Sensata Technologies

WHAT DESIGN ENGINEERS NEED TO KNOW ABOUT VCA (VOICE COIL ACTUATOR) TECHNOLOGY

WHITE PAPER

Voice coil actuators (VCAs) are emerging as an extremely valuable solution for many precision motion applications. As the need for smaller, higher accuracy linear motion control components increases, these actuators are being used in an expanding array of mission-critical equipment from ventilators that help patients breathe, to guiding the arms of asteroid-collecting spacecraft.

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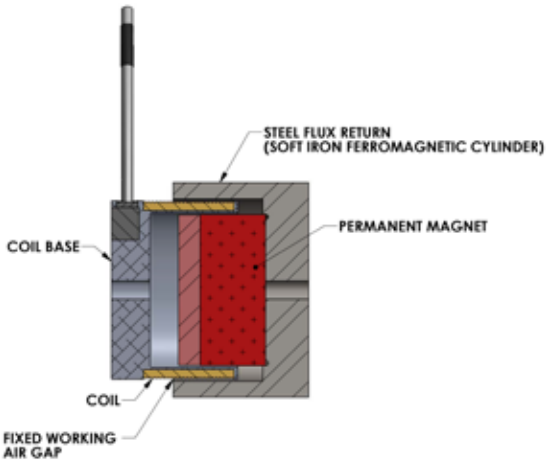
Originally developed for audio speakers, voice coil actuation technology is now being used to provide precise and reliable motion control for a wide range of medical, industrial process and space applications. Even though it has been around for decades, VCA technology, depicted in Figure 1, is still a mystery to many design engineers as until recently, the application spaces for which it was a cost-effective solution were relatively restricted. Many designers had to settle for more traditional, but less flexible, solenoid-based devices. Now that powerful MCUs and precise and efficient drivers are readily available, advanced linear motion designs using VCAs are easier and less expensive to implement.

Any time an engineer is looking at developing a product that requires highly reliable, highly repeatable, and highly controllable motions, they ought to take a look at VCA.

Voice coil actuators offer many benefits to the engineer. They are very simple and extremely robust, yet are as exactly precise as the input given them. VCAs accelerate smoothly and quickly to any position within their stroke with nearly zero hysteresis and are only limited by the system's position-sensing precision and driver capability. Because of this accuracy, these devices lend themselves extremely well to applications such as medical devices, robotics, and industrial process equipment.

Figure 1 - LINEAR VOICE COIL ACTUATOR



Used in a wide range of medical and industrial applications, an axial voice coil actuator is composed of a permanent magnet situated within a moving tubular coil of wire, all inside of a ferromagnetic cylinder. When current runs through the coil, it becomes magnetized and repels against the magnets, producing an in and out, back and forth motion.

STAYING ALIVE - PRECISION CONTROL IN MEDICAL DEVICES

One application area that demands critical precision is the medical industry. Devices like drug-dispensing pumps and ventilators do not work on approximations — every microliter of liquid (or air) has to be carefully measured and managed. The precise motion control a VCA-based solution provides in a medical flow-management system increases accuracy without complexity or bulk.

The challenges in designing medical devices are compounded beyond strict performance and regulatory standards; there is also the need for small and lightweight devices to allow for portable use by caregivers moving room-to-room in a facility. This demand for performance in a constrained space lends itself well to a VCA solution.

Linear voice coil actuators in particular can be designed to meet the ultra-small size and exacting motion control requirements needed in the medical industry. These tiny VCAs are often used to control inhalation and exhalation valves on ventilators to provide the exact amount of air specified and the necessary reliability for life-critical applications (Figure 2).

Figure 2

VCAs such as Sensata's LAH08-15-000A are often used to control inhalation and exhalation valves on ventilators as their precision, reliability, and small size meet the demands for life-critical applications in the medical industry.

Another advantage with of these types of VCA motors are their bi-directional capabilities, permanent magnets, and magnetic latches, enabling the VCA to remain in position at one end or the other of a stroke during a power failure, ensuring the valves stay open or closed in a disruptive power situation.

These compact VCAs measure just 0.75" in diameter and weigh only 2.3 ounces, yet can deliver a peak force of nearly two pounds in an operating stroke of ±2 mm with low hysteresis, zero cogging, high acceleration, and a long-life cycle. This accurate linear motion control can also serve other precision medical systems like anesthesia machines as well in ultrasound probes, blood analyzers, and lab equipment.

