Siemens Digital Industries Software

End-to-end vehicle verification

Siemens verification tools make for faster development and safer, more secure vehicles

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Introduction

Future automobiles are bringing about the convergence of a huge range of technologies. Electrification; sensors; connectivity; cloud computing; big data; AI – they're all intimately connected in functional safety and their driver-assist features for autonomous vehicles, vehicle-to-anything (V2X) communication, and infotainment electronics.

Furthermore, these vehicles are the ultimate systems-of-systems-of-systems. At the lowest levels we have individual sensors and integrated circuits. They interact in the various subsystems of the vehicle, and those subsystems comprise the vehicle itself. But it doesn't stop there: the vehicle is but a part of the overall vehicular environment, which includes other vehicles, pedestrians, infrastructure, and even the cloud.

This makes verification of automotive systems an enormous task. There are literally millions of scenarios to be checked out. And each of those scenarios has variants. For example, one scenario might have the car approaching a pedestrian in a crosswalk. But that could be at different times of day, with different weather, with different pedestrian clothing, and with different racial types. All of which present a verification project that, realistically, could never be accomplished using manual, physical means.

At the 2016 Paris Auto Show, Toyota CEO Akio Toyoda warned that, ""14.2 billion miles of testing is needed." In a 2014 article, Autonomous Driving, Roland Berger noted that, "Design validation will be a major – if not the largest – cost component." And the McKinsey report, When Will the Robots Hit the Road, cautioned that, "While hardware innovations will deliver, software will remain a critical bottleneck." Warning lights are flashing for anyone not taking the full burden of automotive design seriously enough. This is not a business where one can come in unprepared for some back-breaking work.

As if raw complexity weren't enough, safety and security complicate matters further, since lives are at stake. Certification is coming, as standards like ISO 26262 and, soon, the SOTIF (Safety of the Intended Functionality) standard for defining test scenarios become established. Vendors must do more than pay lip service to safety; they must prove safety.

All of these demands join the usual challenges of getting a cost-competitive product to market as quickly as possible. The problem cries out for verification tools that can make this process manageable. A combination of realistic scenario modeling, hardware emulation, and mechatronic verification are required to get a new car on the road quickly and efficiently.

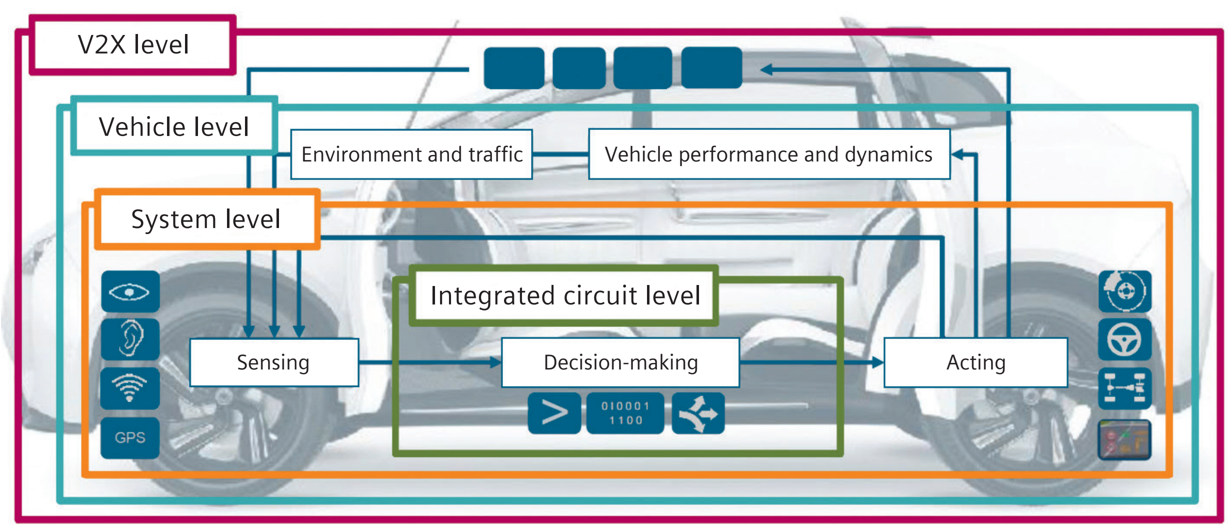

Figure 1: Vehicles are systems of systems of systems of systems.

