Allied Motion

Motion Solutions That Change the Game

Understanding Electric Traction and Steering for Robotic Vehicles

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Electric Traction and Steering Solutions Provide Rugged, Economical, User-friendly Solutions for Autonomous Robots, AGVs, Lift Trucks, and Similar Vehicles

Smarter, better, cheaper, faster — those words are the mantra of today's global economy. As organizations seek to streamline operations and do more with less, they increasingly focus on advanced logistics vehicles and mobile robots to help get the job done. From smart warehousing in retail to materials handling in manufacturing to telepresence robots in healthcare, robotic vehicles constitute a fast-growing technology sector. Indeed, by 2022, analysts expect the global market for automated guided vehicles (AGVs), alone, to reach $2.65 billion[(1)]. To meet demand, OEMs will need electric traction and steering technologies and products that perform unquestionably. Those assemblies also must be rugged, economical, and easy to install, operate, and maintain. Electric traction and steering solutions deliver on all counts.

Service robot deployments are increasing, but industrial and logistics applications dominate today's automated vehicle market. The types of vehicles in widespread use include warehouse and factory-floor trucks, hoists, pushers, tuggers, and various types of mobile robots. They move unit loads from point to point, put items on and off shelves, fill pallets, load and unload trucks, and assist humans in doing their work. They are operated under a variety of environmental conditions, including extreme heat and cold; dirt, dust, and moisture; and more.

Traction and steering solutions can be divided into two classes: electrical and hydraulic. We won't cover hydraulic-based solutions here, except to acknowledge the use of electric motors to drive the pumps in electrohydraulic applications. Electric steering and traction solutions are cleaner than their hydraulic counterparts and comparatively more efficient.

Electrically driven vehicles can be quite competitive with hydraulic versions. Typical electrically driven AGVs can handle loads of up to 20,000 pounds, for example. They are normally battery powered and can be programmed to automatically return to their charging stations when required. They are clean, quiet, and more precise than hydraulic solutions. This combination of characteristics makes electric actuators appealing for a wide range of industrial and service vehicle applications.

Understanding the Application

Choosing the best traction or steering solution for a logistics vehicle or mobile robot starts with a detailed review of the requirements. As with most automation systems, the specifications include load, torque, speed, acceleration, and duty cycle. For the types of specialty vehicle applications described above, however, there are some special nuances.

Load: The load for an industrial vehicle includes the weight of the unit load and the weight of the vehicle itself. These vehicles are typically supported on some combination of active wheels (drive wheels) and passive wheels (casters). The drive wheels apply the torque. The casters simply help to distribute the weight. In some cases, casters are fitted with steering actuators. Choosing the right traction solution requires understanding how the weight of the vehicle and load will be shared among the drive wheels and casters. This distribution may change depending on whether the vehicle is loaded or unloaded.

Wheels and operating surface: In addition to determining the number and location of drive wheels and casters, OEMs need to analyze the characteristics of the wheel's tire, the operating surface, and the interface between them. The rougher the surface of travel, the greater the rolling friction and, hence, the greater the maximum and continuous torque levels needed to meet acceleration and constant-speed requirements. These numbers also can be affected by the characteristics of the tires, in terms of width and material. A wheel with a narrow, slick tire running on a smooth surface will need to generate considerably less torque to achieve a desired performance than a wheel with a wide tire running on loose gravel, for example.

Turning radius: The required turning radius of the vehicle has a direct impact on vehicle design and the characteristics of the traction and steering actuators. Also, the allowed overall height of the vehicle will at least partly define the clearance available for the wheels. This can limit wheel diameter, which, in turn, affects the wheel-drive motor speed and torque required.

(1) Automated Guided Vehicle Market - Global Forecast to 2022, Markets and Markets, April 2017

Peak torque: Peak torque is calculated using the acceleration torque required for the application. Again, this can be affected by factors like incline, surface texture, and tire material, but mostly by the inertia of the loaded vehicle.

Braking and holding torque: It is essential to know the requirements for static and dynamic performance, both in a power on and power off condition. Specialty braking requirements also should be considered. Does the vehicle need emergency stop capabilities? Does a holding brake need to be applied, for example in the event of power failure?

