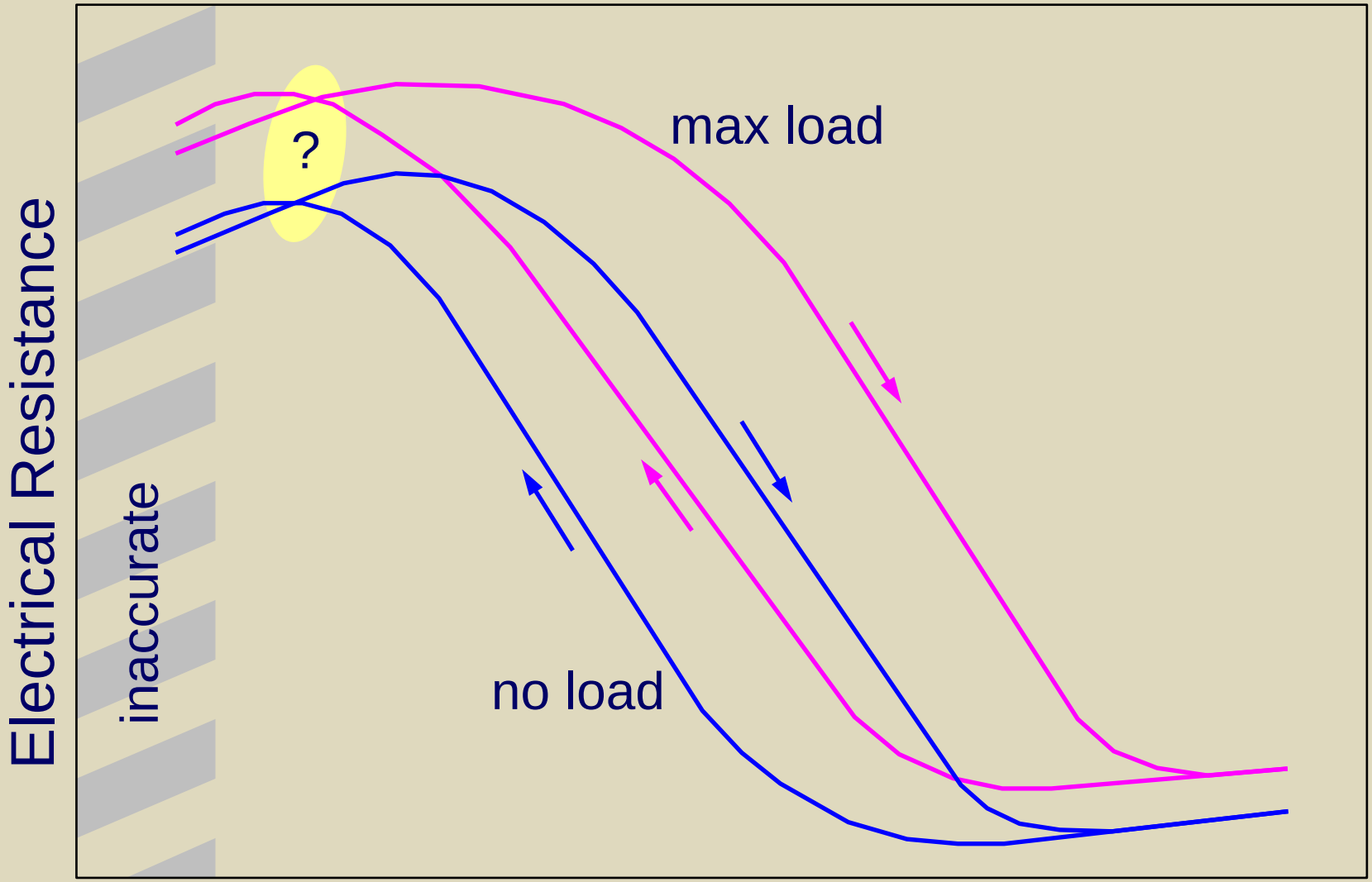

- Measure the temperature of the wire
- **If** temperature is below threshold value
  **then** allow large heating current
  **else** set heating current to zero

