Servo Motor Performance at Stepper Motor Prices?

Robust new sensor system doing more with less

Jack McGuinn, Senior Editor

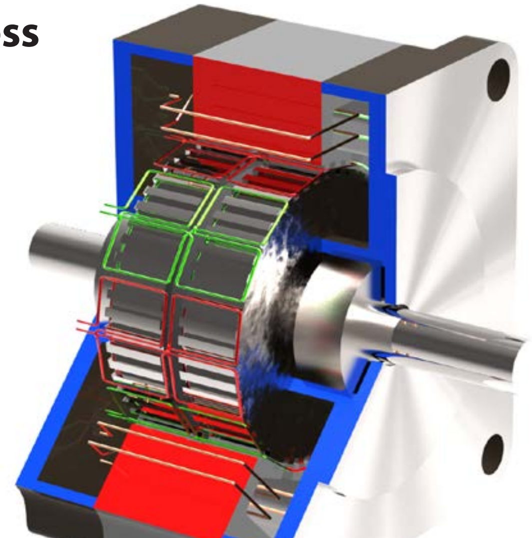


Figure 1 Cutaway view of the Mosolver showing the position sensor coils that have been added to a standard hybrid synchronous motor (All photos courtesy QuickSilver Controls).

Enhancing production with—and for, less—is the standing order in today's manufacturing world. Speeding up production while at the same time looking for ways, to cut, for example, energy costs, is a tricky equation with no single answer; where and how management goes about achieving that can take several paths. But in many manufacturing and countless other end-user environments, easily among the lowest-hanging energy-sucking targets remain NEMA inefficient, non-compliant electric motors, and the systems in which they are incorporated. So any news of a technological advance in that regard is always welcome, and that seems to be exactly what we have with the 2014 rollout of QuickSilver Controls Inc.'s patented Mosolver, i.e.—a servo motion actuator that, according to QuickSilver, "infuses a position feedback sensor into the very structure of a high pole count AC motor," thus eliminating "the need for costly encoders and resolvers."

And Don Labriola, the man behind the curtain whose baby is the Mosolver, offers additional reasons for considering the system a game-changer (*Ed.'s Note: See also sidebar*).

"I believe the Mosolver provides a rugged and cost-effective transition path to transfer up from steppers into Hybrid servo—same form factor. It not only prevents loss of steps, but allows true closed-loop control with a significant improvement in damping. Not only is it smaller than adding an encoder, it is inherently aligned, provides commutation information, and is robust.

"The ruggedness of the polyamide sense circuit within the stator structure of the motor is able to reach or exceed the thermal/radiation/contaminant levels permitted by the motor itself. The flex circuit is stationary, being flexed only for installation. There are no encoder discs to be contaminated or moving parts—other than the motor rotor itself."

And Labriola also explains that "the elimination of a separate feedback device reduces cost and size, eliminates alignment (and loss thereof) and greatly improves ruggedness of the system." What's more, by combining the motor and resolver into one package, the Mosolver enables a compact, inexpensive and robust closed-loop motion control.

As you might imagine, the newly developed QuickSilver sensor is critical to the Mosolver's enhanced capabilities and its claims of uniqueness. What impresses is that the sensor was developed in-house—with no outside brainpower.

"The Mosolver was developed in house to allow replacement of encoders for size, cost, resolution, and robustness reasons," says Labriola. "We add sense coils on a polyamide flex circuit to the stator structure. In the case of a 2-phase hybrid stepper/servo, only a slight modification to the stator is needed to