Average power: Actuators need to be sized to the worst-case scenario, taking into consideration factors like incline, rolling friction, etc. Average power is also determined by the speed and acceleration profiles, and duty cycle (frequency of vehicle starts and stops).

Power source: Is the vehicle battery-operated or is it fed from a generator that's driven by an "ICE" (Internal Combustion Engine)? What are the voltage rails of the system? Are there current limitations? What is the desired operating time per charge?

Environment: Environmental conditions must always be taken into account when selecting components. Will the vehicle be used inside? Outside? Both? What is the operating temperature range? Will it be exposed to contaminants such as dust, moisture, or corrosive chemicals? How about salt spray?

Shock and vibration: Shock and vibration can be influenced by a variety of factors. The higher the operating speed, the greater the shock level introduced by collision. Uneven surfaces can introduce vibration, especially when traversed at high speeds. It is important to evaluate these factors, which can be surprisingly high. Some warehouse applications can subject equipment to shock loads of up to 80 g.

Electric Traction Solutions

Traction actuators provide motive power to the vehicle drive wheels. Although traction solutions can provide some steering functionality by controlling the relative speeds of drive wheels, their primary function is to move the vehicle. Key considerations for choosing or designing traction solutions include torque, speed, efficiency and size.

It is important to choose the best solution for the application, a process that begins with the wheel motor. Options include brush DC motors, brushless DC motors, stepper motors, and AC synchronous or asynchronous (induction) motors ***(see http://tinyurl.com/ycdugugu).*** As in most aspects of engineering, there is no single ideal solution. The optimal choice depends upon the requirements of the application, including the factors listed above, and involves a number of trade-offs (see table 1). That said, the most common motor selections tend to be brush or brushless DC motors, and AC synchronous motors, with brushless motors increasing in popularity. Stepper motors are effective for very specific, low-power niche applications. AC induction motors are also used in some wheel drives.

AGVs and other autonomous vehicles or mobile robots are most commonly driven by one or more independent powered wheels. This approach provides a great deal of design flexibility in terms of torque and acceleration while being compatible with a variety of steering configurations. Other approaches for powering vehicles exist; most notably, non-powered wheels connected by a transaxle that is in turn powered by a drivetrain. This is outside the scope of this discussion, however.

We can divide powered-wheel traction solutions into two classes: discrete and integrated. Discrete traction assemblies consist of a collection of individual components that are typically located away from the wheel itself (off-wheel designs). In an integrated design, the motion components are integrated into the wheel assembly itself, whether as part of an integrated package (on-wheel designs) or connected directly to the wheel (in-wheel designs). Let's consider each class in detail.

Table 1. Comparison of motors for traction-wheel solutions

Type	Advantages	Disadvantages	Best used for
Brushless DC and AC Synchronous Motors	- Highest power density - Highest efficiency - No wearing components	- Higher cost - Requires commutation drive	- Weight/efficiency critical applications (e.g. mobile/battery operated equipment) - Greater than 2000 hours of operational life
Brush Motors	- Medium power density - Lower cost - Simpler motor control	- Includes wearing components (i.e. brushes) - Increased maintenance	- Simple, low-cost DC-powered applications - Less than 2000 hours of operational life
AC Induction Motor	- Lower cost - No wearing components	- Lower power density & efficiency - Higher space claim	- Large applications for which weight and efficiency are not critical - Greater than 2000 hours of operational life

Off-wheel Traction Solutions

In an off-wheel traction solution, one or more electric motors transmits power to the drive wheels. Locating the motor away from the wheel assembly can provide useful degrees of freedom in the mechanical design of the vehicle.

Off-wheel traction solutions use a drivetrain to transfer power from the motor to the wheel. The most common drivetrains include belt and pulley, chain and sprocket, or gearbox and coupling. All three can be used to confer a mechanical advantage, decreasing the size and cost of the motor. As with the motors, the different types of drivetrains involve trade-offs (see table 2).

Depending on the cost of the drivetrain, the architecture may lead to lower cost of ownership. On the downside, the addition of the drivetrain increases complexity, maintenance, points of failure, and space claim. For best results, the options need to be carefully analyzed in the context of a given project.

Off-wheel designs offer several benefits. Without the constraint of building the motor into the wheel or directly adjacent, OEMs have greater ability to modify performance, size, and configuration. The choice of drivetrains adds another degree of design freedom. The distributed architecture makes it easier to add accessories such as encoders, holding brakes, and drives.

