THOMSON™
Linear Motion. **Optimized.**

Steer-by-Wire Systems with Integrated Torque Feedback Improve Steering Performance and Reduce Cost

Geoff Rondeau, Product Manager
Thomson Industries, Inc.
Wood Dale, IL
540-633-3549
www.thomsonlinear.com

Hydraulic steering systems have long dominated the industrial utility vehicle market because of their familiarity both to vehicle designers and operators. More recently, a trend has been seen towards the use of electronic steer-by-wire systems that provide greater design flexibility by enabling software to customize the connection between the steering wheel and steering mechanism. Several suppliers offer integrated steer-by-wire systems targeting the industrial utility vehicle market. A key differentiating factor is the method used to provide torque feedback to give the operator a heightened sense of vehicle control. The latest generation of integrated steer-by-wire systems consume less power, are less expensive, and offer the ability to be programmed to provide a wide range of value-added features.

Moving away from hydraulic steering

Hydraulic steering technology has been used in industrial utility vehicles for decades. Engineers are familiar with its ruggedness in unfriendly environments, and its power density which enhances performance in the most difficult applications. But recent trends in the industry position hydraulic steering as less advantageous for many industrial utility vehicles. Hydraulic steering systems require a motor, pump, valves, hoses and fittings. Utility vehicles that utilize hydraulic drives for other functions may or may not have a hydraulic pump with enough capacity to accommodate the steering system.

There has been a general trend away from hydraulics in other applications as well. Many manufacturers are looking to cut back or eliminate the use of hydraulics, so it is becoming much harder to find spare capacity on a hydraulic pump for the steering system. If spare capacity is not available then it becomes necessary to add a hydraulic system dedicated to steering which substantially raises the cost of this approach. Electronic steer-by-wire systems, on the other hand, are completely self-contained and do not require external pumps or hoses. This means that they are usually considerably less expensive than hydraulic steering when the cost of the pump, valve, hoses and fittings are taken into account.

Another reason for considering a move away from hydraulic steering is the desire to improve battery life of electric powered vehicles and reduce energy consumption of fossil-fuel powered vehicles. Hydraulic vehicles tend to consume relatively high amounts of power because the hydraulic system continually consumes supply power whether or not the steering system is being operated. Electronic steering also consumes considerably less power because power is drawn only when operating the steering systems.

Advantages of electronic steer-by-wire systems

Another reason for the trend away from hydraulic steering is substantial performance improvements that have been made in electric motors in recently years. The power density of electric motors has

substantially increased because of advances in magnetic materials, lead/ball screw efficiency, construction, manufacturing techniques and electronics. Today's electric motors can deliver substantially more power while maintaining high levels of efficiency. Steer-by-wire systems have also benefitted by the improved reliability of all electronic and electrical products. Electronic steering systems provide nearly maintenance free operation and are thus much less prone to fail due to lack of maintenance.

Electronic steering also offers substantially greater design flexibility than hydraulic or direct drive systems. There is much greater flexibility in locating the steering wheel because it no longer has to connect directly to a mechanical drive shaft or a hydraulic valve which in turn needs to be connected by hoses to the steering motor. Electronic steering eliminates the need for costly telescopic mechanical linkage or long hydraulic hoses in man-up vehicles where the operator is hoisted up to pick stock from high warehouse racks.

Electronic steering also provides far more opportunity in configuring the steering functionality of the vehicle. Design engineers themselves can easily change the steering ratio with a software command and can even design the vehicle so that the steering ratio can be changed in the field or programmed to change on the fly depending on vehicle operating conditions. For example, an electronic steering system could be configured to have a high steering ratio at low speeds and a lower ratio at high speeds to help avoid sudden turns at high speed, or configured to allow for rapid maneuvering at low speed. Electronic steering can be programmed to indicate that the vehicle is nearing the end of the steering range by increasing torque resistance. Electronic steering also opens up the door to other more advanced options such as using torque resistance to prevent the operator from steering towards detected obstacles.

Unique torque feedback device

A critical consideration in moving to electronic steering is that operators are used to the tactile response, or "feel," provided by both direct mechanical and hydraulic steering systems. The earliest generations of electronic steer-by-wire systems did not provide this feedback and they did not achieve acceptance by vehicle users. Thomson has developed a unique torque feedback device that provides several significant advantages. The new approach works much like a brake by using a magnetic actuation system to apply force to a friction disc that impinges upon a rotor. The friction disc utilizes an innovative material whose static-to-dynamic-friction performance is not subject to the slip-stick effect that in a conventional brake generates a higher level of friction when the shaft is stationary.

