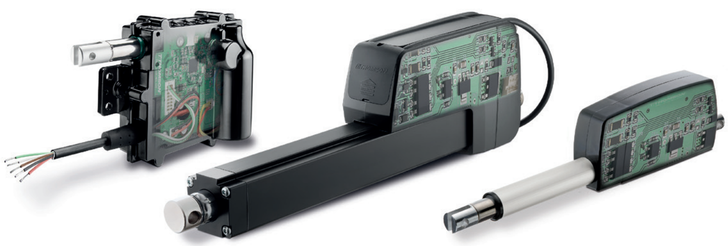
The Fundamental Benefits of Smart Actuators

How a new generation of intelligent electromechanical actuators is extending the scope of industrial automation and reducing costs

Executive Summary

The incorporation of programmable microprocessors into motion control devices a decade or so ago has provided a wave of innovation that is just beginning to take hold. Spurring that innovation is a new generation of software-programmable actuators designed to participate in standard network architectures. This extends motion control automation to previously undeveloped functions, while enabling absolute position feedback, low-level switching, synchronized load balancing, improved monitoring and diagnostics, with environmental resistance. The benefits include safer operation, enhanced motion control, increased uptime and lower overall operating costs.



Introduction to Smart Actuators

As digital transformation of global industry accelerates, a new generation of actuators is emerging to drive motion control innovation and operational effectiveness to new heights. By incorporating onboard intelligence, standard network protocols and environmental hardening, the latest generation of electromechanical actuators is providing a smarter, safer and cleaner alternative to hydraulic or pneumatic solutions for most applications — from small surgical robots and plant floor material handling to large off-road agricultural and construction vehicles.

Starting in the 1990s and blossoming in the new century, embedding microprocessors into actuator housings has enabled consolidation of formerly device-based functionalities such as switching, position feedback and system diagnostics into programmable software operations. This not only reduces installation, operation and maintenance costs but also provides a more flexible, expandable infrastructure for future innovation in motion control.

Smart electromechanical linear actuators, such as the four Thomson Electrak® HD units shown here, help engineers design machines with components that communicate with each other and operate without the need for manual interaction.

Embedding microprocessors into actuators meets market demand for greater safety, functionality and modularity. Key to this shift is the actuators' ability to support standards-based networking.

Performance Optimization

While onboard electronics themselves improve position monitoring and control, fulfilling the emerging promise of the digital transformation also requires support for standard networking architectures that will enable more complex optimization strategies. Standards compliance simplifies system design and enables technology from multiple vendors to talk to each other. Among the industrial communications standards commonly deployed are PROFINET, HART and Ethernet/IP, but one that is emerging as particularly valuable for many actuator-driven applications is the J1939 CAN bus protocol.

J1939 provides a standard messaging structure for communications among network nodes under control of an electronic control unit (ECU). Every message on an actuator module representing a J1939 bus node has a