Off-wheel designs enable the motor, mechanical components, and electronics to be in protected areas of the vehicle. This location can reduce exposure to shock and contamination, increasing lifetime and reducing the chance of unplanned downtime.

On the downside, off-wheel designs are less efficient than integrated designs because of drivetrain and coupling losses. The presence of multiple mechanical elements reduces reliability. The latter point can be addressed by component choice—a planetary gearbox rather than a worm gear, for example—but that may affect cost, size, and audible noise.

Belt and pulley or chain and sprocket drivetrains tend to be exposed to a significant amount of contamination. This vulnerability introduces the need for regular cleaning and lubrication to prevent early failure, although wear is unavoidable nonetheless.

Perhaps the biggest drawback to the discrete approach is the amount of additional engineering and assembly required of the OEM. Instead of buying and installing a single unit, OEMs need to research, specify, and assemble each component. In general, discrete designs tend to cost more than integrated packages simply because vehicle manufacturers may not have access to the economies of scale introduced by volume manufacturing. Integrated traction solutions provide a better alternative for most situations.

Table 2: Comparison of off-wheel traction-wheel power trains

Type	Advantages	Disadvantages	Best used for
Belt and Pulley	- Economical	- Higher maintenance—belts require tensioning - Limited lifetime—belts wear out - Bulky	- Light loads - Budget-sensitive projects
Chain and Sprocket	- Can transfer higher torque - More robust than belts and pulleys	- Higher-cost precision machining - Sprocket teeth wear over time - Higher maintenance—lubrication	- Larger vehicles with higher weight, more power
Gearboxes (Planetary Type)	- Higher mechanical advantage - Good efficiency - Lower maintenance - Longer life - More compact	- Some backlash - Higher cost	- High-weight vehicles with limited space

Integrated Traction Solutions

In an integrated traction actuator or powered wheel, all elements required are contained within a single assembly. The approach virtually eliminates engineering costs for the OEM compared to off-wheel designs. The OEM chooses the traction solution with the desired performance and features, and installs it as a single purchased component for their product. Integrated traction solutions can be further subdivided into two types: in-wheel designs and on-wheel designs.

In-wheel traction solutions: In an in-wheel traction solution, a brushless electric torque motor is directly integrated into the wheel. The stator windings are affixed to the wheel mounting structure and vehicle frame, sometimes through a suspension of some type, while the rotor magnets (we'll consider only permanent-magnet motors here) are integrated into the wheel hub.

Torque motors for in-wheel designs fit entirely in the wheel, and usually within the axial width dimension of the wheel and tire, making for a compact, low-space-claim solution (see figure 1). They do not require any sort of drivetrain or coupling.

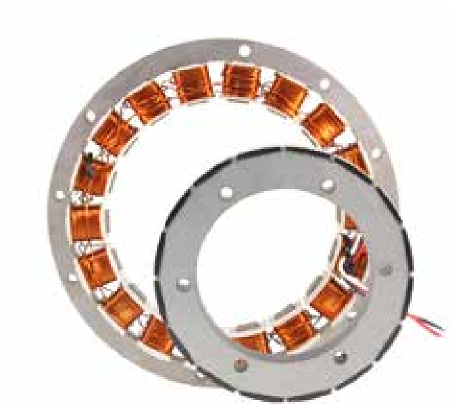

Figure 1: In-wheel motors consist of electric torque motors built directly into the rim and hub of the wheel.

In-wheel solutions do exist that use housed, pancake-form motors, but these solutions also have gearing integrated into the wheel.

The power and torque capability of direct-drive in-wheel torque motor designs are dependent upon the restrictions of available envelope size. Wheels for logistics vehicles tend to be standardized around certain diameters. For an in-wheel traction actuator, the motor must fit within the wheel. While motor performance can be finessed by winding and magnet design, at the end of the day, diameter and wheel width set an upper bound on torque.

In general, in-wheel traction solutions are reserved for applications in which space claim and/or audible noise are bigger concerns than budget. Military and security applications, for example, may be good fits.