# Our Method

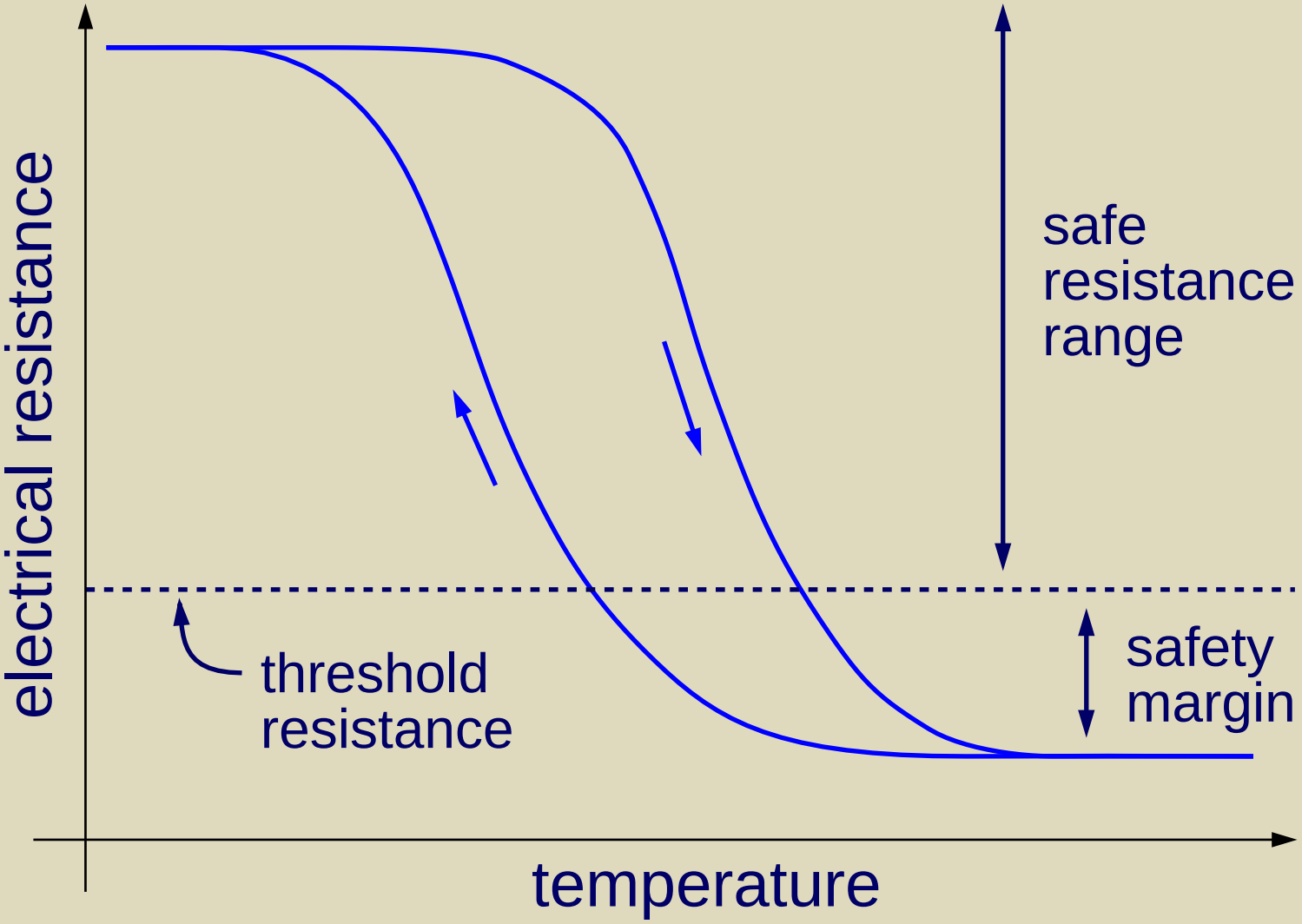



- Measure the resistance of the wire
- Calculate a maximum safe heating current as a function of measured resistance
- Set the heating current to the minimum of
  - the maximum safe heating current
  - the current requested by the control system