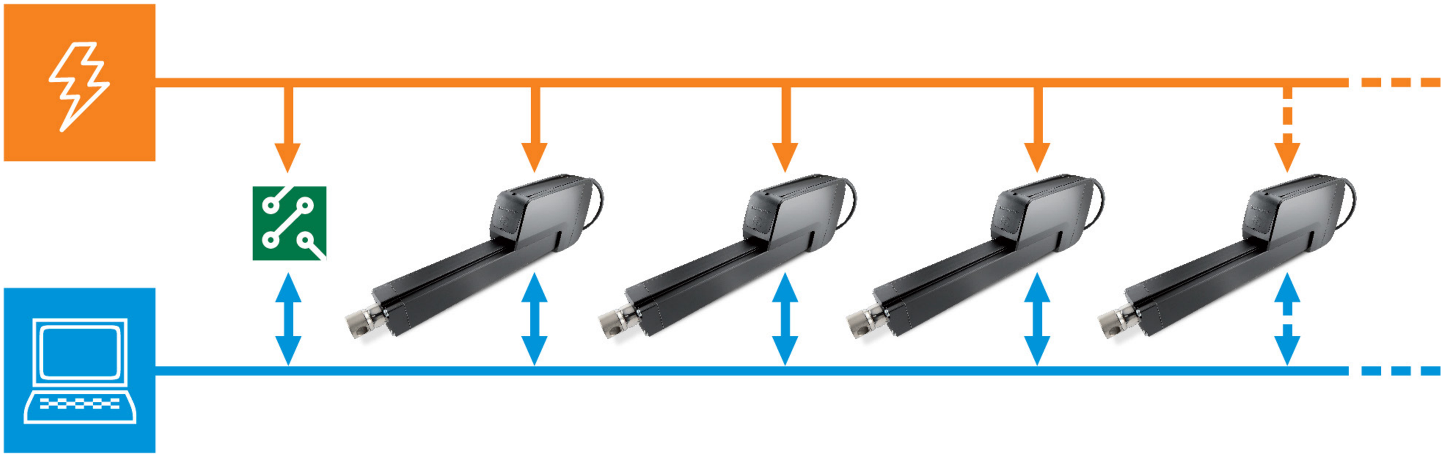


Figure 1. CAN bus network architecture. With just two wires for power (orange line) and two for network communications (blue line), smart actuators provide efficient, compact communications with each other and with gears, sensors and other devices (green box).

standard identifier indicating message priority, data and ECU source. This enables plug-and-play interchanges of supporting devices that share the same network and comply with the messaging structure.

Figure 1 shows a typical CAN bus network, illustrating four actuators with built-in CAN bus-compliant intelligence and connected directly to both a battery and control source. The green box represents gears, sensors or other components that could also be connected to the network. The orange line represents the two-wire bus that transmits the low voltage of power needed for the system, and the blue line represents the wires that are used for information exchange. The result is an efficient, compact solution that enables real-time performance monitoring and advanced control.

With onboard J1939 compatibility, actuators speak the same language as the ECU, allowing device and application communication across a shared bus. This is dramatically different from conventional electronic architectures, which require a standalone ECU for each operation. This also enables more complex control strategies, for example, deploying the same actuator in multiple applications.

Although originally developed for off-highway applications, J1939 is increasingly applied across many industries and applications.

Extending the Scope of Automation

Linear actuators have always represented the point at which automation strategies intersect with the physical world. Cutting-edge intelligence and communications capabilities open the door for involvement in new applications and operational efficiencies, many of which are already happening.

Complementing the fundamental programmability built into today's actuators are the following five capabilities realized through the combination of onboard intelligence and J1939 networking: absolute position control, low-level switching, synchronized load balancing, improved monitoring and diagnostics, and environmental resistance.

Advantages of a J1939 CAN Bus for Smart Actuation

Power is distributed across common wiring, eliminating the need for separate wiring between each device and the power source.

Switching is embedded in the actuator electronics, eliminating the need for cumbersome external switching and connectors, etc. All commands are executed in the actuator.

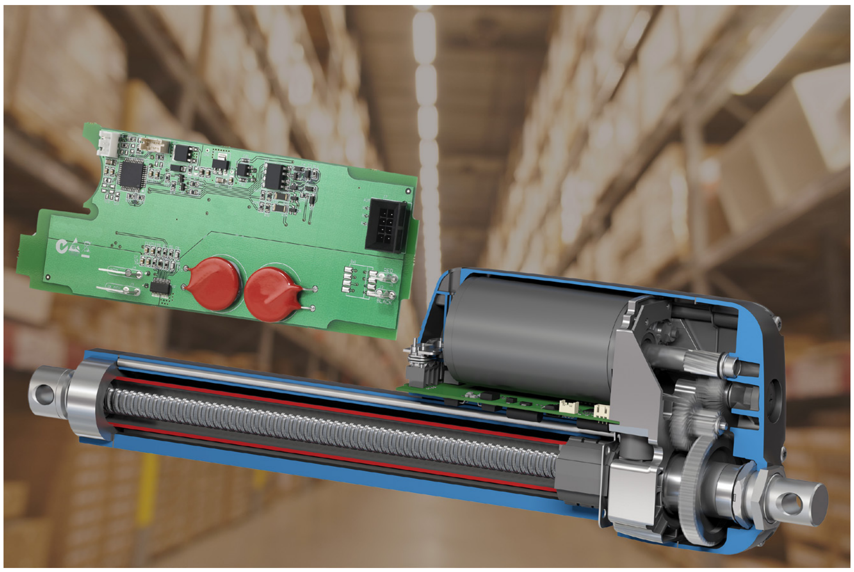
Information flows to an electronic control unit (ECU) from each device via the network bus, eliminating the need for independent connections between the devices and the ECU.

