Automotive iQ

15th Annual
AUTOMOTIVE STEERING SYSTEMS EUROPE 2023
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AUTOMOTIVE BRAKING SYSTEMS EUROPE 2023
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ADVANCED STEERING & BRAKING: TECHNICAL GUIDE TO DRIVE-BY-WIRE

A COLLECTION OF INTERVIEWS WITH BY-WIRE PROFESSIONALS FROM THE STEERING & BRAKING SPACE

THORSTEN ULLRICH
HEAD OF SYSTEM ENGINEERING FUTURE BRAKE SYSTEMS AT
CONTINENTAL

DAVID ANTANAITIS
TECHNICAL FELLOW - BRAKES AND CONTROLS
GENERAL MOTORS

IMRE SZEPESSY
VICE PRESIDENT ADVANCED STEERING AT
THYSSENKRUPP PRESTA AG

thyssenkrupp
Presta AG

KEYUR R PATEL,
SOFTWARE SUPERVISOR, ADVANCE SOFTWARE ENGINEERING,
NEXTEER AUTOMOTIVE CORPORATION

nexteer AUTOMOTIVE
a leader in intuitive motion control

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TECHNICAL CONFERENCES & EXHIBITION | MUNICH, GERMANY

With steer-by-wire and brake-by-wire still dominating the steering and braking space, Automotive IQ hosted a series of interviews with by-wire experts in the industry. Automotive IQ has hosted both Advanced Steering and Braking conferences in Europe and the USA, and this November both conferences return to Munich at the H4 Hotel München Messe, 14th - 16th November, 2023.

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Ahead of Automotive IQ's 15th Automotive Braking Systems 2023 conference, which focuses on the latest developments in brake systems, including brake-by-wire technology, Automotive IQ interviewed Thorsten Ullrich, Head of System Engineering Future Brake Systems at Continental, to gain insight into all things brake-by-wire, including safety and functionality, as well finding out what challenges the industry are facing with the development.

Q: So, Thorsten, from your professional point of view, regarding safety, practicality, and function - how is brake-by-wire different to previous braking systems such as regenerative braking or electronically controlled braking?

Thorsten: Brake-by-wire is already a reality. Electrohydraulic brake-by-wire technology was introduced with the so-called Onebox Brake systems, which combine brake actuation and modulation. However, these systems still feature a mechanical fallback, which guarantees a degraded brake performance in the event of a fatal system or power supply failure. As a next step, we expect to see 'true' by-wire technology in the sense that the mechanical fallback is omitted, and the system safety is based solely on redundancy of the electronic systems and the power supply.

Q: How is the industry ensuring that a vehicle with brake-by-wire will have guaranteed smooth, non-harmful braking with minimal NVH issues, that is also responsive?

Thorsten: The design of the brake actuators takes the requirements for both responsiveness and smoothness into account. The capability of the brake actuator, e.g., the electrical power installed, must suffice to build up the full braking force in a short time – equivalent to what a trained driver can achieve with a conventional brake system today. The task to control these actuators smoothly with minimal NVH impact is a challenge for the control strategies and especially the control software.

Q: How can you ensure that wheel-lock is reduced or made redundant when emergency braking with brake-by-wire?

Thorsten: Antilock Braking (ABS) has been developed to a very high-performance level today. When brake-by-wire technology and especially electromechanical actuators are introduced, it will be a key requirement to tune the control functions as well as the actuators so that this performance level is maintained.

As brake-by-wire systems with electromechanical actuators follow a distributed architecture with central controllers and smart actuators, new options for degraded modes arise. This can lead to a better availability of Antilock Braking compared to today's systems.

Q: What issues in development of brake-by-wire are you facing, and what are your solutions?

Thorsten: Dual circuit hydraulic brake systems are very reliable. It will be a big challenge to design brake-by wire systems without mechanical fallback so that a comparable level of reliability is achieved. On the other hand, refined degradation strategies can be applied to these systems. A key success factor will be to follow a rigorous System and Software Engineering Methodology in the development of these products.

Q: What are your views on the adoption roadmap for all EVs having a brake-by-wire system?

Thorsten: Electrification is one, but not the only trend leading to the adoption of x-by-wire technologies. Vehicle platforms following the rolling chassis concept benefit from the decoupling of the user interfaces (pedals, steering wheel).

In the braking domain, this can already be achieved by electrohydraulic brake-by-wire systems without mechanical fallback and an electrical interface to a brake pedal with sensorics and force feedback (pedal feel simulator).