On-wheel traction actuators: An on-wheel integrated traction actuator is an assembly built and delivered as a single element (see figure 2). It's a hybrid design, combining the benefits of the off-wheel and in-wheel approaches. OEMs purchase a single part, prebuilt to interface with the vehicle frame. Only bolting of the assembly to the chassis and connecting the wiring harness are needed. Performance and interoperability have already been validated by the traction actuator manufacturer.

Figure 2: The WheelMax™ wheel drive from Allied Motion incorporates motor, gearbox, and feedback, along with accessories, in a single unit.

The specifics of on-wheel traction-wheel designs vary depending upon the application and manufacturer. At its most basic, an on-wheel integrated traction wheel incorporates a tire and wheel, a mounting structure, a motor, a gearbox, and a commutation feedback device for those cases in which a brushless motor is used. More sophisticated versions may include on-board electronic drives, position feedback, and accessories such as holding brakes.

On-wheel traction actuators use standard motors, making the approach simpler and less expensive than in-wheel designs. The inclusion of a gearbox lowers torque requirements for the motor, which reduces its size, weight, and cost. Minimizing space claim is essential for logistics vehicles and robots, and cost control is a factor for every OEM. Incorporating a gearbox does increase complexity and points of failure, but because it's built into the assembly, it can be sealed to provide ingress protection and lubricated-for-life performance.

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Probably the biggest advantage of an on-wheel traction drive is that it is built of components selected and integrated by the manufacturer to address the challenges of industrial vehicles. This approach enables the standard wheel to deliver a higher level of performance than discrete off-wheel designs. At the same time, it needs less space, and engineering and assembly costs for the OEM are less. The on-wheel traction actuator also provides a standardized design platform that can be customized by the manufacturer to suit the OEM (see figure 3).

Figure 3: Cutaway shows a design concept for a 14-inch (356 mm) diameter on-wheel traction-wheel drive. This wheel consists of the wheel with tire, cycloidal gearbox, brushless torque motor with commutation feedback package, and parking brake.

Although on-wheel integrated wheel actuators offer many benefits, they are not ideal for all applications. For budget-sensitive and/or low-volume vehicle projects, an on-wheel, integrated type traction assembly may be overkill. However, for OEMs wanting an all-in-one solution that involves less work on their part, the on-wheel or integrated wheel drive is an attractive approach.

Electric Steering Solutions

Logistics vehicles and mobile robots need to be steered to specific locations, rapidly and accurately. Increasingly, that task is performed by electric power steering (EPS) systems. As with traction solutions, electric vehicles impose specialized requirements on the architectures and components chosen for electric steering.

Motion type: The simplest motion requirement is a straight line. In some cases, the vehicle is mounted on rails and does not require steering, just motive power from the drive wheels. At the next level of complexity, vehicles are steered by driving fixed traction wheels at different speeds (see figure 4). This differential-speed approach can provide some maneuverability. When applied to very tight or rapid steering operations, however, this method can wear out the tire material and stress the joints where the wheels attach to the chassis.

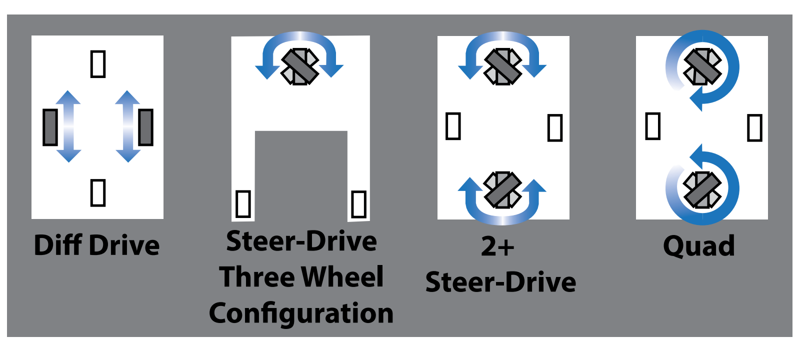
To support motion perpendicular to the line of travel (crabbing) the vehicle needs at least two actively steered wheels capable of rotating 180°. An exotic solution like a Mecanum or Omni wheel can also support crabbing, but these are not considered here.

Does the vehicle need to rotate in place, that is, revolve on an axis? In that case, it needs two-to-four actively steered wheels, each with a minimum of 360° of rotation, or at least two wheels on a centerline of the vehicle that can rotate in the same direction simultaneously.