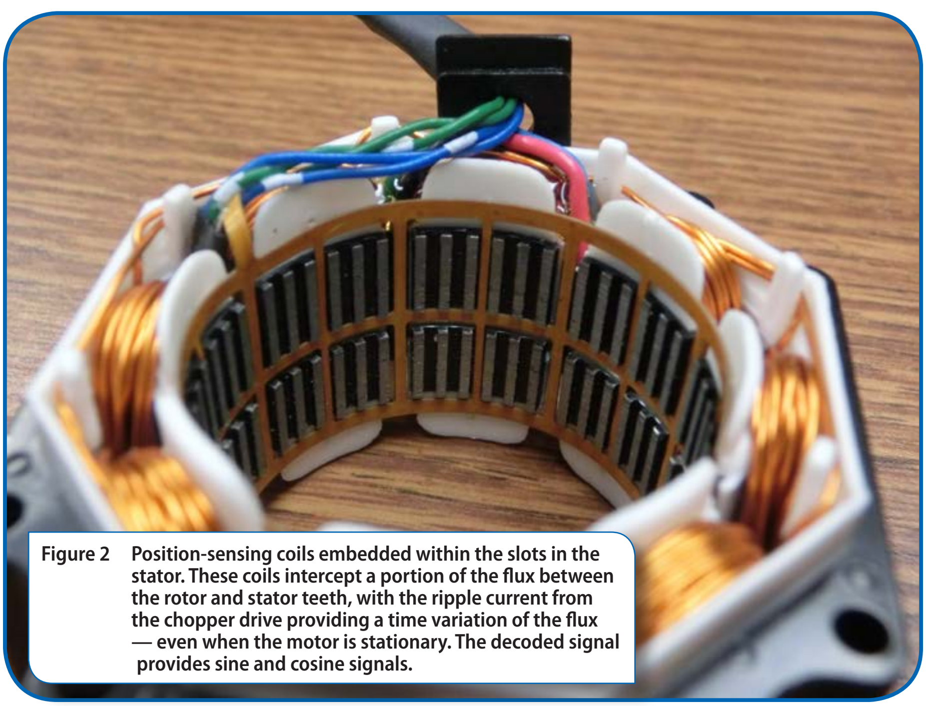


Figure 2 Position-sensing coils embedded within the slots in the stator. These coils intercept a portion of the flux between the rotor and stator teeth, with the ripple current from the chopper drive providing a time variation of the flux—even when the motor is stationary. The decoded signal provides sine and cosine signals.

"Operating these motors closed-loop takes advantage of their manufacturing-optimized design, low magnetic materials cost, and excellent motor torque capabilities. Gone are the low-frequency resonance problems, most of the noise and heating problems, and problems with lost steps."

allow passage of the flex circuit along the portion of the stator facing a magnet in the rotor. As the gap there is quite large, the modification does not appreciably change the magnetic paths."

The sense coils appear to be critical to Mosolver's efficacy as well; we asked Labriola to more fully explain that part of the system.

"The sense coil is arranged in the stator to intercept a portion of the flux arising from the motor PWM (pulse width modulation) drive. The ripple current associated with a PWM drive causes a flux variation — even when the motor is not in motion. The sense coil has differential sections arranged in the stator structure to measure the differences in the flux traveling through different sections of the stator. The position of the rotor teeth with respect to the stator teeth determines the path of minimum reluctance for the chopper-induced flux variations; and the paths vary with rotor position. Appropriate placement produces sine and cosine signals with a period corresponding to an electrical cycle of the motor.

"The sensor coil is completely contained within the existing motor frame, requiring no additional volume in the application. The use of a polyamide flex circuit containing only traces makes the sensor very robust, i.e. — polyamide circuits that have a very wide usable temperature range — from cryogenic to as high as 350°C — can be made to be low out gassing for vacuum applications, and can withstand high radiation doses without damage. By using both the existing magnetic structure and the existing motor PWM drive, the sense coils allow both commutation and position feedback with very little electronic overhead."

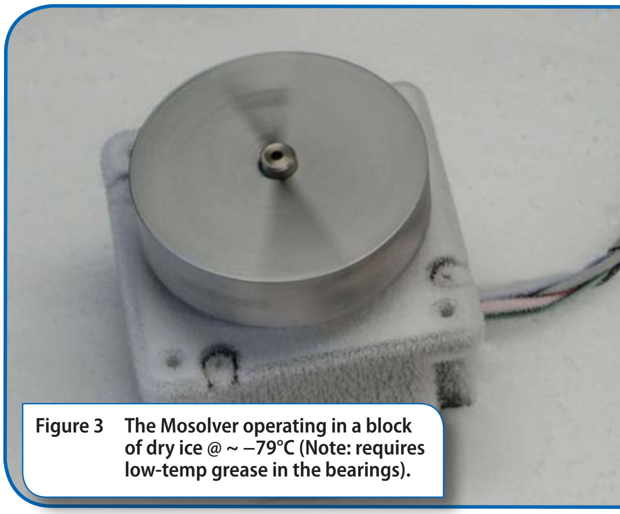


Figure 3 The Mosolver operating in a block of dry ice @ ~ −79°C (Note: requires low-temp grease in the bearings).