The new material also provides a proportional torque force over a wide range of applied forces. The air-gap between the friction material and the rotor remains constant regardless of wear to the friction material. Unlike other materials used in torque feedback devices, the new friction material is insensitive to temperature so it provides consistent performance over a wide range of operating conditions without the need for a temperature compensation system. The new material generates a consistent frictional force over its life and does not generate any frictional force when current is turned off. The torque feedback device also provides faster response to very small changes in current.

Integrated systems reduce development costs

Nearly every industrial utility and personal mobility vehicle manufacturer has either introduced steer-by-wire or has an initiative underway to introduce it in the near future. Many of these companies are

designing and sourcing their own systems. This can be a challenging task because of the need to specify a sensor, building or buying a system to provide torque feedback, providing a drive motor and integrating these components with each other and with the vehicle.

Thomson provides a complete electronic steer-by-wire system that substantially reduces product development and sourcing costs while providing an advanced design that has been proven in the field. Thomson electronic steer-by-wire systems include redundant shaft position sensors, torque feedback device with friction assembly and electromagnetic actuator, drive motor and protective housing. The original equipment manufacturer simply needs to connect the drive motor to their gearbox, bolt the steering wheel to the housing and program the device to provide the desired functionality.

The architecture offers a wide range of mechanical interfaces, voltages, torques, drive horsepower, etc. as standard, so it can be adapted easily to most any application. The Thomson system is, in most cases, less expensive than hydraulic systems, internally developed electronic steering systems and competitive commercial electronic steering systems. Thomson has a number of electronic steering system installations in the field.

Application Success

Nilfisk-Advance, Inc. is the world's largest manufacturer of professional cleaning equipment. The company's Advance Captor 4300B and 4800B battery rider sweeper-scrubbers clean nearly twice as fast as conventional sweepers and scrubbers because they can both sweep and scrub in a single pass. They also provide largest-in-class 80 gallon tanks, the largest main broom in their class and the productivity of an engine machine without the noise and fumes.

These cleaning machines were originally designed with direct drive steering and electrical torque assist. Nilfisk-Advance engineers made the decision to upgrade the steering system to electronic steer-by-wire in order to improve steering performance, reduce power consumption and make it possible to add additional features. "We considered hydraulic steering, however, the vehicle only has a small hydraulic power pack used for lifting the hopper and closing the dump door," said Kurt Vetse, Mechanical Engineer. "This power pack is designed for intermittent use so going to hydraulic steering would have required a new continuous-duty power pack. This would have significantly increased the cost of the steering system. We didn't want to devote the extensive resources nor expose ourselves to the risk that would have been required to develop our own steer-by-wire system from scratch. So we looked at three leading commercial steer-by-wire solutions. We selected the Thomson unit because of its compact size and low cost."

