HIL test systems in the automotive industry

Multi-domain simulations with HIL systems are standard in aviation. But automotive OEMs (original equipment manufacturers) also benefit from real-time simulations. This requires a powerful and standardized test system.

Advanced driver assistance systems (ADAS), in modern vehicles are becoming increasingly complex and autonomous. The more authority these systems have, the more they need to be considered as highly critical safety applications. This leads to new challenges for the automotive industry, especially in terms of sensor fusion. To ensure reliable qualification, the systems need to be tested and validated according to ISO 26262. Lab tests in simulated hardware in the loop (HIL) real-time scenarios, which have been a standard procedure in aviation for quite some time now, are becoming increasingly important for the automotive industry. The growing complexity of ADAS in turn is resulting in higher technological and quality requirements for test systems.

Lab-based HIL validation with real-time scenarios

Hardware in the loop test systems enable an ex ante testing of the ADAS qualifications in the lab. Test drives on the road are not only expensive, time-consuming and hardly adaptable, but they also entail certain risks. Consequently, there are numerous advantages to have these systems validated in advance using real-time scenarios: The procedure is not time dependent; it reduces test times on the road and in turn also shortens development cycles. As a result, it is more cost-efficient and comes with a minimum risk for damages.

The lab enables a flexible creation of test cases with arbitrary changes to the scenario and a possible introduction of errors. This approach results in the elimination of gross errors and faulty functions right from the start, in order to proceed to real test drives after a successful lab validation. For as long as it is impossible to prove that HIL simulations are fully comparable to reality, the final validation will be done in a real driving situation on the road. Yet, the more these test drives lead to the same results as previously found in the lab, the higher the confidence level in connection with lab tests will be.

Multi-domain simulations

In aviation, multi-domain simulations using HIL systems have been part of the standard procedure for quite some time now. Real-time simulations on the original equipment are used for large parts of the validation and verification processes, e.g. to simulate the plane behavior in real-time to the line replacement units (LRUs).

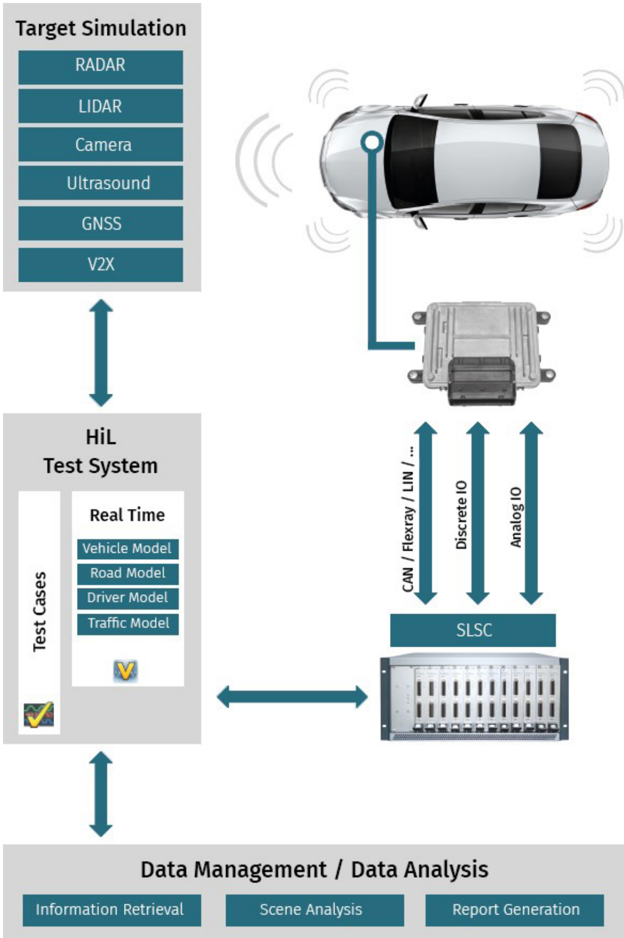

Figure 1: ADAS iiT one stop test solution (Source: SET)

Every plane natively uses sensor fusion. Every flight control system applies sensor fusion by taking the various sensor values to then validate and verify them before inferring and implementing the correct reaction.

The automotive industry also looks back on a longstanding tradition to use HIL simulations for validations. Previously, it was, however, not necessary to come up with such precise, complex, and detailed scenario models for the vehicle environment as it is now. In order to test sensor fusion systems in HIL environments, the models need to precisely convey the vehicle's surfaces and inertia, road situations as well as traffic environments and the behavior by others in traffic.

Not every manufacturer uses the same scenario model for simulations. Consequently, HIL systems need to be able to operate various scenario models by different ▷

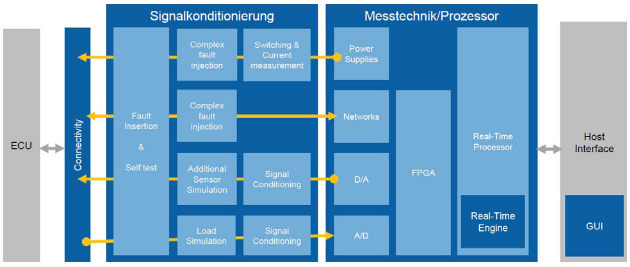

Figure 2: HIL architecture with electronic control unit (Source: SET)

manufacturers in parallel – e.g. IPG Carmaker as one scenario model together with other models like Tass Prescan. This requirement calls for flexibility, as it should be possible to flexibly convey error modes on all levels with arbitrary changes to the scenarios.