Turning radius: Turning radius likewise impacts design architecture. A three-wheel counterbalance truck riding on a single drive/steering wheel and two casters will have a fairly large turning radius. A vehicle with four steered wheels, each able to rotate 360°, will have the smallest turning radius and the most flexibility for other movements without resorting to the exotic wheels mentioned above.

Turning radius may also impose limitations on the size of wheels or motors that can be used in the vehicle. Especially in the case of small vehicles, OEMs must take care to ensure sufficient clearance for the steered wheel(s) to avoid any contact of the wheel and chassis during operation.

Figure 4: Common steering architectures for logistics vehicles include (from left) differential-speed steering, steering with a single steered wheel coupled with two fixed casters, steering with two steered wheels capable of turning 180°, and steering with two steered wheels capable of rotating at least 360°. (Courtesy of Transbotics Corp.)



Torque: As with traction solutions, the load, driving surface, and tire material all affect the amount of torque required to steer the wheel. The velocity of the vehicle also has a major effect on torque demand. Pivoting the steered wheels of a fully-loaded forklift truck at standstill requires substantially more torque than when the truck is in motion. Steering motor and gearbox must be sized to deliver sufficient torque to address this extreme scenario.

Sensor type: Forklifts, AGVs and similar equipment may operate in very tight quarters. The control steering algorithm and/or human operator need to have accurate knowledge of wheel angles, so wheel position sensing and feedback are necessary. Relative wheel position feedback is economical but it does require a homing sequence at startup to establish a known steered wheel position (see figure 5).

Absolute position sensing is a better alternative, but has traditionally involved the use of proximity sensors or multiturn absolute positioning sensors. These add cost, but there is a more economical solution available. This approach cleverly uses Hall-effect sensing in the traction actuator's gearing to establish absolute wheel position without any need for a homing routine.

Safety: Especially in the case of vehicles moving in proximity to humans, safe operation is of utmost importance. As a result, the industry has evolved a comprehensive set of safety standards. Meeting these standards requires a combination of redundant systems and specialized hardware. In the case of a steer-by-wire system, no mechanical steering linkage exists. The system must detect any problems, quickly bring the vehicle to a complete stop, and then apply a brake.

Reliability: For operations designed around the performance of automated systems, vehicle downtime—even if production equipment is running just fine—can still impact productivity. It is essential that systems perform while simultaneously remaining economical enough to be viable solutions. Reliability is particularly important in the context of the recent industry shift toward service-oriented models. OEMs increasingly sell the service of moving goods, and thus uptime, rather than the vehicles themselves. In this case, reliability is not just a selling point but an essential aspect of the business.

Figure 5: In this integrated traction-wheel assembly with steering package, the right-angle permanent-magnet gear motor turns a pinion that rotates the wheel about its centerline. The small white pinion and blue sensor provide feedback information to the vehicle controller to indicate the position of the wheel.

Integrated Electric Power Steering (EPS) Assembly

One common type of EPS assembly consists of an electric motor mechanically coupled to a swivel-mounted wheel (see figure 6). The EPS unit incorporates a pinion gear that turns a steering gear fixed to the wheel assembly. The EPS can then rotate the steered wheel as commanded by the control system (or operator, in the case of manual control).

Figure 6: Allied Motion's EPS90 integrated steering motor actuator, shown with the SWS steering wheel sensor accessory, includes the motor, gearing, feedback sensor, and power and control electronics.

The system controller gathers input from integrated sensors in the EPS actuator and calculates path commands that it sends to the drive electronics of the EPS. Communication takes place over a fieldbus and/or wireless Ethernet network. The most common protocol used is CANopen. As mentioned, this approach is referred to as steer-by-wire because no mechanical steering linkage exists between the operator's steering wheel (or the vehicle's controller in the case of non-manually steered vehicles) and the steered wheel.

Electric steering solutions generally include gearboxes for mechanical advantage, which enables the steering assembly to generate sufficient torque using a smaller, less expensive motor.

Ideally, steering actuators should be located as close as possible to the wheel, preferably integrated with the wheel assembly. This minimizes intervening mechanics that couple the steering unit to the wheel.

Depending on the vehicle, a vertical orientation of the traction and/or the steering motor may be preferable (see figure 7). This configuration can take advantage of available vertical space when horizontal space is at a premium. It also enables a smaller turning radius for the vehicle.

