Efficient SMA Actuation - Design & Control Concepts

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Shape Memory Alloy – SMA

Phase transformation from Martensite to Austenite during a heating and cooling period

„Metal muscles“ – Nickel-Titanium (NiTi) wires

500μm SMA wire lifting 10kg
**SMA Properties**

- HIGHEST ENERGY DENSITY
- High Forces
- Unique form factors
- Noiseless operation
- Bio-compatible
- SELF-SENSING

Compact and Lightweight Actuator-Sensor Systems

SMA drawbacks:

- High strokes require long wire length or gear/transmission system
- Holding activated positions is **energy-intensive** (mono-stable)
- Frequency directly coupled to cooling time of the SMA wires (biasing mechanism necessary)

→ Development of an SMA actuator, that...

- ...has a **compact design** and can still generate high strokes and high forces.
- ...can hold 2 positions energy-free (**bi-stable**).
- ...can reach **higher frequencies** in both switching directions.
Core item: **Bi-stable element** (e.g. metal sheet beam)
Actuator Properties

1. **Bi-Stability → 2 defined energy-free positions**

2. **Antagonistic Wires → No passive cooling time**

3. **Actuator Stroke** scaled by SMA attachment

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**PATENT PENDING** - (licensed in USA)


SMA Suction Cup
**Bi-stable SMA Suction Cup**

1. **Standby**
   - No wire actuated
   - Membrane in plane state
   - Suction cup ready to grip

2. **Gripping**
   - Lower wire actuated
   - Bi-stable spring snaps upwards
   - Vacuum generation
   - Gripping of workpiece

3. **Holding**
   - No wire actuated
   - Bi-stable spring maintains vacuum
   - Workpiece is fixed

4. **Release**
   - Upper wire actuated
   - Bi-stable spring snaps downwards
   - Vacuum purge
   - Workpiece released

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Bi-stable SMA Suction Cup

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Proportional SMA Actuators
Advanced Control Concept

Given supply voltages in applications:
12 V, 24 V, 48V, 230 V, 400 V, ..., DC/AC

Magnitudes higher than recommendations

- High Speed Activation
  → High strokes and forces in *millisecond*-range

- Energy-efficiency
  → Activation under *adiabatic* conditions

Experimental Setup


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### Energy-Efficiency

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*Energy savings up to 80%*

**Relevance:**
- Trigger, safety, 1-time actuation, ...

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AC Activation

Real time energy measurement

\[ W_{el} = \sum_{i=1}^{n} U_i \cdot I_i \cdot \Delta t \]
Energy-Efficient PWM

Same displacement with 63% energy savings
Thank you for your attention!