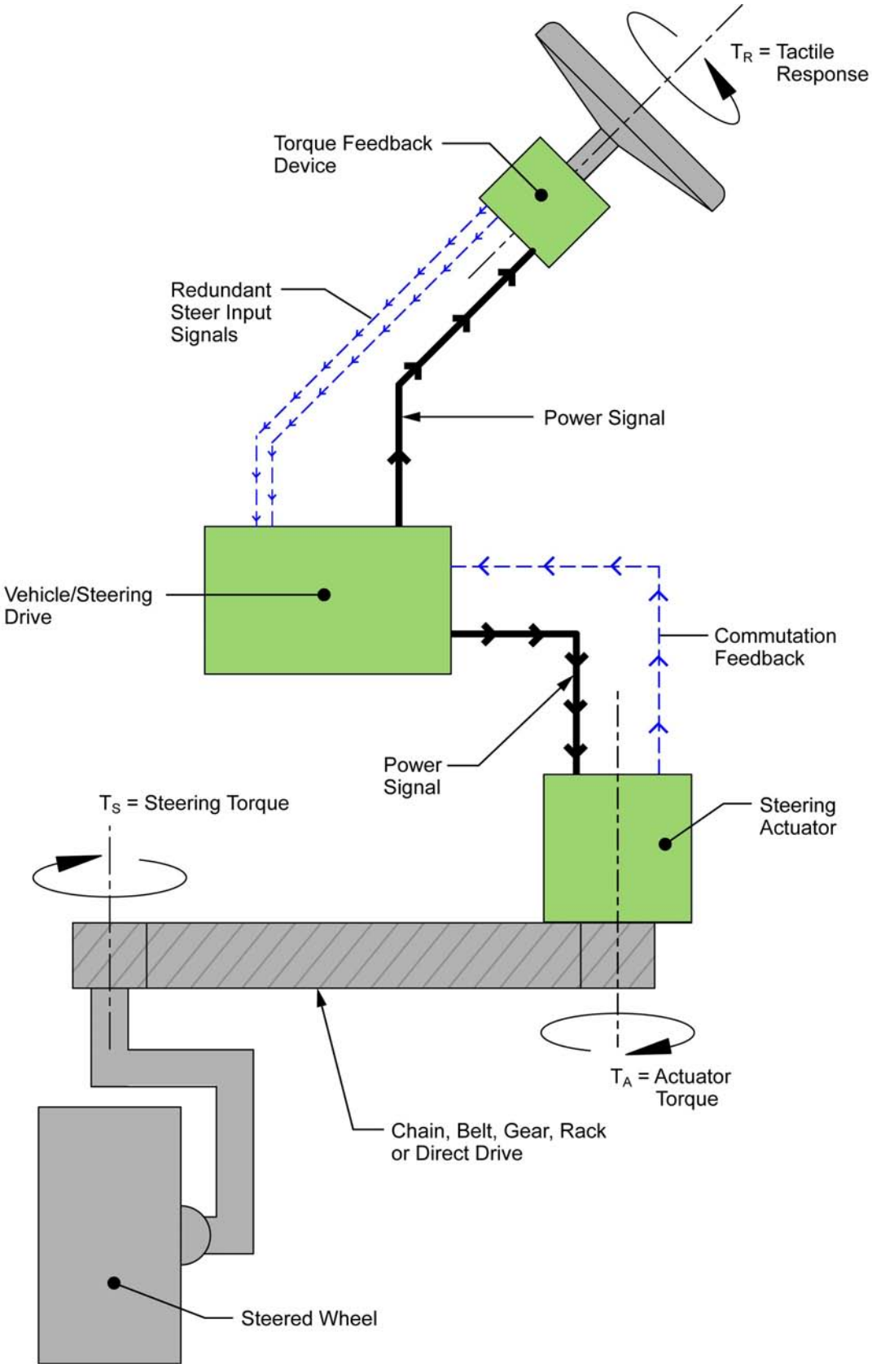
The Thomson integrated steer-by-wire unit incorporates all of the capabilities needed for steer-by-wire including torque feedback technology that provides repeatable performance over time and temperature and no torque at zero current. The steer-by-wire unit bolts right on to the existing gearbox that Nilfisk-Advance, Inc. uses to turn the steered wheel, and fits within the existing console. This greatly reduced the amount of engineering effort required for integration and enabled Nilfisk-Advance, Inc. engineers to focus on delivering performance improvements to customers.

Nilfisk-Advance, Inc. engineers adjusted the torque feedback to simulate the hydraulic steering systems that many customers are used to. They configured the unit to provide fewer lock-to-lock steering wheel

turns than are required by most hydraulic systems to reduce the amount of operator effort. They also decreased the level of steering sensitivity when the vehicle is going straight in order to make it easier for the operator to keep the vehicle on a straight path.

Nilfisk-Advance, Inc. ran the Thomson integrated electronic steer-by-wire systems through thousands of cycles on life test fixtures. The units performed perfectly in these tests which simulated the service life of a machine. “The integrated steer-by-wire system replaced the old torque-assist unit, a shaft and a u-joint while providing a cost reduction of 25%,” said Steve Strand, Continuation Engineer for Nilfisk-Advance. “The ability to fit within the envelope provided by the existing console saved thousands in tooling costs. Feedback from customers who have driven the prototypes has been very favorable, and the scrubber-sweepers with the new steering system will soon enter production.”

Torque Feedback Device


T_R = Tactile Response
Torque Feedback Device
Redundant Steer Input Signals
Power Signal
Vehicle/Steering Drive
Commutation Feedback
Power Signal
T_S = Steering Torque
Steering Actuator
T_A = Actuator Torque
Chain, Belt, Gear, Rack or Direct Drive
Steered Wheel