NEW SCALE TECHNOLOGIES
Ingeniously Small Motion Systems

APPLICATION NOTE

Using SQUIGGLE motors in Closed-Loop Motion Systems

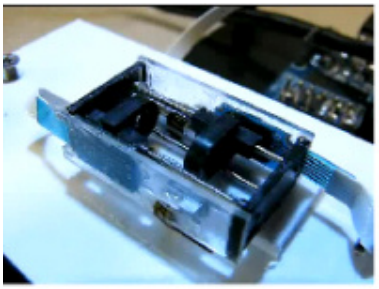

Figure 1 - This closed-loop system incorporates two SQUIGGLE motors and two TRACKER position sensors, driving two lens groups for autofocus and zoom. The entire module is only 6.5 x 13 x 23 mm.

New Scale has created a number of tiny, high-resolution closed-loop systems with SQUIGGLE motors. We have expertise in specifying position sensors and creating application-specific closed-loop systems for our OEM customers. This application note provides an overview of SQUIGGLE motors in closed-loop systems.

SQUIGGLE motors have excellent position resolution: users can signal the motor to move very small distances, measured in microns or nanometers. However, the motor speed varies with applied load and device friction. Therefore you need a closed-loop control system if you need to achieve exact positioning, repeatable positioning, or precise speed.

The basics of closed-loop control

In a closed-loop positioning system, a sensor detects the actual position and feeds the information to the motor controller. The controller compares actual position to desired position, and moves the motor to correct any error. This allows the motor to reach a precisely controlled position.

Similarly, controlled speed is achieved by adjusting the driver gain to minimize the difference between the required position and the actual position at regular time intervals.

SQUIGGLE motors are prized for their tiny size, and most users want tiny position sensors to match. Many choices are available, ranging from miniature encoders to simple limit switches. New Scale has also introduced its TRACKER position sensors, a line of miniature position sensors with smallest size and direct digital output right from the sensor.

Choose an option with resolution and travel range to fit your application.

Determining position resolution

Position resolution is determined by three factors:

- the resolution of the position sensor
- the resolution of the motor
- the A/D converter in the controller.

If you need to know the position within 10 microns, your position sensor must have a resolution of 5 microns or better, your motor must have a position resolution of 2.5 microns, and your A/D converter must be capable of resolving the feedback signal into small enough increments to allow signals to the motor at its best resolution.

Here's a design example: say you want to have 10 microns resolution over a travel range of 2 mm. A possible solution is to use a Hall Effect sensor with a magnetic strip 4 mm long (using the more linear center of the magnet and avoiding the last mm on each end). A 10-bit A/D converter will supply resolution of 0.001 of the 4 mm, or 4 microns. The motor resolution is 0.5 microns, so the limiting factor is the A/D converter. Assuming some background noise, this will still be enough sensor resolution to achieve 10 microns repeatability. With a higher resolution A/D chip, the position resolution would be even better.

The TRK-1T02-E TRACKER position sensor evaluation pack includes an 11 mm long magnetic strip for 7 mm of travel, and provides a resolution of 2 microns. Its on-chip encoder provides direct digital output, eliminating the need for an A/D converter.

SQUIGGLE motors in closed-loop systems - some examples

Phone camera modules

Some of New Scale's smallest closed-loop systems to date have been created for the phone camera market, to move lenses for focus and zoom. This market requires the smallest sensor possible, with resolution on the order of tens of microns or better.

We have created several such systems. One uses an SQL-1.8 SQUIGGLE motor to push lens holders along rails (Figure 1). **TRACKER miniature encoders** are integrated into the device and provide feedback resolution of 2 microns. The complete system includes two lenses, two motors and two encoders, in a module measuring only 6.5 x 13 x 23 mm. Both motors are driven by the NSD-1102 dual piezo motor driver ASIC.

Lock modules

For electronic lock applications, tiny size is prized but the required motion is simpler: the motor must move from as fast as possible from its reverse limit (lock open) to its forward limit (lock closed) and back. For this and similar applications, a standard SQL Series SQUIGGLE motor can be integrated with simple limit switches to indicate the end of its travel range.