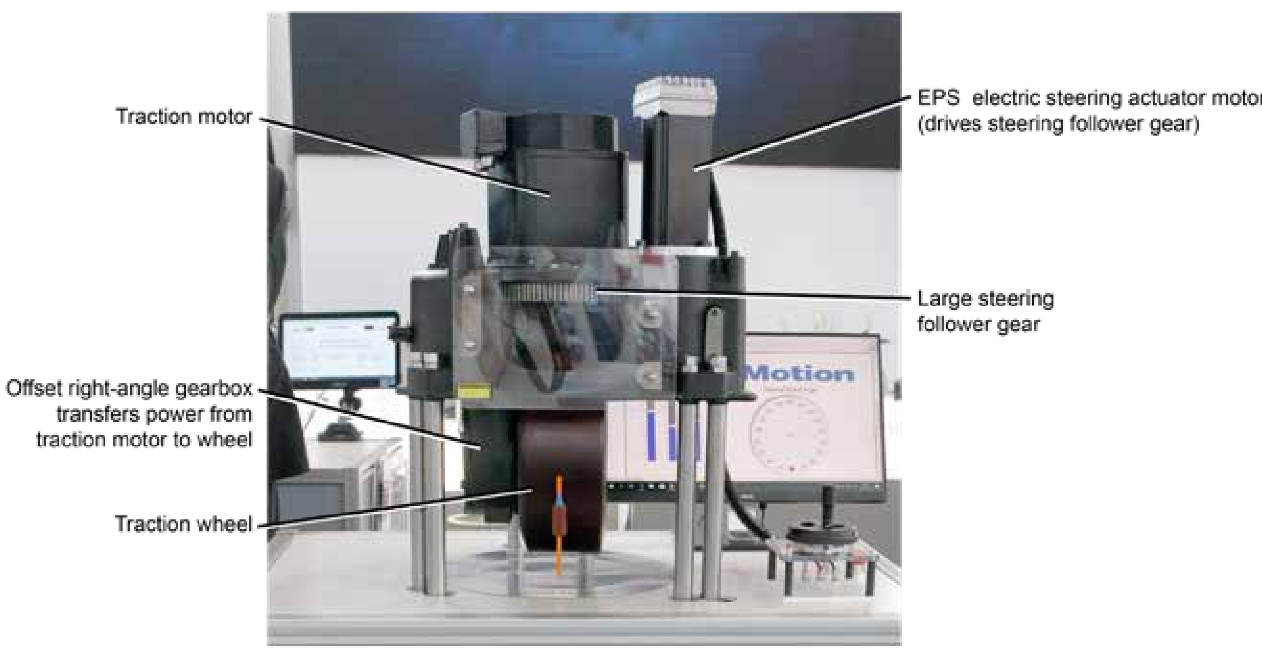


Figure 7: Demo stand shows a complete vertically-oriented steered traction wheel assembly. The EPS steering actuator can be seen to the right of the traction motor, and the steering gear it drives can be seen between the traction motor and the wheel itself.

Design Approaches

As with traction solutions, steering solutions can be divided into discrete and integrated architectures. The optimal choice is driven by the needs of the application.

A discrete solution is based upon an assemblage of selected components. Such designs lend themselves more readily to customization. The drawback here is that OEMs spend more time integrating the system, which ultimately carries a higher cost for them. More time spent integrating a steering system means less time focused by the OEM design team on their primary objective, which is the design of the vehicle itself.

Discrete solutions become even more difficult when the same wheel needs to provide both power and steering functionality. To serve the application, the entire wheel assembly, which may include two different motors, needs to describe the smallest possible circular envelope when it turns. In these cases, a fully-integrated EPS unit will provide the OEM with the most compact solution possible (see figure 8).

An integrated electric steering system brings benefits similar to that of an integrated traction actuator. The ability to buy and install the unit as a single integrated assembly greatly simplifies design and installation. The components are engineered to work together optimally. Gearboxes, for example, are designed to match the torque and power they must handle, and to minimize backlash, to reduce wear, and to maximize lifetime. Because the components are purchased in volume, assembly is less expensive than if they were procured in lower quantities by the OEM.

Integrated solutions also minimize wiring. External wiring and interconnects cost money, add time and complexity to the assembly process, and decrease reliability. In an integrated design, the electronics are integrated within the actuator. This speeds assembly. Integrated electronics also boost reliability.

