Spiketon M1: A Compact, High-Precision Guided Actuator

Spiketon M1 is a high-performance *guided actuator* developed by Spike Dynamics. It functions either as a moving carriage that travels along external rails (hence "guided"), or as a stationary unit that moves rails—or loads—relative to itself.

At its core, Spiketon M1 is built from a lightweight structural frame, manufactured from steel, titanium alloy, technical ceramics, or high-strength polymers. In the most basic version, its muscle-like mechanism can even be stamped from sheet metal in a single press motion, offering extremely low-cost fabrication.

How It Works

The actuator is powered by miniature **piezoelectric piezo stacks**.
The green and orange **modules** visible in the **drawings** are these active components.

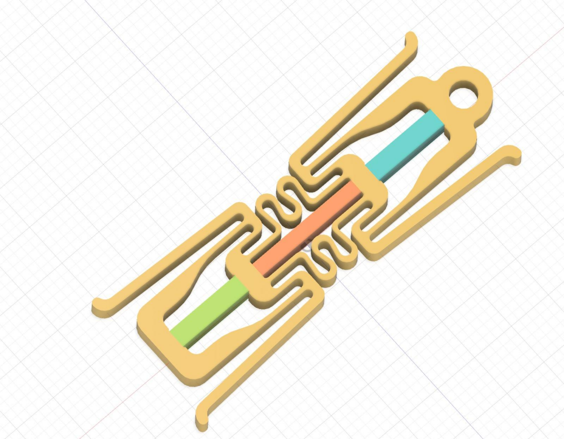
These modules expand slightly (about **0.1%–0.2%** of their length) when a sinusoidal voltage of **100–150V** is applied. Due to the elastic constraints of the surrounding frame **(beige color)**, this causes a controlled extension and contraction of the actuator body.

- **Green modules** cause lateral movement of the "feet" or clamps, pushing outward to grip surfaces.
- **An orange module** controls elongation or shortening of the actuator body.

This cyclical coordination enables inchworm-like locomotion:

1. The front clamps engage with the surrounding structure.
2. The body elongates via the orange module.
3. The rear clamps engage, front clamps release.
4. The orange module contracts—pulling the rear end forward.

This simple but powerful motion is repeated at high frequencies, enabling rapid bidirectional movement with high reliability.



Drawing 1: Structure of Spiketon M1 showing piezoelectric modules (green, orange, blue) embedded in a flexible frame (beige).

Performance and Materials

Each piezo stack—just **2 mm × 3 mm** in cross-section—can generate forces up to **100–300 N**, capable of moving **10–30 kg** loads. The materials used, such as ceramic and titanium alloys, allow operation in extreme environments with wide temperature swings, radiation exposure, and without any need for lubrication.

- **Non-magnetic** (ideal for sensitive environments)
- **Compact** and scalable
- **High-precision**, with excellent repeatability
- **Fully solid-state**, with no rotating parts or gears

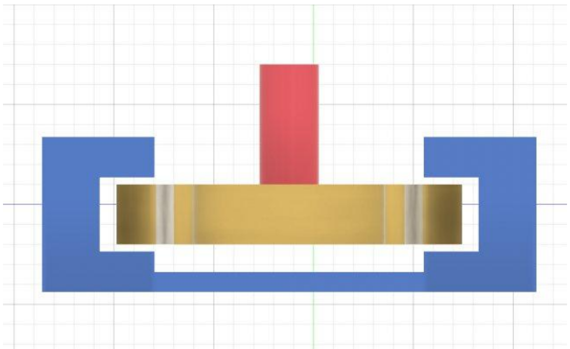
Why We Call It a Muscle

A ring-shaped anchor on the actuator's frame allows it to be connected to a **tendon**, mimicking biological muscle action. As the actuator contracts and expands, it pulls the tendon with significant force—just like a bicep pulling a forearm.

In fact, a single Spiketon M1 unit measuring **10 mm thick, 15 mm wide, and 40 mm long** can replace a human bicep in terms of output force—while operating up to **10× faster**, and with significantly less weight and volume.

Mounting and Rail Interface

Drawing 2 shows how the Spiketon M1 actuator can be mounted for guided motion along a rail. In this configuration, the actuator body (gold) is enclosed between two rigid blue rail elements, while the red component—screwed into the central threaded ring—acts as a mechanical driver that pushes or pulls against the environment.



Drawing 2: Example of Spiketon M1 moving along a rail. The actuator is clamped between two structural rails (blue), and a threaded red screw transmits force from the actuator's internal ring.

Physical Rail Implementation

Drawings 3 and 4 show real-life examples of aluminum profiles that can be used as rails for the Spiketon M1 actuator. These extrusions are readily available online and provide a lightweight, rigid, and manufacturable track for actuator motion.

Drawing 3: Red aluminum rail profile shown in hand. The internal groove accommodates the actuator body, allowing guided movement.

Drawing 4: Silver anodized aluminum profile with internal channel, suitable for integration with Spiketon M1.