Cross-linked domains, interfaces, and gateways

The complexity of individual control devices and the interdependent cross-links of domains are increasing massively as well. To provide all relevant data to the sensor fusion unit of the vehicle, the sensors not only need more but also more detailed information on their surroundings. To test high-resolution sensors, the target simulators in the scenario models of the HIL test system consequently need to become more complex and need to provide a higher resolution.

Physical domains, interfaces, and gateways are also exponentially increasing and are subject to rapid changes. Additionally, backbone communications in testing are undergoing transformation as well: It's no longer only the Classical CAN network, but also CAN FD, Flexray, Ethernet, and BroadR-Reach or Mostbus that is used.

Depending on the application, the Classical CAN will continue to be used in vehicle development, but thanks to its higher transmission rate, CAN FD is much faster and can transport much larger data volumes – instead of eight bytes for the CAN network, this is 64 bytes. With Flexray and Ethernet solutions, speeds, and capabilities are increasing exponentially, but with a much higher degree of complexity – and thus rising costs.

The special challenge in the HIL testing of ADAS functions, especially in terms of sensor fusion functions, is to synchronously simulate these more strongly interconnected functions in a real-time environment. In other words, the algorithms of the sensor fusion unit used to evaluate the vehicle surroundings need to perceive these simulations as real and they also need to simultaneously see the same scenario in real-time everywhere.

This development has led to a rapidly increased complexity of HIL systems in all dimensions. Meeting these new challenges requires powerful, standardized, and modular test systems, which enable flexible adaptation to the needs and testing requirements at hand. One of the main advantages with open platforms is that they enable modular expansion and that they are provider independent. ▷

Figure 3: Modular system architecture using SLSC (Source: SET)

Standardized measurement technology platforms like PXI can be used to convey a multitude of signal types. A standardized signal conditioning like SLSC (switch load and signal conditioning) enables complex functions like fault insertion or sensor simulation – which means that it is no longer necessary to develop these functions on a per project basis. Thanks to these two open platforms, it is also possible to integrate necessary special functions without having to change the underlying architecture.

Closed loop test scenarios for validation

It is actually possible to simulate the entire sensor system used for the car's ADAS functions on the electronic and physical interfaces of HIL systems. Either the sensors are electronically simulated in real-time systems on the interface level or the actual sensors are physically stimulated by target simulations.

Through simultaneous emission of radar signals, simulating targets for Lidar sensors and projecting an image for the camera, for instance, multi-level and multi-domain simulations synchronously provide the sensor fusion unit with the same scenario from all interfaces. In real-time, all this information is collected from the simulated car surroundings. Vice versa, the reactions by the sensor fusion control device are synchronously returned to the simulated surroundings to adapt the simulation accordingly and to achieve closed loop scenarios. Multiple options for the testing environment enable fault insertion on a physical, protocol, and model level allowing for a reproducible showcasing of complex errors, to ensure the sample's systemic reaction in light of various fault situations.

Procedure according to ISO 26262

As ADAS are starting to act more autonomously, they increasingly need to be considered as highly critical safety applications. To provide solid proof for their reliability and safety, these systems need to be tested and validated according to ISO 26262. Depending on their importance, corresponding risks are given an ASIL rating between A and D.

ISO 26262 includes in detail requirements, which OEMs and suppliers must meet in terms of development processes and how these processes need to be documented. These requirements also cover qualification and validation depths and go all the way to include a description of safety items of systems with a critical effect on safety. In turn, this has had a huge effect on development processes in the automotive sector.

Increasing safety requirements for assistance systems go hand in hand with an increased complexity and safety evaluation during validation. With a high likelihood, this step needs to ensure that images, simulations, and simulation tools actually correspond to the expectations of the control device.

ISO 26262 also results in a growing similarity between development and testing processes for systems in the automotive branch and for aviation systems with their highly critical safety impact. Due to the high autonomy of flight systems, these safety features are tested according to the strict regulations in RTCA DO-178 and RTCA DO-254. As a matter of fact, flight control systems, capable of flying a plane on their own have actually been around for quite some time now.

So far, the automotive branch has yet to come up with control device capable of driving a car completely autonomously. There are, however, plans to introduce autonomous level 3 and level 4 systems to drive a car autonomously, which would have complete control over steering, acceleration, and braking. The logical consequence: With increased complexity, these systems would also have to significantly step up in terms of safety.

Figure 4: Scenario model IPG on a HIL system (Source: SET)

When comparing the standards, they show a vast similarity, e.g. in terms of development processes for software and hardware, for test cases, safety levels, or requirements in terms of reliability. The only differences can usually be found in the probabilities. Where a flight control system in aviation holds complete authority, its safety rating for reliable operation needs to be 10^{-12} – in automotive the corresponding value is 10^{-8}.

In aviation, there is an authority to monitor that the prescribed processes are maintained. Manufacturers of aviation electronics need a license for development and subsequently the licensing authority checks for every project if the company processes have been applied correctly or not. So far, the automotive branch lacks a corresponding body: There is no institution to assist OEMs or suppliers in terms of correct implementation of processes according to ISO 26262. Going forward, it remains to be seen if such verification will be done voluntarily by an institution purposely created or by a true authority comparable to FAA in aviation. One thing, however, can be said for sure: In light of the outlook on autonomous driving, the correct implementation of the safety regulations according to ISO 26262 will become inevitable. ◀

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