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SOFT ROBOTICS

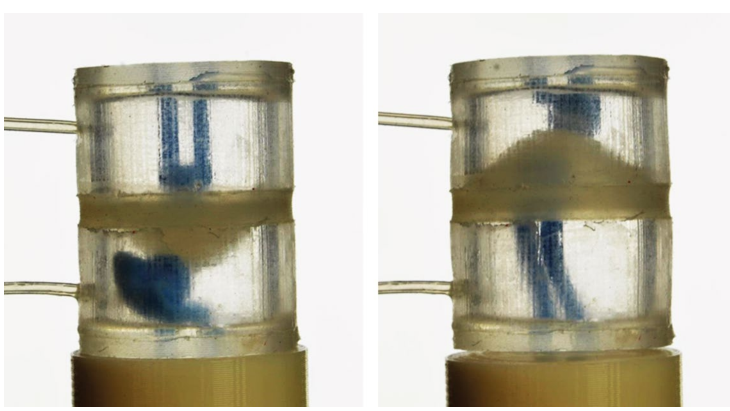
Making the switch

> "Combining the bistable valve with soft control elements … will allow the execution of more complex functions"

Soft robots enable applications that interface with humans, for example, as exoskeletons or in surgery. However, soft pneumatic devices are typically not completely soft because they are controlled by hard valves. Now, George Whitesides and collaborators, writing in *Science Robotics*, report on a soft mechanical switch to control airflow in soft actuators.

The soft valve consists of a hemispherical membrane separating two chambers. Its orientation — upward or downward — depends on the pressure difference between the chambers. The membrane position controls airflow through tubes that run through each chamber: in one chamber the tube is closed by the membrane pushing on it and in the other chamber the tube is left open and air flows. The valve requires power only for switching, which occurs when the pressure difference reaches a threshold, causing the membrane orientation to become unstable and invert. The thresholds of pressure difference depend on membrane thickness and the angle between the wall and the membrane at its edge. "The pressures at which the instability occurs can be designed to match the pressure limits between which a soft actuator operates," explains Philipp Rothemund, an author of the article. "The valve can therefore be designed to autonomously perform the control function. We demonstrated this by incorporating the soft valve into a soft robotic gripper, which was able to grasp an object once it came into contact with the gripper, much like if you were to catch a ball with your eyes closed, using only your sense of touch."

Because the switching is hysteretic, that is, the membrane only inverts orientation when the pressure difference crosses the up-to-down or the down-to-up threshold, the valve is also insensitive to fluctuations in pressure and can be used as a noise filter, analogous to noise filters used in digital signal processing. The design of the valve can also be modified to make an oscillator that converts a constant pressure supply into periodic pressure oscillations, which is demonstrated in an earthworm-like walker powered by a constant pressure source.



Daniel Preston

The valve design still needs tweaking before it can be used in technologies. "In the current design, the valve consists of over ten separate parts and requires a similar number of fabrication steps. For the valve to be adopted in technological applications, we envision an integrated design that requires fewer fabrication steps," says Daniel Preston, another author of the article. "Additionally, we have tested the durability of the valve only at the lab scale, over 100,000 actuation cycles. Even though we did not observe any substantial changes in performance, longer durability tests would need to be performed to demonstrate that the valve satisfies the requirements of commercial applications."

There are also possibilities to expand the functionality of the valves. "Combining the bistable valve with soft control elements, which were developed for microfluidic circuits, or combining multiple bistable valves will allow the execution of more complex functions. There are many different types of instabilities that occur in soft structures, which may be used in the future for the control of soft actuators," concludes Preston.

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ORIGINAL ARTICLE Rothemund, P. et al. A soft, bistable valve for autonomous control of soft actuators. *Science Robotics* **3**, eaar7986 (2018)