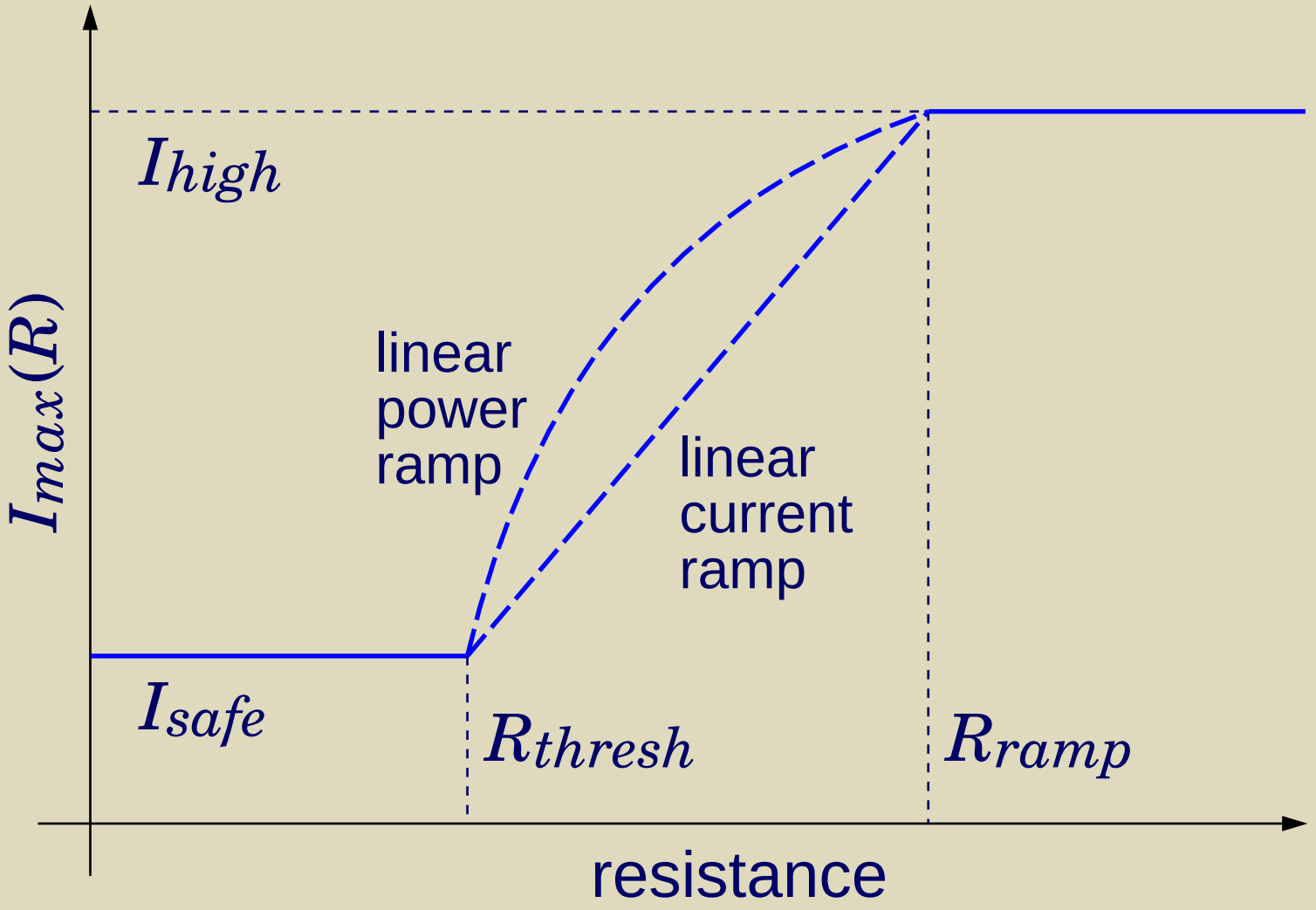
# Resistance vs. Temperature



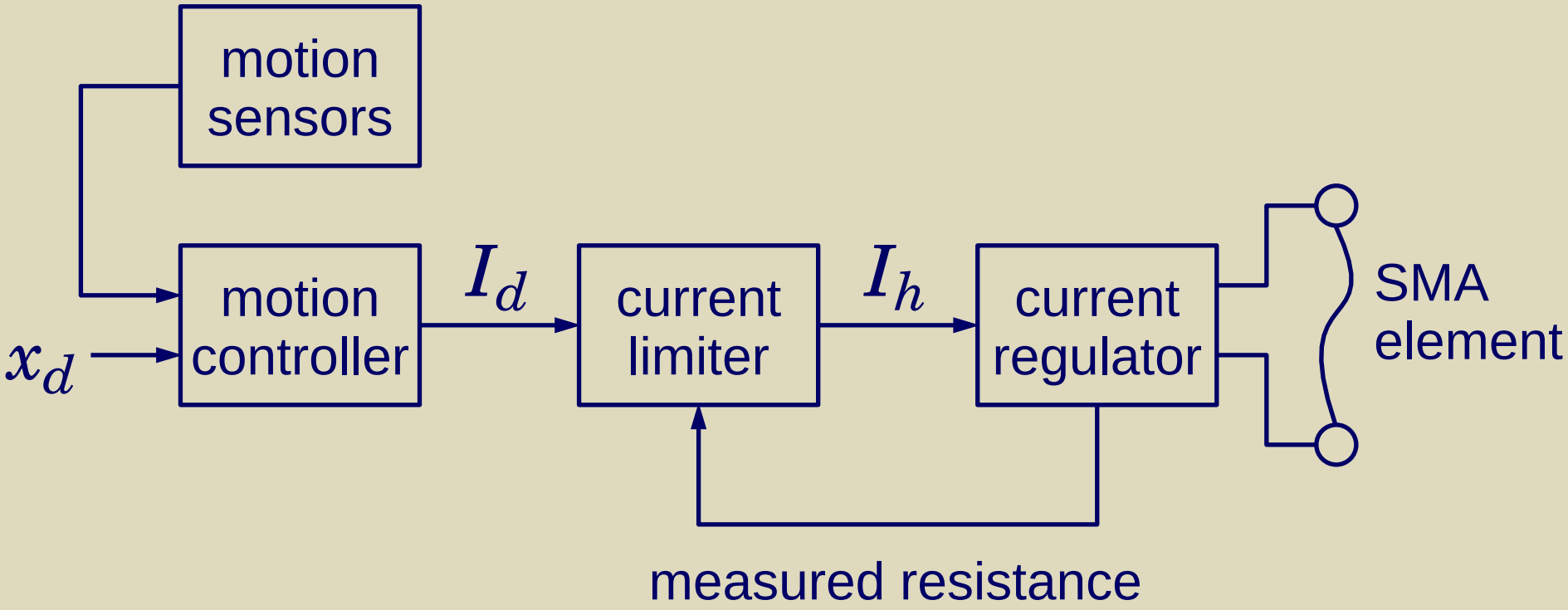
# Selecting Threshold Resistance



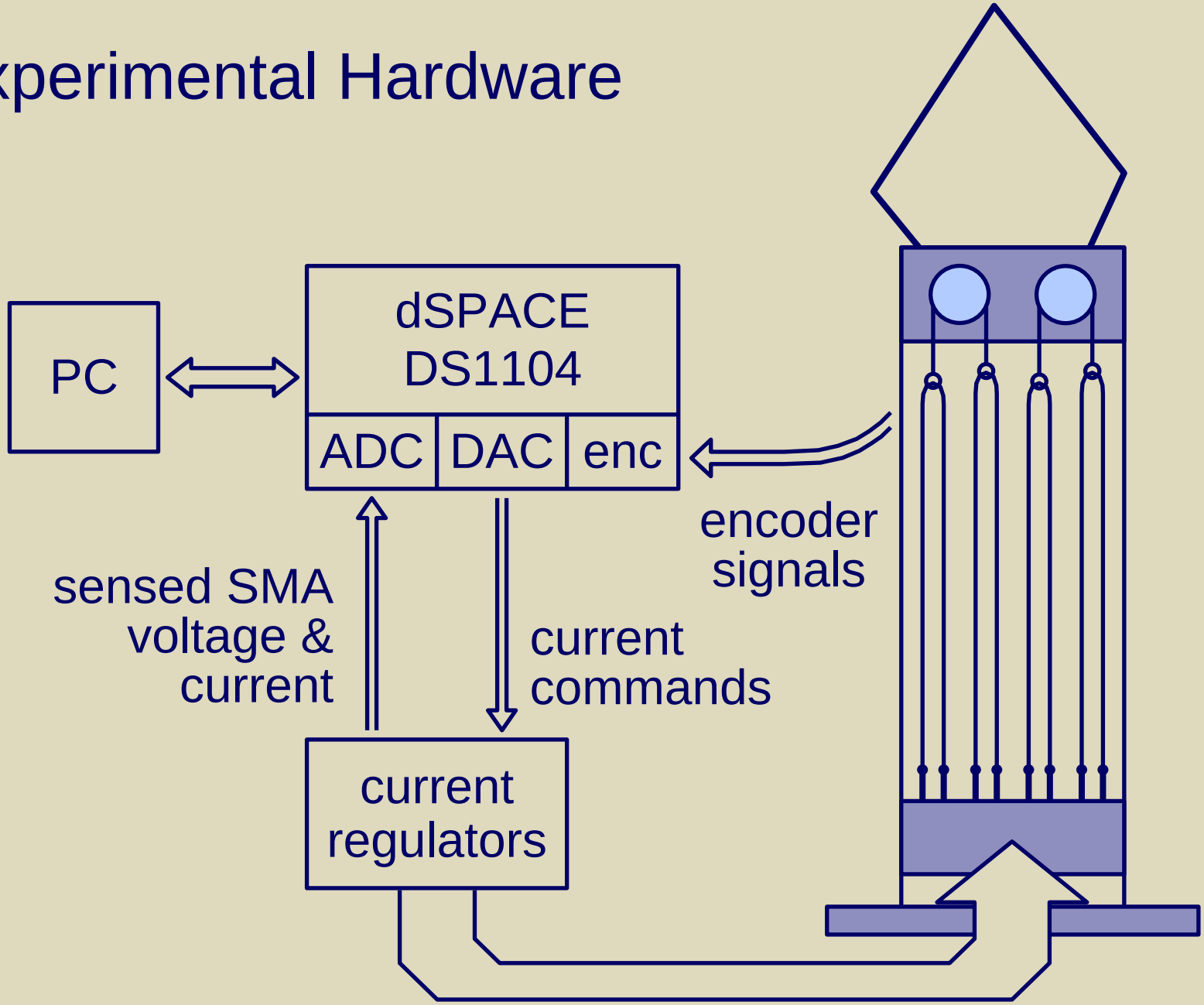