As a next evolution step on the brake-by-wire roadmap, 'dry' (electromechanical) brake actuators will be introduced. It can make sense to introduce dry brakes for the rear axle only. This not only is a minimum risk approach but can also facilitate the introduction of brake-by wire in larger vehicles where electromechanical front wheel brake actuators have their limitations.

However, to tap the full potential of dry braking technology, in regard to simplified production and service, electromechanical brake actuators on all four corners will be introduced.

Automotive IQ speaks with David Antanaitis, Technical Fellow - Brakes and Controls at General Motors to learn more on the development of brake-by-wire technology, including the the architecture put in place, the safety protocols, and the design considerations that must be considered.

"Safety is an overriding priority in architecting DC-BBW systems. Design concepts invariably include redundancies for control, power, and for actuation. This results in systems that deliver comparable and, in most cases, higher performance in the face of any single point or common cause failures than current centralized state of the art hydraulic brake systems."

All of David's comments in this interview are his opinion, and do not necessarily represent General Motors or its affiliates.

Q: While BBW is not a new technology, the business imperatives to make brake-by-wire viable were previously not there. It's safe to say that most OEMs are looking to introduce BBW technology into their vehicles by the end of the decade, but we're keen to understand the real reasons why adoption of BBW is increasing. In your opinion, what is driving OEMs & Tier-1s to move towards brake-by-wire systems?

David

I will first clarify, when we say 'brake-by-wire' in this context, it is referring to de-centralized brake-by-wire (DC-BBW), with actuation moved from a central location and located at or near each brake corner. There is not one dominant reason for the renewed interest. The content of brake systems has been steadily growing in the past decade; with the loss of engine vacuum as a reliable source of actuation energy and the added content to address this, with the widespread adoption of electric parking brakes, with the burgeoning array of driver assistance and even automated driving features and the redundancies that they need – making it a smaller step from current state of the art to de-centralized brake-by-wire.

The sharp increase in demand for energy efficiency, driven by global regulations and by the shift to electric vehicles makes the promise of zero or near-zero residual drag of BBW very attractive. The added freedom in placement, the configuration of vehicle controls, the reduction in total brake pedal stroke, especially when combined with steer-by-wire can create significant packaging synergies that cascade through the entire vehicle and even enable re-imagining the vehicle cockpit entirely.

The rise of the 'software defined vehicle' with powerful computing centers and the promise of delivering a variety of new features and functionality with over the air updates creates a demand for clean, simple, non-vehicle integration intensive control interfaces to actuators throughout the vehicle including brakes.

Q: We know that OEMs are trying to keep a fixed solution on BBW architecture, but as there is not a designated standard and there is a desire to avoid an isolated solution, what is the BBW system architecture being put in place?

David

Perhaps one of the most immediate questions is around the communications protocol. CAN is widespread and proven in the field but has performance limitations. Publicly available market research studies generally suggest a rapidly growing demand for automotive ethernet to resolve these limitations, but this introduces other technical challenges. The solution for the brake-by-wire system will be beholden to what the rest of the vehicle is doing; and divergence in OEM strategy for the overall vehicular communications will result in divergences in strategy for DC-BBW. This drives electronics hardware differences for DC-BBW.

Another area where some divergences are possible, even likely, but may come to agreement over time, is what level of controls and functionality are housed in each actuator, and what functionality is centralized in a separate control module. On one end of the spectrum – will actuators be just that, an actuator with no processing power internally and entirely dependent on an external controller for everything, from base motor control to diagnostics? Or, on the other hand, will the actuator have its own processor and even be able to perform slip control functions on the wheel it is responsible for as well as diagnostics? I suspect that the industry will settle on a common solution for these questions over time.

Q: What safety protocols do you have in place to ensure the performance and reliability of brake-by-wire technology?

David

Safety is an overriding priority in architecting DC-BBW systems. Design concepts invariably include redundancies for control, power, and for actuation. This results in systems that deliver comparable and, in most cases, higher performance in the face of any single point or common cause failures than current centralized state of the art hydraulic brake systems. Further, the shorter pedal stroke places the full span of driver control of the brake system into a range that is comfortable to more drivers. The unprecedented level of "smarts" in system enables diagnosis of and taking remedial action for a wider range of failures with more advance warning to the driver versus current state of the art.

Millions of brake systems on the road today are already brake-by-wire during normal operation, reverting to manual hydraulic braking only when compelled by a failure in the system. Although these are centralized hydraulic systems, they have already created an extensive knowledge base for controls, for diagnostics, and for remedial action strategy that flows well into DC-BBW strategy.