Other equipment that might be integrated into the system connects with the network in the same way, eliminating the need for separate wiring, controls and additional configuration.

A typical CAN network supports up to 256 nodes, including multiple actuators or other devices on each node – something that would be all but impossible with a conventional network.

Absolute Position Feedback

Position control with an embedded J1939-compliant actuator is superior to that of a hydraulic actuator because it provides an absolute reading of position. The potentiometer device providing position feedback is mechanically linked to the screw inside of the actuator, which enables it to provide a consistently accurate stroke measurement regardless of actuator power loss or disconnect.



Smart actuators integrate electronics within the actuator housing, enabling switching, synchronization and networking to be managed automatically based on signals from a common external source, such as a programmable logic controller (PLC).

A 14-bit signal informs the user of the actual actuator stroke position between 0.0 mm and a fully extended stroke, the accuracy of which depends on the stroke length and mechanical tolerances of a given model. Accuracy of the signal itself, for example, could be 0.1 mm/bit, which could contribute to overall system positional accuracy of +/- 0.5 mm or better depending on tolerances in the gearing, ball nut and screw assembly.

Achieving that kind of positional accuracy on a hydraulic system is expensive and hard to maintain. Instead of receiving a consistent electronic signal, monitoring the position of hydraulic actuators requires measuring the amount of fluid that is being pumped through the lines and then using externally mounted encoders and limit switches to signal a control box when the desired points have been reached. Interpreting this requires external potentiometers, encoders, limit switches, controls and pumps to keep fluid in motion throughout the system. When pumping stops, system creep affects the position and requires recalibration. It also renders hydraulic actuation much less effective for heavy duty applications requiring consistent, high-precision position control over longer periods.

Smart actuators allow for encoding, limit switching and potentiometer functionality with software to deliver absolute position feedback immediately. Absolute position control also enables consistent, reliable position memory. Because many mobile off-highway (MOH) machines are run by the season and might sit idle for eight or nine months, for example, it is sometimes valuable to disconnect the battery to prevent it from draining. Without absolute position capability set at the factory, the user will have to recalibrate every time they disconnect and reconnect the battery.

Such advanced position control and switching enable the actuator to perform with an infinite number of movement profiles and custom motion strategies. Users can, for example, program the actuator to seek forward a few millimeters or make a small set of movements back and forth to reach a desired position. And because the system knows what it is supposed to do and monitors performance in real time, it can flag potential variances and trigger advanced algorithms to manage further alarms and corrections or shut down.

Low-Level Power Switching

Low-level power switching is another valuable feature of smart actuators. The J1939 protocol allows operators to program the actuator to extend, retract or stop smoothly using low-level electronic signals rather than a higher-energy electrical current. This improves safety by providing an interlock function and simplifies design by enabling the user to switch the actuator's direction using low-level current.

With low-level power switching, inrush can be to up to twice the full load amperage for up to 150 milliseconds, as compared to four times the full load current provided by a standard actuator. Using only about half the standard current load to switch the actuator allows a direct connection to a programmable logic controller (PLC). This eliminates the need for expensive relays and the related installation costs and simplifies the control scheme. Low-level switching also improves safety, saves energy, and provides a smoother start to the movement profile. Manufacturers of logistics trains, for example, are increasingly