Similar to the medical industry, equipment used in military and aerospace applications is dominated by a need to be as precise as possible in any environmental situation, so it has to be as rugged as it is accurate. In cases like these, custom solutions can help ensure that all the specifications to achieve desired performance are considered in the initial equipment design.

OUT OF THIS WORLD - FAIL SAFE OPERATION ON SPACECRAFT

To address the unique requirements for a space-based application, Sensata engineers created a moving-magnet VCA that could handle the harsh requirements for a spectrometer moving mirror on the Origins-Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-Rex) spacecraft, which launched in September of 2016 to rendezvous with the Asteroid Bennu in 2018 and return samples to Earth in 2023.

This customized moving magnet VCA was attached to the moving-mirror assembly of the OSIRIS-Rex Thermal Emission Spectrometer (OTES) to properly position it to scan the surface as the spacecraft approached the asteroid. The custom VCA was specifically manufactured to ensure high reliability and fail-safe operation. Redundant technology, low-outgassing, and high precision for exact motion control positioning were all key requirements to the actuator design.

Of course, given the extremely tight confines of a spacecraft, it was also critical to stay within the specific size, weight, and power limits, which were achieved in a compact housing measuring approximately 2" in diameter by 3" long. To meet the critical need for near-zero emissions, Sensata developed the actuator with as few adhesives or inks as possible and only spaceflight-approved materials, using mechanical assembly methods within a clean manufacturing process to eliminate substances that could cause outgassing. In addition, high-energy Neodymium Iron Boron magnets were incorporated to provide superior operating efficiencies.

This custom magnet solution and clean assembly methodology was migrated into a range of actuators with varying sizes, resulting in high performance VCAs measuring 12–65 mm in diameter and 12–75 mm in length (at mid-stroke) that are ideal for semiconductor, military, space, and test and measurement applications (Figure 3).

Figure 3

High precision voice coil actuators like Sensata's model LA05-05 meet the high purity and low outgassing requirements for semiconductor, military, and space applications.

SMOOTH OPERATIONS - LOW FRICTION IN INDUSTRIAL AND PROCESSING APPLICATIONS

Moving items from one place to another is an extremely popular application, but it isn't always as simple as hooking up a motor to a conveyor belt. In many of continuously operating applications, inconsistent motion caused by excessive friction can not only steal profits but also create work flaws that reduce yields. For applications like these, VCA solutions that exhibit extremely low hysteresis and friction while delivering precise and consistent bi-directional position control, like the VCA shown in Figure 4, are ideal.

Key to the VCA's low-friction design is a symmetrical flex circuit that prevents friction caused by movement coupled with a solid brass ball-cage to further reduce it. This design delivers an operating performance with a hysteresis of just 10 mN compared to similar style actuators that deliver as much as 50 to 200 mN. Other performance attributes of the VCA include a peak force of 4.7 N, a total stroke of 7.4 mm and a compact size of just 38 mm in diameter by 48.3 mm in length.

Figure 4

VCAs deliver low hysteresis/low friction for reliable and precise motion control in a compact package..

BRINGING IT TOGETHER- TOOLS TO SPEED UP DEVELOPMENT

Design tools that aid the engineer in understanding and implementing any given technology are critical to its adoption, and VCAs are not exempt. Self-contained kits, like Sensata's Voice Coil Actuator Developer's Kit (Figure 5), that include a VCA with a built-in feedback sensor and a programmable controller with PC-compatible motion control software allow users to take advantage of the benefits of VCAs without needing to specify the electronics required for a complete control system. This type of tool can help designers quickly develop an actuation system and demonstrate a working design with velocity, position, force, reciprocation, and acceleration control to address nearly any application.

Figure 5

Self-Contained Voice Coil Actuator Developer Kits enable designers to quickly evaluate and implement a VCA-based motion solution.

MOVING FORWARD WITH VCA TECHNOLOGY

The ability to put advanced precise linear motion anywhere is empowering both legacy application spaces as well as new uses not previously developed due to cost or complexity challenges. For example, a VCA built into an electric-vehicle charging system could raise and align the coil from the floor to the one in the bottom of the vehicle for optimum energy transfer, or on printer-head positioning in a high-resolution 3D printer

The number of areas that can benefit from VCA technology are constantly expanding as engineers use VCAs to address complex, delicate, or sensitive motion applications. The key is to specify and develop the proper solution for the application, building on the strengths of the technology and the user's needs.