Q: What design considerations must be considered when developing brake-by-wire systems?

David

De-centralized brake-by-wire has a broad span of influence within the vehicle. It imposes some strong requirements on other systems in the vehicle, it creates some strong enablers, and there are also numerous interactions where it can create value in the vehicle, but only if taken advantage of in its design. Strong requirements to the rest of the vehicle include the power supply to the system, which must have enough redundancy and be sized appropriately for the current draw. The wiring to the wheel area must not be overlooked where wire bundles comprised of 7 or more wires must absorb suspension and steer motion without contacting unfriendly surfaces and with life of vehicle durability.

The communication network must have sufficient redundancies and speed. Strong enablers to the design of the rest of the vehicle include the ability to provide brake-based park, eliminating gear-based parking pawl mechanisms, and it also enables significant changes on the manufacturing side, especially with a completely "dry" system. To take advantage of characteristics such as shorter overall pedal stroke, no front of dash penetration and overall, more compact apply system, the vehicle must be architected around these characteristics. Pedal stroke alone can have cascading effects for packing from bumper to bumper and can be taken advantage of in many ways.

Q: What technologies are required to ensure the successful implementation of brake-by-wire systems?

David

DC-BBW does depend on a number of technologies to be successful, perhaps one of the most critical is the low voltage power supply. There is existing technology that provides sufficient redundancy and integrity of the power supply to enable the burden on the human driver to be part of the backup solution to be relieved. However, it is in the realm of relatively new and developing technologies where costs are coming down and the fault tolerance of the electrical system is being maximized.

The communications technology is also critical. State of the art wheel slip control can update control actions with a 2-microsecond turnaround time; with DC-BBW the turnaround time for communications between the system level controller and any actuator mounted controllers needs to be comparably quick.

The brake pedal emulator will be the main control of the brake system, the main interface to the driver, and for DC-BBW to be successful the BPE and rest of the system must integrate seamlessly to provide an intuitive, comfortable and pleasing feel to the driver in every use case.

Finally, but not all inclusively, BBW needs the most creative and the most cutting edge thinking-on-controls algorithm design. Everything from motor control, to clamp load or pressure control, to the software that integrates the system, to the software that performs diagnostics and drives remedial actions, relies on the very best in controls design and integration. This is where the success of DC-BBW can be made or broken. The software is what integrates the system; it will be at the heart of meeting customer expectations for the brake system feel and response to control inputs, to vehicle dynamic and slip control functionality, and to overall reliability in the field.

AUTOMOTIVE IQ'S EXCLUSIVE INTERVIEW ON STEER-BY-WIRE WITH **IMRE SZEPRESSY,** VICE PRESIDENT ADVANCED STEERING AT **THYSSENKRUPP PRESTA AG**

Q: So, Imre, let's get straight to it, what do we need to achieve a breakthrough in SbW?

Imre: Firstly, we need to focus on an acceptable business case. Define if SbW (with dual power and VCOM) is really the only 'steering system' with AD L3 and up. Is SbW coming with brake-by-wire?

Secondly, when we apply higher level integration with drivetrain and brakes it gives potential for alternative steering functions (ASF) as a fall-back solution, followed by cost-down/functional optimizations. We need clear instructions from the OEM side; not only for components, but the optimization on the vehicle level, that needs close work between Chassis/Drivetrain/Brake departments in OEMs.

Thirdly, requirements, use-cases need to be redefined! Such as egress/ingress and steering torque misuse, to be able to make cost-down and better fitting to new systems.

Q: What functions need to be sold with SbW to generate attraction?

Imre: SbW is the steering system for AD. The steering wheel can be "silent" or can indicate the vehicle driving direction with small motion in AD mode. However, the main attraction, which is also valid for non-automated systems, I'd say would be the flat or 'joke' steering wheel. This seems as a clear expectation and shows the difference from conventional EPS, which gives the wow effect! Flat wheels give more legroom too and need comfortably small steering angles (in the range +-180deg), and with those the direct steering ratio is also a wow effect.

The flat wheel with at least a retractable steering column (into dashboard) shall support egress/ingress and of course all AD needs (space in AD mode) with a clear view to dashboard and LCD dashboard panels.

Q: What do you perceive as the most appropriate concept to achieve an extended availability of steering performance without increasing high costs?

Imre: It needs to have the right design for load collective, extensive component validations and re-use of proven E/E components.