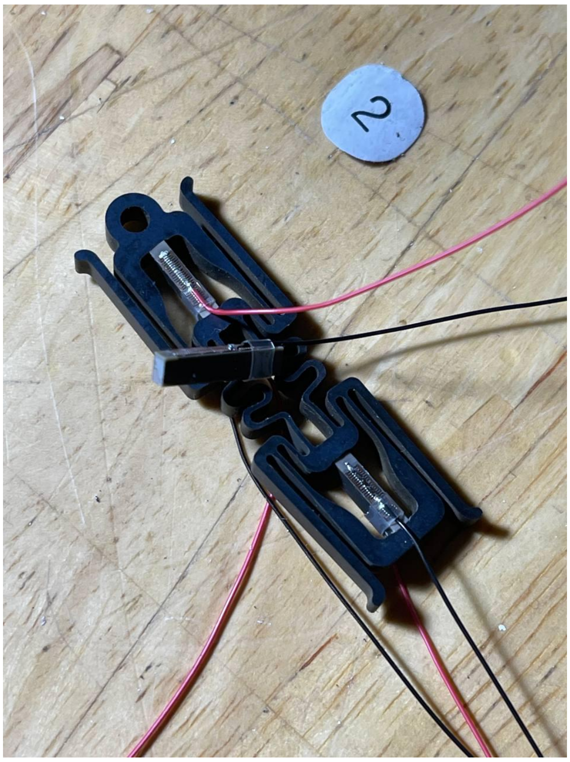
Prototyping and Materials

Drawing 5 shows a partially assembled prototype of the Spiketon M1 actuator. The black frame is made from high-carbon blade steel—originally chosen for its hardness and cutting resistance. However, later experiments showed that this material is suboptimal for actuators: although extremely hard, it lacks the necessary balance of strength and ductility.

The lesson: actuator frames benefit more from “aerospace” steels and alloys than from “sword-grade” ones. Modern stainless alloys with high toughness and moderate hardness performed much better.

In this image, two piezo stacks have been inserted into their slots, while the central slot awaits the third stack. No glue is needed: each module is held in place by the elastic tension of the frame itself. In essence, the entire black frame functions as a single precision spring.

Later tests also demonstrated excellent results with **titanium alloys**, including **Grade 5** and **nitinol**. These materials produce a gray actuator frame that is both visually refined and functionally superior to black steel—especially in demanding environments.



Drawing 5: Partially assembled Spiketon M1 prototype. Two piezo stacks are installed, and the frame is made of high-carbon blade steel, which was later replaced by aerospace-grade alloys for better performance.

Full Assembly Actuation

This second video shows the fully assembled Spiketon M1 actuator in operation. Here, the actuator is compressed between two rigid surfaces—simulating the inner walls of a guiding rail.

The visible movement of the legs is caused by a single piezoelectric stack inside the actuator. Although the displacement appears minimal, it is sufficient to press the actuator’s legs outward against the rail surfaces. This micro-motion is critical to ensuring secure grip and repeatable locomotion at high frequency.

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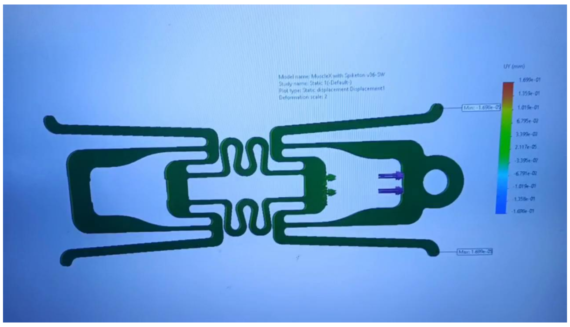


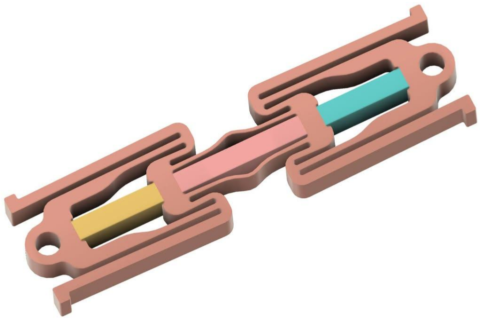
Drawing 7: Still frame from a video showing the fully assembled Spiketon M1 actuator. A single piezo stack creates a small but effective outward motion of the legs under compression between rail walls.

Design Simplification

Drawing 8 presents a later, more streamlined version of the Spiketon M1 actuator. Compared to the earlier design shown in Drawing 1, this version features fewer decorative spring curves surrounding the central piezo stack.

Instead of using multiple curled or coiled springs, the central body is now suspended by slightly curved elastic plates. These simplified elements serve exactly the same functional purpose—flexibly supporting the central section—while offering a more compact and manufacturable design.

This design evolution was the result of extensive simulation and testing, confirming that elegant simplicity can match the performance of more visually elaborate structures.



Drawing 8: Streamlined Spiketon M1 design with curved plates instead of coiled springs. A result of iterative testing and structural optimization.