leaking into the dome. Instead the affected stack gas stream pressure rises detectably, thereby enabling a system shutdown. All electrical and fluid connections to the stack are made inside the pressure dome and require special plumbing and electrical dome interfaces for this to be accomplished. Further benefits of the dome are that it can act as a containment shield in the unlikely event of a catastrophic failure.

Studies indicate that, for a given active area (and hence, cell ID), frame outside diameter must become ever larger to support stresses at higher operating pressures. This can lead to a large footprint and increased costs associated with thicker and/or larger diameter endplates, tie-rods, and the frames themselves. One solution is to employ rings that fit snugly around the frame. This complicates stack assembly and is sometimes difficult to achieve in practice, as its success is strongly dependent on frame and ring tolerances, gas pressure, and operating temperature. A pressure dome permits an otherwise low-pressure stack to operate at higher pressures without growing the electrolyzer hardware.

The pressure dome consists of two machined segments. An O-ring is placed in an O-ring groove in the flange of the bottom segment and is trapped by the flange on the top dome segment when these components are bolted together with high-strength bolts. The pressure dome has several unique features. It is made (to ASME Pressure Vessel guidelines) in a high-strength aluminum alloy with the strength of stainless steel and the weight benefits of aluminum. The flange of the upper dome portion contains specially machined flats for mounting the dome, and other flats dedicated to the special feedthroughs for electrical connections. A pressure dome can be increased in length to house larger stacks (more cells) of the same diameter with the simple addition of a cylindrical segment.

To aid in dome assembly, two stainless steel rings are employed. One is used beneath the heads of the high-strength bolts in lieu of individual hardened washers, and another is used instead of individual nuts. Like electrolyzers could be operated at low or high pressures simply by operating the electrolyzer outside or inside a pressurized dome.

This work was done by Timothy Norman and Edwin Schmitt of Giner Electrochemical Systems, LLC for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18772-1.

Cascading Tesla Oscillating Flow Diode for Stirling Engine Gas Bearings

John H. Glenn Research Center, Cleveland, Ohio

Replacing the mechanical check-valve in a Stirling engine with a micromachined, non-moving-part flow diode eliminates moving parts and reduces the risk of microparticle clogging.

At very small scales, helium gas has sufficient mass momentum that it can act as a flow controller in a similar way as a transistor can redirect electrical signals with a smaller bias signal. The innovation here forces helium gas to flow in predominantly one direction by offering a clear, straight-path microchannel in one direction of flow, but then through a sophisticated geometry, the reversed flow is forced through a tortuous path. This redirection is achieved by using microfluid channel flow to force the much larger main flow into this tortuous path.

While microdiodes have been developed in the past, this innovation cascades Tesla diodes to create a much higher pressure in the gas bearing supply plenum. In addition, the special shape of the leaves captures loose particles that would otherwise clog the microchannel of the gas bearing pads.

This work was done by Rodger Dyson for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18862-1.

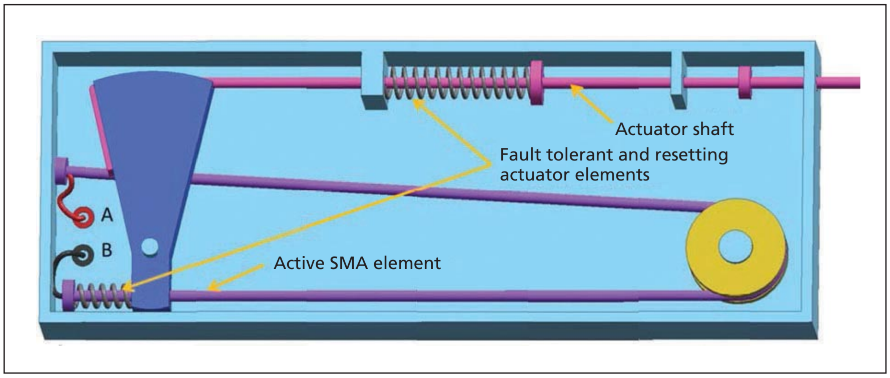
Compact, Low-Force, Low-Noise Linear Actuator

This actuator has potential uses in military and automotive applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Actuators are critical to all the robotic and manipulation mechanisms that are used in current and future NASA missions, and are also needed for many other industrial, aeronautical, and space activities. There are many types of actuators that were designed to operate as linear or rotary motors, but there is still a need for low-force, low-noise linear actuators for specialized applications, and the disclosed mechanism addresses this need.