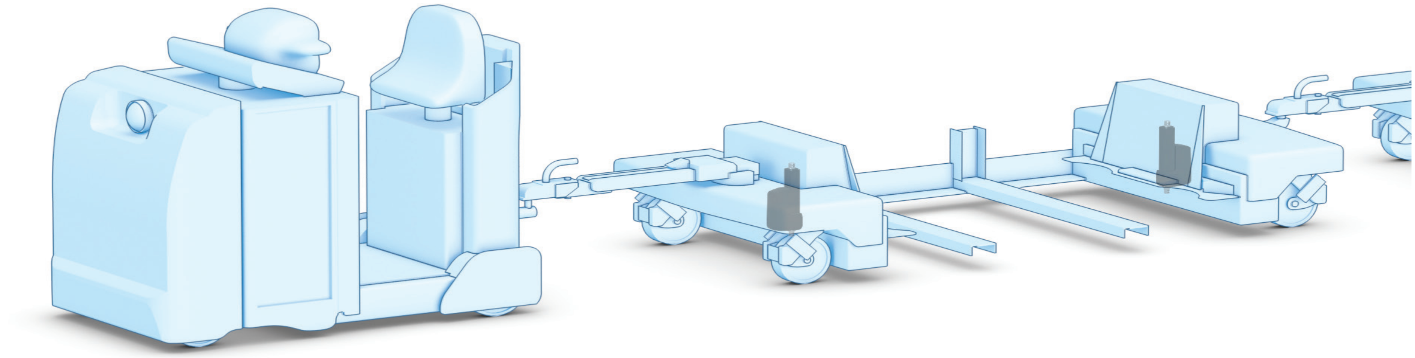


Figure 2. The Thomson Electrak® HD, with its built-in J1939 CAN bus capabilities, makes it easy to build intelligent logistics systems such as the material handling train shown here.

deploying smart actuators. (Figure 2) Some are combining PLC-compatible low-level switching with verified positioning and end-of-stroke shutoff to help increase load capacity, regulate operations and reduce maintenance.

Low-level power switching also improves safety by reducing the hazard of electrical shock and simplifying design by allowing lower-rated control components. Soft start capability also allows use of lower-rated power supplies and puts less stress on batteries and charging systems in vehicles. Low-level switching could also be programmed to put the actuator into a sleep mode when the actuator is idle, which would extend battery life by reducing energy consumption and battery drain.

Dynamic braking control is yet another benefit of low-level power switching. Once the power is cut to an actuator, inertia of the moving load could keep it moving between 5 and 10 mm before coasting to a full stop, depending on how the actuator is mounted. Dynamic braking reduces this coast by shorting the motor leads together and stopping the motor. Such low coast results in a much more accurate position and controlled load, improving repeatability and positioning capability.

Synchronized Load Balancing
With the J1939 model, system developers will have much greater flexibility to program the sensors and internal electronics to synchronize operations among multiple actuators. The simple two-wire architecture enables any actuator to know the position of any other actuator. With that data, actuators can configure units to vary in speed depending on load or change speed to compensate if units speed up or slow down.

Synchronization allows users to simplify their designs by implementing actuators or multiple lifting points in a platform or other mechanical structure. This helps spread and move the load evenly instead of relying on a rigid and sometimes more complicated structure. It also enables use of lower-load actuators in sync for lifting heavier loads that might otherwise rely on a large single cylinder that may be difficult to fit into the design.

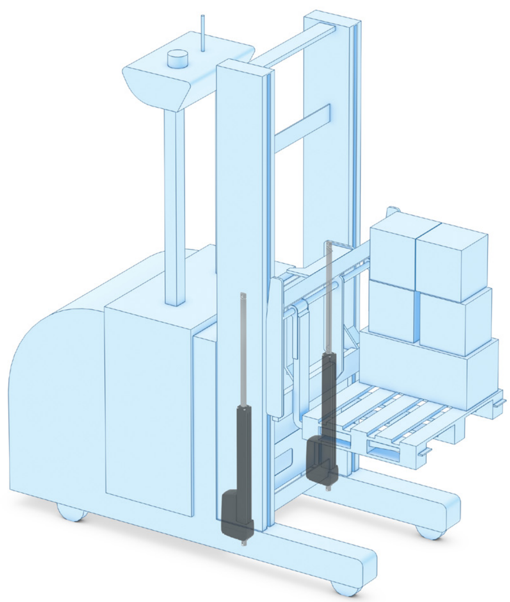


Figure 3. Heavy loads raised and lowered on this automated guided vehicle (AGV) benefit from the actuators' ability to synchronize and avoid an imbalance.