# Maximum Safe Heating Current



# Control System Architecture

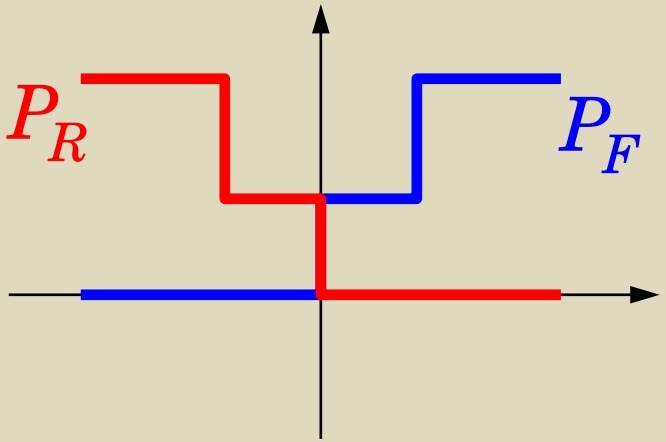


# Experimental Hardware



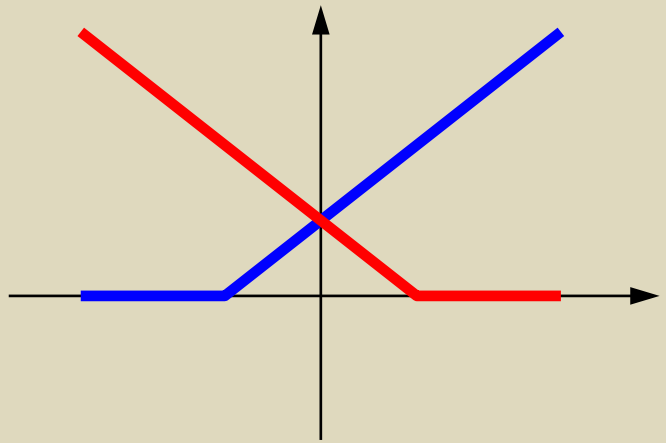
# Motion Controller

- Currently using Grant's two−stage relay controller