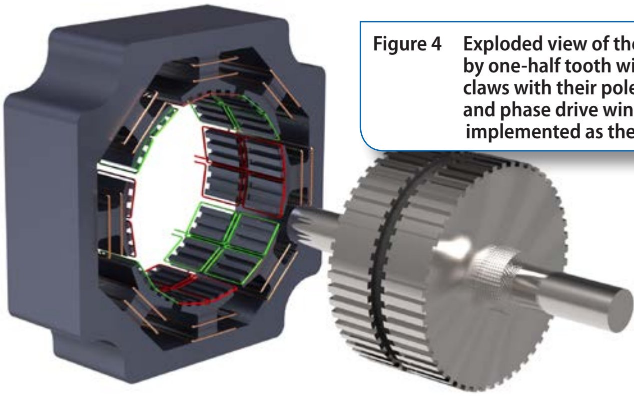


Figure 4 Exploded view of the Mosolver. The rotor has two pole caps, with the north and south poles skewed by one-half tooth width; the magnet is between the pole caps and is axially magnetized. The stator claws with their pole teeth are also exposed, showing the location of both sensor windings (red, green) and phase drive windings (copper). The actual sensor windings have a multiple turns-per-coil, and are implemented as the flex circuit shown in Figure 2.

And of course software is always central to the performance of systems as mentioned above, and the Molsolver is no different. As described by Labriola, "The software manages the trajectory generation, the control system, the digital drive signal timing, and the decoding of the sensor signals. The software effectively eliminates much of the additional hardware required for resolvers by making the existing motor and drive serve multiple purposes. The software also serves the function of the resolver/digital hardware for resolver based-systems."

At this point QuickSilver is focused on incorporating the Mosolver/sensor in hybrid servo motors that are built on a high pole count 2-phase hybrid motor—more commonly known and deployed as "step" motors. The drive and the presence of feedback allow these same motors to fully operate as servo motors, thus taking advantage of their low cost, high reliability, and very high, continuous torque capabilities. Labriola also revealed that the company is in the process of applying these sensors to Sawyer motors, including a planar structure in which the technology is applicable to a range of 2- and 3-phase motors.

And if you're a systems/line integrator or are otherwise involved in specifying motors/systems, you'll want to know that the Mosolver should have no trouble "fitting in."

"The Mosolver was designed and first implemented for the upgrade of hybrid step motors to hybrid servo motors," says Labriola. "There is a

"The elimination of a separate feedback device reduces cost and size, eliminates alignment (and loss thereof) and greatly improves ruggedness of the system."

very large usage of step motors — a much higher quantity of these motors are used than standard servo motors. Operating these motors closed-loop takes advantage of their manufacturing-optimized design, low magnetic materials cost, and excellent motor torque capabilities. Gone are the low-frequency resonance problems, most of the noise and heating problems, and problems with lost steps. The controller needs to be designed to acquire and decode sensing these signals."

When asked, Labriola says that birthing the Mosolver — from prototypes to board layouts to software modifications for enabling optimal operation — took about a year. Since then (2014), a tweak or two has been added.

"A slot is required around the circumference of a 2-phase hybrid motor to accept the sense coil," Labriola explains. "The differential coils optimally cross the center line of the magnet to produce a differential signal. The location of such a slot with other motor types varies. Motors designed for a good sinusoidal back-EMF (electric/magnetic fields) tend to produce more sinusoidal sense signals."

Referring back to motor/energy issue, motor environment ratings are a serious factor, as enforced compliance becomes more and more of a reality — a reality that will not go away,

"The software effectively eliminates much of the additional hardware required for resolvers by making the existing motor and drive serve multiple purposes."

given that most of the motors on factory floors and everywhere else in this country are woefully out-of-date, and therefore NEMA compliance. Quicksilver takes the view that "the Mosolver environmental ratings are essentially limited only by the motor for wide temperature, wet, and vacuum applications, as well as for operation in radiation environments."