Synchronizing large work platforms. For large work platforms, synchronized actuators self-correct as loads shift. For assembly stations, they can provide similar ergonomic lift support for off-center or awkward loads.

Lift gates. For lift gates, synchronized actuators enable smoother handling without the complexity and maintenance requirements of a traditional hydraulic solution.

Material handling. For industrial logistics trains and other automated guided vehicles (AGVs), synchronized actuators automatically correct imbalances between the front- and back-end loads, or left- and right-side loads. (Figure 3)

Oven doors. Synchronized actuators enable smoother, safer opening and closing of oven doors.

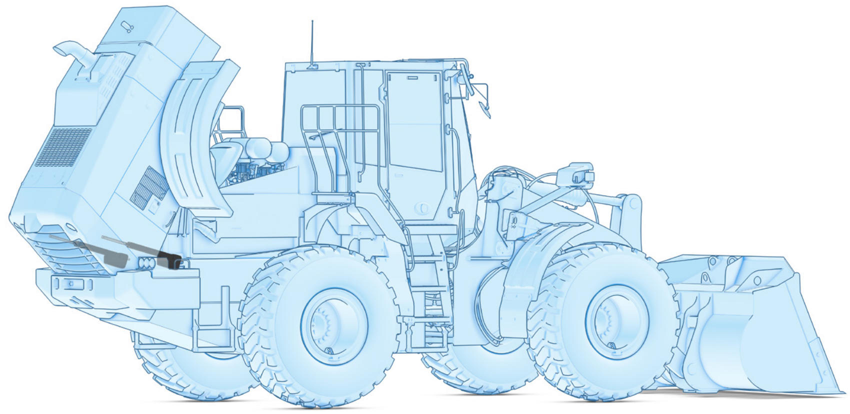


Figure 4. Synchronized actuators on the heavy hood of this front loader allow the operator to safely access engine components.

Agricultural combines. Combines require multiple motion control functions, which have traditionally been isolated or dependent upon multiple external structures such as switches and cables. Today, J1939 networking capability enables synchronization of two or more actuators, including those controlling a rock trap door, gate latch, ladder, grain tank and auger.

Hood lifting. For some MOH vehicles, standard operating protocols require raising the hood to check engine compartments before each run. As a trend toward larger engine compartments requiring heavier hoods continues to grow, however, these are becoming more difficult to handle. Deploying an actuator on either side of the hood helps raise and lower it, but larger hoods can buckle. Deploying an actuator on both sides of the hood and synchronizing them across a vehicle network, however, results in more ergonomic, safer and better maintained equipment. (Figure 4)

Patient care. Synchronization can be especially valuable in patient care applications where it can improve the quality of care by controlling operation of lift tables and columns, and stair lifts.

Improved Monitoring and Diagnostics

An actuator that fails at the wrong time could damage equipment or present a safety hazard, especially in heavy duty agricultural, construction and MOH applications. Conventional electric actuator designs, however, are more susceptible to continuous overloading, and can damage the motor and other components. Onboard intelligence can help prevent such incidents by providing users with an understanding of what is happening to the actuator without physically opening or inspecting it. Onboard electronics can answer questions like: How many cycles has it moved in the application? How much current is it drawing from the power supply? How much “life” does the actuator have left based on cycle count? How much voltage is left on the battery power supply? These questions are answered by a diagnostics package only available when the electric actuator is equipped with integrated onboard controls.

If the recorded temperature of the operations is higher than that for which the actuator is rated, for example, the electronics will guide the system to a safe shutdown. Feedback can arrive as quickly as ten times per second as the actuator constantly tests itself. If it detects a problem, such as surpassing a temperature threshold, the actuator finishes its programmed move – either fully retracted or extended – stops and sends an error flag to the computer, all in fractions of a second.

Onboard electronics also monitor for signs of unsafe loading. If, for example, an actuator that is designed to move a 2000-pound load with 18 amps of current, outputs an amperage that is beyond a factory calibrated trip point, the electronics will shut the unit down at the same point every time. To avoid productivity problems resulting

Smart actuators monitor the following system vital signs continuously and remotely

Current. Current monitoring is a critical safety feature that shuts down the actuator on overload and eliminates the need for the traditional noisy, mechanical clutch.