If we use dual channels in the steering system and ASF from the vehicle level (e.g. steer-by-brake or drivetrain) we can achieve high reliability and availability with moderate costs. With regards to the brake and drivetrain, we shall use them in the correct way, of course to generate steering force.

The given standards have to be met, but the new "DIN Norm" which is being worked out by the SbW VDA Working Group will be a great directive. This will lay down the needed steering performance in case of failure modes, which will be also a good input for sizing the system the right way.

Q: How, if possible, can we achieve this extended availability of steering performance without creating restrictions, such as weight, sensors etc.?

Imre: Through higher level integration using more actuators on steering; saving on integration with domain controllers on the chassis level and using cross-redundancies in the vehicle for sensors and actuators.

Q: What is the backup strategy if the SbW system fails?

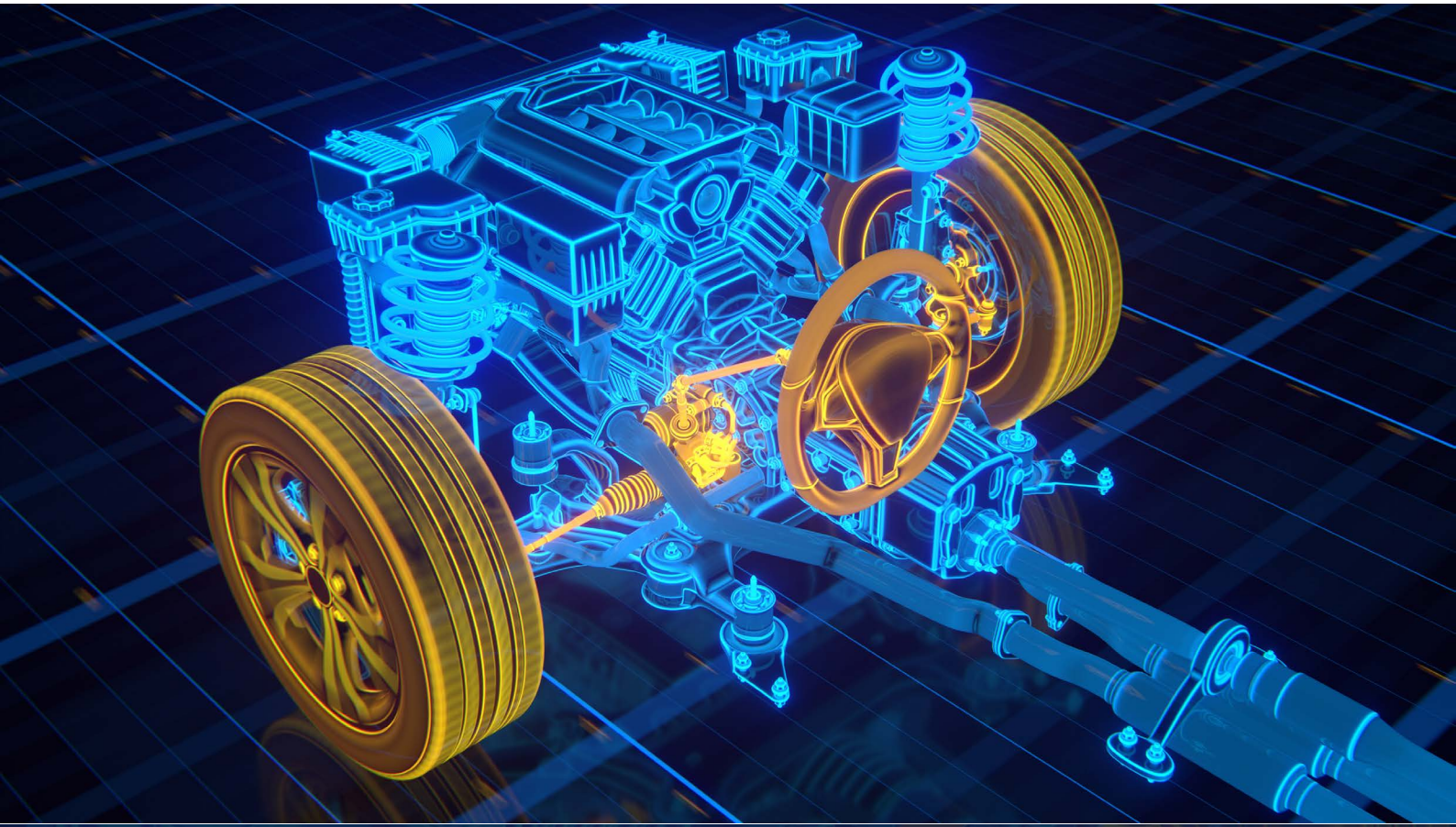
Imre: The proposal is to rely on ASF with limited vehicle speed (depending on ASF capabilities – e.g. achieving 0.3g lateral acceleration, and the minimally needed manoeuvrability at low speeds are essential). After one system failure, there will be reduced vehicle speed and a warning proposed, with a defined transition (preparing the driver for limp-aside or limp-home). After a total loss of rack position control, the vehicle shall rely on ASF, such as limp-aside or limited speed (30-50 km/h) transition period to stop.