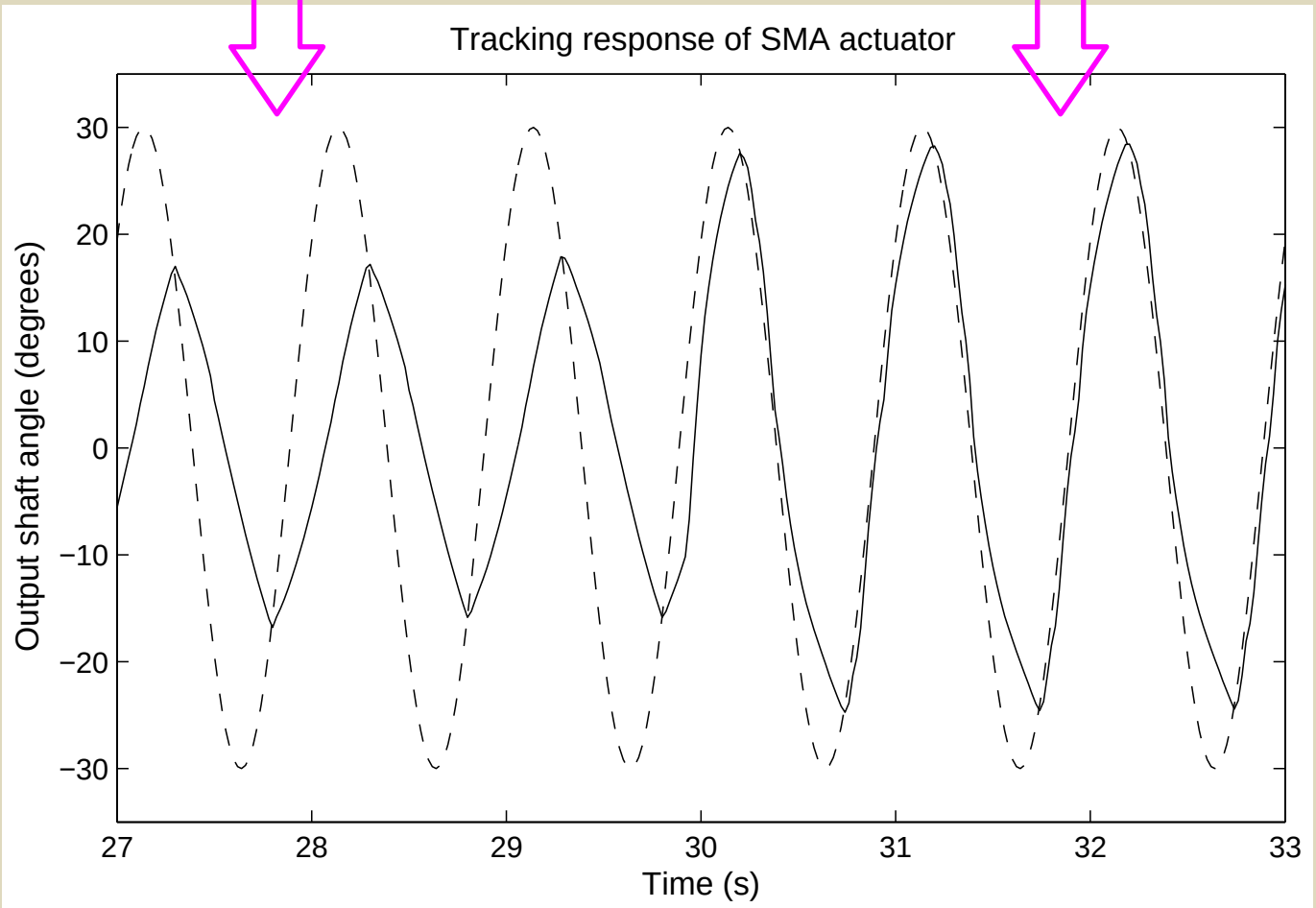

- Starting to experiment with other control laws, like this modified proportional controller

Power vs. Error



# Tracking Response

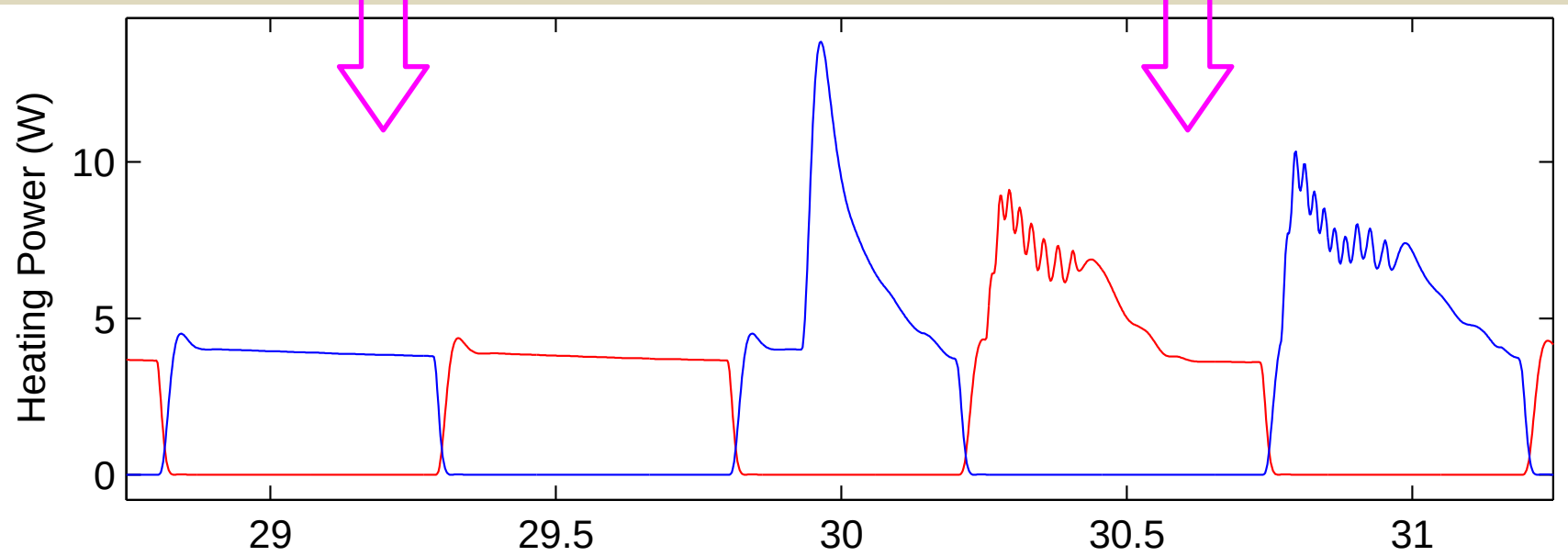
$I_h <= I_{safe}$ $I_h <= I_{max}(R_{meas})$



# Power to Each Actuator

$I_h <= I_{safe}$

$I_h <= I_{max}(R_{meas})$



# Conclusion

- Electrical resistance provides an indication of SMA temperature that is sufficient for preventing overheating.
- Rapid heating via the proposed method yields a substantial increase in speed, without changing the cooling regime.
- Next step:  A better motion controller.