Small stages

New Scale has also created several closed-loop positioning stages. The model SQ-2115 linear stage (figure 2) has superior resolution (0.020 microns) and long, 15-mm travel. We used a linear optical encoder and an SQ-100 series SQUIGGLE motor inside the body of a 63.5 x 63.5 x 17 mm (2.5 x 2.5 x 0.66 inch) stage. The incremental encoder counts pulses and has a zero reference built in to give a repeatable position on startup.

By centering the optical encoder in the body of the moving stage we achieve the most accurate position feedback possible. In comparison, some motors use a rotary encoder on the motor shaft as a sensor. This does not see any errors from the gear box, coupling or backlash of the slide, resulting in lower precision.

A custom linear micro stage (figure 3) is a smaller example, at only 25 x 25 x 10mm (0.98 x 0.98 x 0.39 inches). This stage uses a Hall Effect magnetic position sensor inside the stage body. A benefit of the Hall Effect sensor is that it acts as an absolute position sensor: working by measuring the field along a magnetic strip, it retains position information even after power-down cycles. An SQL-3.4-10 SQUIGGLE motor is mounted onto the bottom plate and the screw pressed against the end of the top plate, which is spring loaded against the screw. Used with the MC-1000 controller, this closed-loop stage has 10 microns resolution over 2 mm of travel. New scale is developing a high-resolution controller option with 16-bit A/D converter to achieve a resolution of less than one micron.

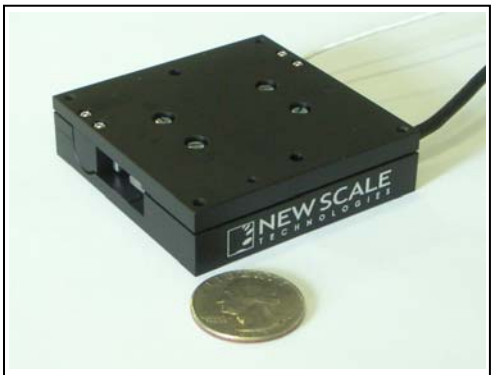

Figure 2 - This high-resolution closed-loop stage has 0.02 micron resolution and measures 63.5x63.5x17 mm. It uses a linear optical encoder and an SQ-100 series SQUIGGLE motor.

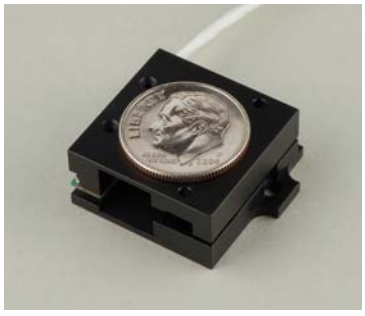

Figure 3 - This smaller closed-loop stage has 10 microns resolution and measures 25x25x10 mm. It uses a Hall Effect sensor and an SQL series SQUIGGLE motor.

Controllers

New Scale's SQUIGGLE motor controllers can accept an analog or digital quadrature (RS-422) signal from a position sensor to provide closed-loop operation. The software provided allows the user to define the range and resolution, which are then used in the positioning commands.

The electronics use PID (Proportional, Integral and Derivative) controls to actively tune the response of the motor to the feedback signal. These coefficients are interactive and work to keep the motor speed from leading, lagging or oscillating with respect to the sensor feedback signal.

Standard New Scale controllers include a 10-bit A/D converter. A new high-resolution OEM control board features a 16-bit A/D converter for higher resolution of the analog feedback signal.

In summary, closed-loop control systems provide repeatable and accurate positioning in tiny modules that take full advantage of the SQUIGGLE motor's small size and high precision. New Scale has demonstrated a number of miniature closed-loop systems, and works with OEM customers to design complete closed-loop systems that meet unique requirements. As position sensors and control electronics continue to improve, we expect to see even greater resolution and precision in tiny packages. Contact us today to discuss your needs for closed-loop miniature motion systems.

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