The advantages of the integrated approach extend from hardware to software. An integrated EPS unit includes embedded software, which can be tailored to the demands of the application. This saves engineering hours, not just in terms of developing code but in terms of software validation, which is an expensive and time-consuming aspect of safety. Single unit, integrated designs also can be certified as a unit, again saving the OEM valuable time and resources.

Integrated systems are not universal solutions, however. They may not be good fits for applications requiring high degrees of customization. Also, maintaining spares of complete actuators may be more expensive than having an inventory of discrete actuator components. On the other hand, downtime is usually very expensive for the OEM's customer, so an actuator swap-out to get quickly back running may result in a lower total cost of ownership (TCO) compared to discrete systems.

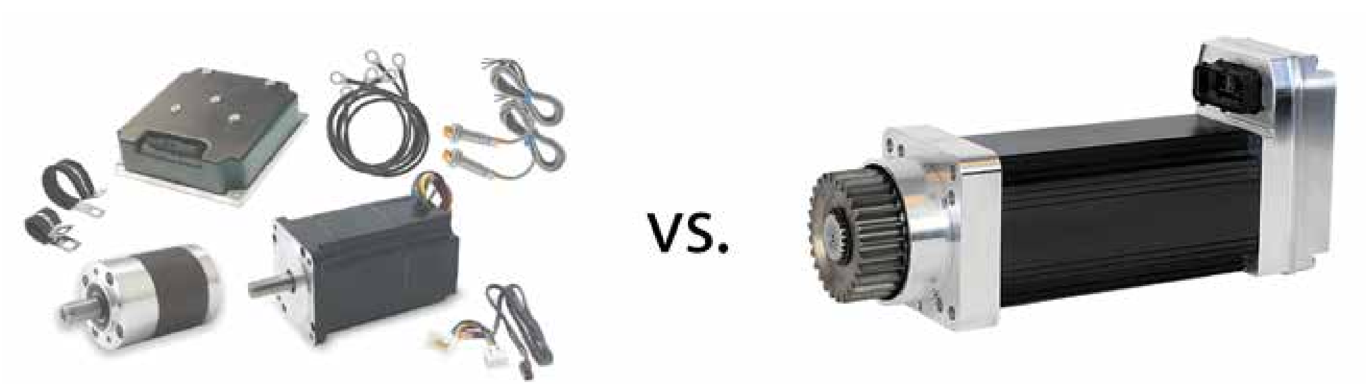


Figure 8: The Allied Motion EPS steering motor actuator (right) is more compact and economical than a subsystem built from discrete components (left). The integrated approach also minimizes engineering and assembly hours for the OEM

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Conclusion

Electric traction and steering solutions are fast becoming the go-to technologies for logistics vehicles and mobile robots. The level of uptake is driven in part by a continuing increase in sophistication and functionality, coupled with falling costs. Availability, ease of use and repair, and TCO are also important to the industry.

There was a time when OEMs who wanted to incorporate electric actuators had to build their own systems from scratch. Today, they can choose from an array of integrated traction and steering solutions, either off-the-shelf or customized to the application. Not only do electric traction and steering actuators improve logistics vehicles, they also improve the logistics of producing logistics vehicles.

Call Allied Motion to discover how our vehicle traction actuator and electric power steering solutions can benefit your next project.

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The Feel of the Wheel

In conventional steering systems, the driver gains a feel for the vehicle through a mechanical linkage to the wheels. Steer-by-wire systems have no such connection. As a result, electric steer-by-wire power steering systems need to simulate the "feel of the road" for the operator by incorporating a level of resistance in the operator's steering wheel.

The most common technologies to induce friction in steer-by-wire systems are mechanical brakes, electromagnetic brakes, and magnetic systems. Mechanical and electromagnetic brakes apply friction to provide the driver with a more realistic sense of how the vehicle is moving on the driving surface. Friction-based designs can be problematic, however, providing a "slip-stick" sensation at startup that can mislead the operator (see figure A).

Mechanical brakes can be effective, but because of the friction contact, they wear over time, requiring both monitoring and regular maintenance. Performance varies depending upon temperature, which is a problem for materials-handling vehicles, since they may be driving from cold-storage rooms to the outdoors throughout the day. Steering feel performance needs to be consistent.