A simpler implementation of a rotary actuator was developed where the end effector controls the motion of a brush for cleaning a thermal sensor. The mechanism uses a SMA (shape-memory alloy) wire for low force, and low noise. The linear implementation of the actuator incorporates a set of springs and mechanical hard-stops for resetting and fault tolerance to mechanical resistance. The actuator can be designed to work in a pull or push mode, or both. Depending on the volume envelope criteria, the actuator can be configured for scaling its volume down to 4×2×1 cm^3. The actuator design



The **Actuator** is driven by shape memory alloy as a primary active element. Electrical connections to points A and B are used to apply electrical power in the resistive NiTi wire, causing a phase change that contracts the wire on the order of 5%.

has an inherent fault tolerance to mechanical resistance. The actuator has the flexibility of being designed for both linear and rotary motion. A specific configuration was designed and analyzed where fault-tolerant features have been implemented. In this configuration, an externally applied force larger than the design force does not damage the active components of the actuator. The actuator housing can be configured and produced using cost-effective methods such as injection molding, or alternatively, its components can be mounted directly on a small circuit board.

The actuator is driven by a SMA -NiTi as a primary active element, and it requires energy on the order of 20 Ws(J) per cycle. Electrical connections to points A and B are used to apply electrical power in the resistive NiTi wire, causing a phase change that contracts the wire on the order of 5%. The actuation period is of the order of a second for generating the stroke, and 4 to 10 seconds for resetting. Thus, this design allows the actuator to work at a frequency of up to 0.1 Hz.

The actuator does not make use of the whole range of motion of the SMA material, allowing for large margins on the mechanical parameters of the design. The efficiency of the actuator is of the order of 10%, including the margins. The average dissipated power while driving at full speed is of the order of 1 W, and can be scaled down linearly if the rate of cycling is reduced. This design produces an extremely quiet actuator; it can generate a force greater than 2 N and a stroke greater than 1 cm. The operational duration of SMA materials is of the order of millions of cycles with some reduced stroke over a wide temperature range up to 150 °C.

This work was done by Mircea Badescu, Stewart Sherrit, and Yoseph Bar-Cohen of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47991

Ultra-Compact Motor Controller

Applications include industrial robotic arms, industrial machinery, and automobiles.

Lyndon B. Johnson Space Center, Houston, Texas

This invention is an electronically commutated brushless motor controller that incorporates Hall-array sensing in a small, 42-gram package that provides 4096 absolute counts per motor revolution position sensing. The unit is the size of a miniature hockey puck, and is a 44-pin male connector that provides many I/O channels, including CANbus, RS-232 communications, general-purpose analog and digital I/O (GPIO), analog and digital Hall inputs, DC power input (18–90 VDC, 0–l0 A), three-phase motor outputs, and a strain gauge amplifier.

This controller replaces air cooling with conduction cooling via a high-thermal-conductivity epoxy casting. A secondary advantage of the relatively good heat conductivity that comes with ultra-small size is that temperature differences within the controller become smaller, so that it is easier to measure the hottest temperature in the controller with fewer temperature sensors, or even one temperature sensor.

Another size-sensitive design feature is in the approach to electrical noise immunity. At a very small size, where conduction paths are much shorter than in conventional designs, the ground becomes essentially isopotential, and so certain (space-consuming) electrical noise control components become unnecessary, which helps make small size possible. One winding-current sensor, applied to all of the windings in fast sequence, is smaller and wastes less power than the two or more sensors conventionally used to sense and control winding currents. An unexpected benefit of using only one current sensor is that it actually improves the precision of current control by using the "same" sensors to read each of the three phases. Folding the encoder directly into the controller electronics eliminates a great deal of redundant electronics, packaging, connectors, and hook-up wiring. The reduction of wires and connectors subtracts substantial bulk and eliminates their role in behaving as EMI (electromagnetic interference) antennas.

A shared knowledge by each motor controller of the state of all the motors in the system at 500 Hz also allows parallel processing of higher-level kinematic matrix calculations.

This work was done by William T. Townsend, Adam Crowell, and Traveler Hauptman of Barrett Technology, Inc.; and Gill Andrews Pratt of Olin College for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Barrett Technology, Inc.
625 Mount Auburn Street
Cambridge, MA 02138-4555
Phone No.: (617) 252-9000
Web site: www.barrett.com

Refer to MSC-23930-1, volume and number of this NASA Tech Briefs *issue, and the page number.*