Voltage. Continuous monitoring of voltage protects the actuator by preventing motion if it detects it operating in an environment outside of the acceptable range.

Temperature. Internal temperature is monitored and, if outside the acceptable range, the actuator is shut down after extending or retracting stroke. Built-in temperature compensation allows the actuator to push the rated load at lower temperatures without nuisance tripping.

Load. Trip points can be calibrated at assembly to assure repeatable overload trip points independent of component and assembly variations. This not only assures repeatable performance but relieves the user of having to recalibrate in the field.

from nuisance tripping, the electronics will even compensate for operation in lower temperatures.

With integrated electronics, all such functionality is available instantly to the user and, via the network, it is potentially sharable in support of external troubleshooting. Once problems are identified, the plug-and-play capability gained by integrated standards simplifies repair and replacement. Where replacing a problematic hydraulic actuator might require a service call from the manufacturer that could demand hours or even days of disassembly, reassembly, system bleeding and testing, a smart actuator can be replaced in less than 20 minutes.

Moreover, system health monitoring can occur remotely. For example, an OEM support technician in Iowa can log into a combine in North Dakota to diagnose a failed actuator by analyzing electronic message flags on temperature, position, current and input voltage.

Environmental Resistance

The ability to monitor themselves not only makes smart actuators easier to operate and maintain, their complex electronics also present a level of vulnerability that make this monitoring essential. Ensuring reliable operation requires designing smart actuators to meet the most stringent industry standards for protection from ingress by solid objects and liquids, extreme temperatures, operational shock, vibration, corrosion, voltage variation and electromagnetic interference.

Not every actuator must be protected from all environmental assaults, and each OEM requires its own profile of standards. Likewise, vendors have developed their own sets of procedures for meeting those standards. A major advantage of actuators that embed previously external devices is that compliance with the appropriate standards is done at the factory and need not be repeated once the systems are installed.

Cost Justifying Electromechanical Motion Control

What we have discussed so far are just a few examples of how smart actuators are changing industrial operations, mostly via J1939-based applications. Below are a few more examples of how smart electromechanical actuators are enabling automation that can pay for itself many times over.

- Certain industrial tasks such as raising or lowering a conveyor to handle cartons of various sizes are performed too infrequently to cost-justify automating. These can now be handled cost efficiently with smart actuators because of minimal external infrastructural requirements.
- In building automation, actuators controlling window louvers that regulate the amount of light entering a building, for example, can be programmed to follow the sun to regulate the entry or obstruction of sunlight into a building at various points throughout the day. For larger, heavier solar panels, J1939 has been applied to regulate operation, tracking the sun's position and optimizing exposure to sunlight, while minimizing impact of wind shear and reducing the need for specialized supports.
- In robotics, users of an automated valet parking system use their mobile phones to signal that they are ready to pick up their cars, and an actuator-driven, robotic assembly locates and delivers their car to them.
- On the plant floor, smart actuators installed within AGVs that receive goods from conveying stations and transport them to other stages of operation are also benefitting. As the AGV approaches a conveyor, it signals an actuator to open a hatch and uses image recognition technology to select the desired goods. Once filled, the AGV moves to the next station.

Smart electromechanical actuators are especially cost efficient when compared to hydraulic alternatives. Instead of the cumbersome collection of pumps, valves, reservoirs, messy fluids, hoses and costs needed to operate the hydraulic system, electromechanical actuators provide a single, clean running device that occupies a fraction of the space. Instead of extensive maintenance, installation and material costs, you can enjoy an actuator that is easily installed and requires no maintenance thereafter.

As interest and innovation in integrating smarter devices into industrial control schemes grows, it sets the stage for even greater innovation. Coupled with advancements in robotics, connectivity, cloud computing, artificial intelligence, data analysis, mobility and numerous other areas, smart actuators will continue to push global industry to new plateaus of efficiency and economy.

Thomson Industries, Inc. offers a full selection of smart electric linear actuators to match the requirements of various applications. Visit www.thomsonlinear.com/smart for details.