Electromagnetic brakes are effective but expensive and bulky. They also may not have sufficient response time to meet safety standards.

Systems based on magnetic technology (see figure B) can provide very realistic steering wheel feel (resistance), yet are economical to produce. Because mechanical magnetic systems do not use friction, they do not exhibit slip-stick behavior. The driver experiences a smooth motion that effectively mimics the sensation of driving with a mechanical linkage. When combined with magnetic position sensing, magnetic resistance systems bring realistic performance to steer-by-wire systems. In addition, the "feel "of the steering is programmable, or at least adjustable. The noncontact nature of the technology also eliminates wear and the need for maintenance.

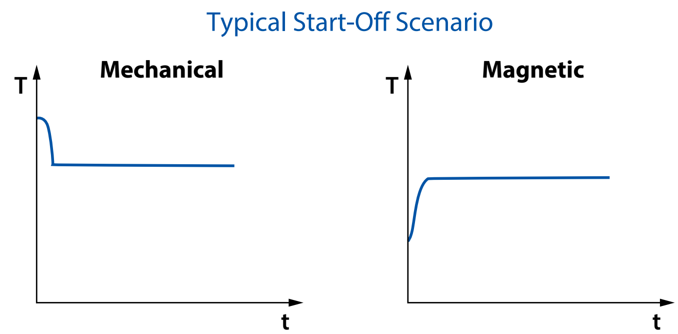

Figure A: As these plots of breakaway torque versus time show, friction-based resistance creates a "slip-stick" sensation at the start of motion that makes it difficult for the driver to make small steering adjustments, for example to drive down a narrow warehouse aisle. Magnetic versions provide a much more realistic experience.

Figure B: The Allied Motion Steering Wheel Sensor (SWS) uses magnetic resistance to simulate the feel of a mechanical linkage in steer-by-wire systems.

Allied Motion Solution Centers

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Allied Motion maintains Solution Centers in three geographically strategic locations to assist our customers with all aspects of their product selection and buying decisions. These three facilities assure you of local support no matter your location around the globe.

Each Solution Center is manned by experienced application engineering and customer service teams, which are available to provide:

- Application analysis assistance
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- Standard product selection
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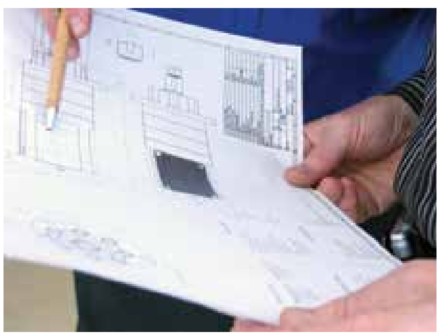
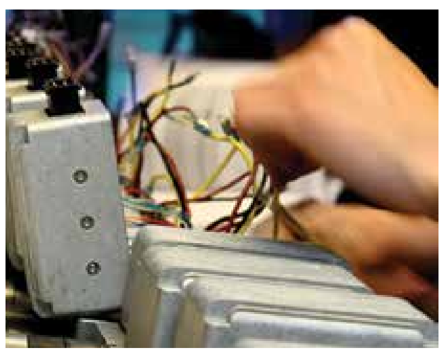


For assistance with all of your motion applications, contact us at one of our continental Allied Motion Solution Centers.

Allied Motion also has a global network of factory trained selling partners to serve you. Call us; we'll put you in touch with an Allied Motion sales partner near you.



Allied Motion Solution Center NA

About Allied Motion Technologies Inc.

Allied Motion (NASDAQ: AMOT) designs, manufactures and sells precision and specialty motion control components and systems used in a broad range of industries within our major served markets, which include Vehicle, Medical, Aerospace & Defense, and Industrial/Electronics. The Company is headquartered in Amherst, NY, has global operations and sells into markets across the United States, Canada, South America, Europe and Asia.

Allied Motion is focused on motion control applications and is known worldwide for its expertise in electro-magnetic, mechanical and electronic motion technology. Its products include brush and brushless DC motors, brushless servo and torque motors, coreless DC motors, integrated brushless motor-drives, gear motors, gearing, modular digital servo drives, motion controllers, incremental and absolute optical encoders, and other associated motion control-related products.

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