Q: Why should the industry attend your presentation at the 14th Automotive Steering Systems conference?

Imre: The conference is an opportunity to support common standards, solutions and address problems that we're facing with systems such as SbW.

Q: What outcomes or solutions are you looking to achieve by coming to the event?

Imre: I'm looking to discuss with OEM experts in SbW. In particular, I'm hoping to get direction on new concepts in SbW and discuss the inputs on SbW Safety Case. Finally, I'd like to discuss the industry expectation on SbW lifetime and lifetime limitations.



Automotive IQ speaks with:

Keyur R Patel, Software Supervisor, Advance Software Engineering, **Nexteer Automotive Corporation**

Learn more the future of steering, focusing heavily on Steer-by-Wire. What will drive Steer-by-Wire adoption in the marketplace? What innovations have been made so far in Steer-by-Wire?

"With SbW's variable steering ratio, Nexteer uses software and algorithms to systematically adjust the steering ratio and optimize performance – without the need for multiple steering gear sizes. As a result, OEMs get a tailored steering feel while standardizing and reducing part numbers."

Q: In the fast-changing automotive industry, what does the future of steering look like?

Keyur

In my view, Steer-by-Wire (SbW) will become the future, dominant steering technology for both electric vehicles (EVs) and internal combustion engine (ICE) vehicles because it opens new possibilities for safety, performance, and packaging enhancements.

On the safety side, SbW enhances stability control, improves braking distances, and is a preferred enabler of features like automatic emergency steering (AES), Brake-to-Steer (BtS), and others. On the performance side, software experts can tailor the steering feel and responsiveness (from luxury to sporty) and even customize the steering feel to an OEM's brand.

As OEMs look at introducing SbW in future programs, OEMs' requirements continue to evolve as they learn system capabilities, performance, and challenges in the development of the system and the benefits SbW has for future mobility like EVs and connected vehicles. For example, there are technical and non-technical OEM requirements that SbW Tier-1 suppliers need to address. Non-technical OEM requirements include meeting the program timing and agility for feature developments, whereas technical requirements include safety redundancy, ASIL ratings of the backup system, and driver intervention. Because the adoption of SbW will happen concurrently with other megatrends like electrification and the software-defined vehicle, I think we'll continue to see new requirements to implement features faster, safer, more securely, and more efficiently.

Q: What will drive Steer-by-Wire adoption in the marketplace?

Keyur

Revamping vehicle platforms for EVs and software-defined vehicles is providing OEMs with an opportunity to reimagine the vehicle and introduce the latest technologies – such as SbW. This would help OEMs appeal to consumers with user-friendly technology and help differentiate them in the race to electrification leadership.

As I mentioned earlier, a key driver in SbW adoption is that it can unlock advanced safety and performance features and functionality which are not available with traditional steering systems today. SbW also opens new possibilities for vehicle light-weighting and packaging flexibility that benefits OEMs – especially in EV applications.

In a traditional steering system, there is a mechanical connection line from the steering column to the steering gear with geometric limitations. This requires the steering system to compete for the same value space as many other critical vehicle systems. By replacing the mechanical connection between these components with algorithms, electronics, and actuators (as is the case with SbW), the need for this mechanical connection line is eliminated – thus offering greater design freedom for locating the steering components and yielding space back for use by other systems.

In addition to packaging flexibility, SbW creates new possibilities for efficiency through parts standardization for automakers. Today, different steering ratios within a single vehicle platform require different steering system designs and different steering gear (physical hardware). With SbW's variable steering ratio, Nexteer uses software and algorithms to systematically adjust the steering ratio and optimize performance – without the need for multiple steering gear sizes. As a result, OEMs get a tailored steering feel while standardizing and reducing part numbers.