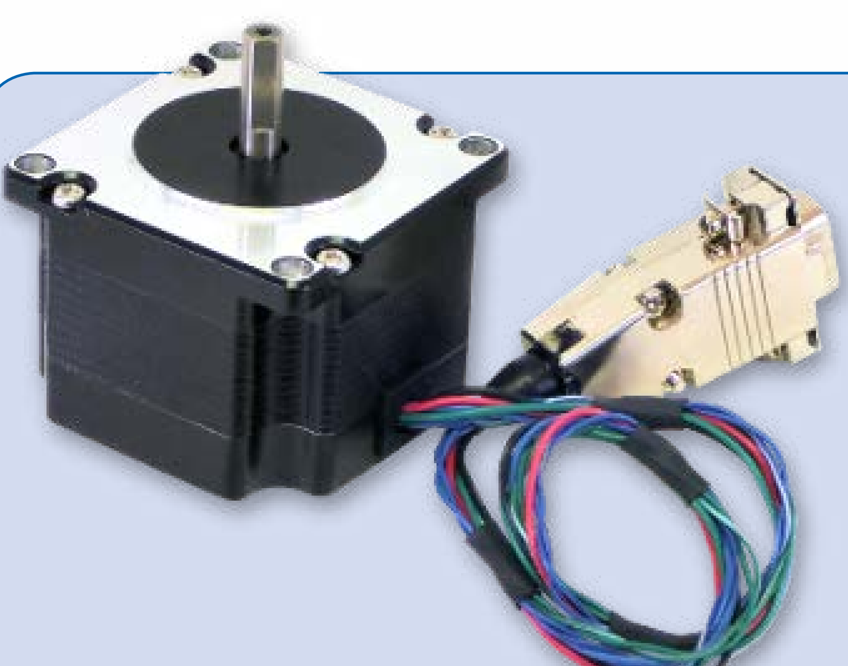
Expanding further, Labriola adds that, "According to the individual extension of the environmental ratings desired, the motor design must be consistent. For example, some magnet materials do not hold up under radiation. Others may need coating to handle wet or vacuum applications to limit corrosion or outgassing, respectively. Wide temperature ranges may require polyamide-coated wires, and special bearings and or lubricants — as well as wire guide inserts made from appropriate materials. These challenges have already been handled for open-loop steppers operating in these environments. Adding closed-loop capabilities allows these motors to operate with better margins and, typically, significantly cooler, as only the current required for the torque load is applied to the motor."

Can the Mosolver be improved?

"Yes!" Labriola enthuses. "We have patents in place to add single turn absolute capability, and are working to add some significant enhancements which we will reveal when they are ready for market!" **PTE**

For more information

Don Labriola
QuickSilver Controls, Inc.
712 Arrow Grand Circle
Covina, California 91722
Phone: +1 (626) 384-4760 (International)
(888) 660-3801 (U.S. only)
Fax: +1 (626) 384-4761
sales@quicksilvercontrols.com
www.quicksilvercontrols.com



Mosolver Datasheet

NEMA 23 QCI-MV23L-1

Continuous Torque: 40 oz-in
Maximum Current: 2.5A
Maximum Speed: 3,000 RPM
Feedback Resolution: 32,000 counts/rev

General Motor Specifications MV23L - 1

Maximum Speed (RPM)	3,000
48v Optimal Speed (RPM)	2,000
Torque (oz - in/Nm) at Optimal Speed	22 0.15
Continuous Stall Torque oz - in/Nm	40 0.28
Peak Power (Mech. Watts)	44
Rotor Inertia oz – in^2 Kg - m^2	.74 1.35e – 5
Weight pounds/Kg	1.05 0.48
Maximum Driver Input Current (Amps - DC)	2.5
Shaft Diameter in/mm	0.25/6.25
Maximum Axial Force (lbs)	13
Maximum Radial Force (lbs) 0.55" from mounting face	15

Environmental Specifications

Operational Temperature
–10°C to +80°C

Storage Temperature
–40°C to +85°C

Humidity
Continuous specification is 95% RH non-condensing.

Shock
Limitation is approximately 50g/11ms.

IP Rating - Standard
IP50

MORE MOSOLVER: AT-A-GLANCE

There is solid basis to QuickSilver's claims regarding what new—if anything—the Mosolver brings to the dance. The motion control system was awarded an over-all Honorable Mention at the 2014 Create the Future Design Contest, an annual engineering + techno-design + entrepreneurial bazaar started in 2002 by the publishers of *NASA Tech Briefs magazine* "to help stimulate and reward engineering innovation." The contest's principal sponsors are simulation software company COMSOL and semiconductor and electronic component distributor Mouser Electronics, along with Analog Devices, a data conversion and signal conditioning technology company, a supporting sponsor.

—*J. Mc Guinn*

Applications

- Medical Devices
- Solar Panels
- Industrial
- Manufacturing
- Harsh Environments
- Robotics
- Food Processing
- Textiles
- Automation
- Packaging

Mosolver Benefits:

- Encoder eliminated
- Cost-effective
- Energy-efficient
- Quiet operation
- Physically robust
- Compact; less real estate required
- Precision

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