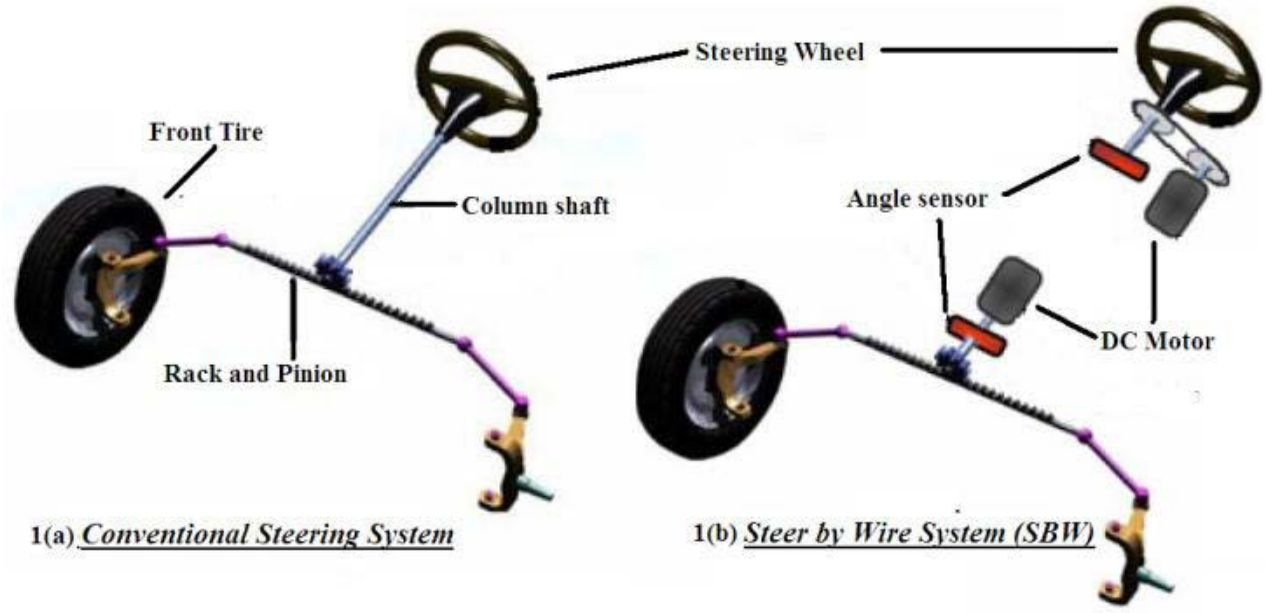
Without a mechanical connection to the steering wheel, SbW further reduces the need for multiple part numbers by enabling automakers to use the same parts for both right- and left-hand drive vehicles across different regions.

Q: What innovations have been made so far in Steer-by-Wire? What lessons have been learned along the way?

Keyur
I'm part of a team at Nexteer that has been working closely with several OEM customers to develop SbW systems that meet their evolving requirements. While working on these projects, I have personally been involved in many areas of innovation, from safety feature intelligence algorithm development to multiple system integration. Each area of innovation requires robustness, safety, and system performance. In my view, understanding the vehicle platform's intended use cases, and lessons learned from the development and legacy know-how, are extremely valuable knowledge that can be carried along the way.

Q: Can you tell us more about Steer-by-Wire and the convergence of megatrends?

Keyur
As more vehicle models move to electric versions, they are also adopting new software, connectivity, and assisted and automated features for advanced safety and performance – and SbW plays an important role in enabling each of these industry megatrends. In such an environment, in my opinion, SbW software development needs to be fast, reliable, modular, and secure with a growth mindset. Continuous Integration (CI), Continuous Deployment (CD), and Continuous Testing (CT) become the new norm. An agile short iterative feature development cycle and maximizing virtual validation will become necessities to meet critical program deadlines. This evolution will also result in benefits such as cost-competitive products, opportunities for software monetization and standardized products which enhance vehicle value to the users and OEMs.



1(a) *Conventional Steering System*

1(b) *Steer by Wire System (SBW)*

In November 2023, the 15th Automotive Braking Systems & 15th Automotive Steering Systems conferences come together alongside our Advanced Suspension & Tire Technologies conferences as part of the Automotive Chassis Systems Technical Conferences & Exhibition. With four main stages running in parallel, three days, over 75 speakers and over 200 high quality attendees, this year's events will give you the opportunity to learn from and network with experts across the chassis domain.

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Steven Wicks
Editor, ***Automotive IQ***

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