Three automotive components

In order for an automated vehicle to function, its systems must perform three tasks:

- Sensing: the vehicle must be able to sense its environment. In addition, there are many internal conditions that must be sensed in order to assure correct operation
- Computing: those sensor outputs must be evaluated to make decisions
- Actuating: those decisions must control some part of the vehicle or some aspect of its operation

All three of these elements need to be included in any comprehensive verification process. And that presents a significant challenge, since there is no time to do physical prototyping using trial-and-error to find issues. And we certainly can't test safety and security thoroughly in a real, physical vehicle. The only way we can do an extensive verification job is to virtualize the entire system – environment and vehicle.

This means that we need tools to:

- Simulate real-world environmental conditions and the outputs of sensors responding to them
- Verify the circuits that perform the decision-making computations, given the sensor inputs
- Take the computed decisions and apply them to virtualized versions of the mechanical systems that those decisions control

Modeling the driving environment

The PreScan tool, from Siemens' Tass division, performs the first task. It can extensively model vehicle infrastructure like roads (or portions of roads), bridges, and intersections; physical objects like trees, buildings, and traffic signs; other vehicles and pedestrians; and weather conditions. It also has an extensive library of modeled sensors, including cameras, radar, lidar, ultrasonic sensors, infrared sensors, V2X communications, and GPS.

These elements work together to allow modeling of realistic roadway conditions, with variants provided for time of day, weather, color of vehicles or pedestrian clothing, pedestrian features, and the numerous other ways these scenarios can be tested. Together, these virtual scenarios produce the signals generated by the various vehicle sensors as they react to the scenario. Those signals can then be used to test the integrated circuits that are responsible for responding to the sensors.

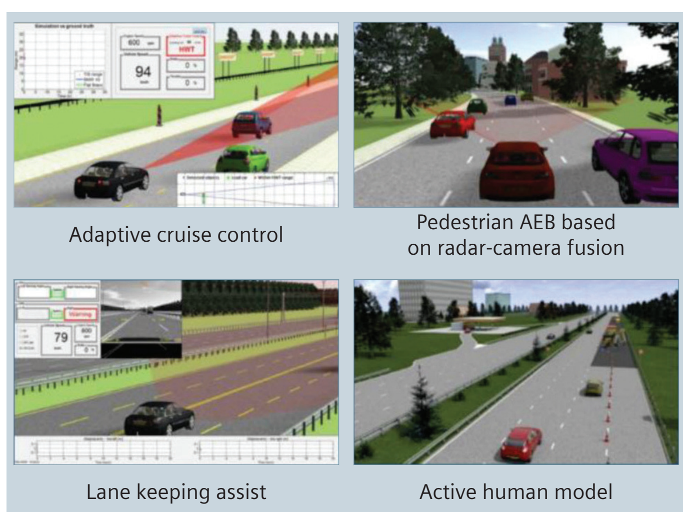

Figure 2: PreScan, from Siemens' Tass group, can model a wide range of real-world scenarios.

Verifying the integrated circuits

When it comes to verifying circuits, simulation is a common tool used extensively for checking out pieces of the circuit. But when it comes to verifying an entire chip, simulation is far too slow. Much of the functionality will be implemented in software, which is practically impossible to simulate – again, because it would take an extraordinary amount of time to do so.

But there's a faster way to verify silicon: emulators. Unlike simulators, which use computer instructions to do their work, an emulator implements the circuit that you're trying to verify in logic chips that make up the heart of the emulator. In Veloce emulators, those logic chips have been custom-designed by Siemens Digital Industries to allow them to implement any digital design within the size constraints of the emulator. And Veloce emulators can handle up to 15 billion gates, effectively removing design size as a constraint. So, while you're not running the actual final silicon chip – which hasn't yet been built – you're still using hardware instead of software, and that can speed things up by 1000-10,000 times.

One key requirement of any verification approach is visibility. You need to be able to see deep inside the circuits so that, if something goes wrong, you can figure out exactly where and why it happened. You can't do that with a real, physical circuit because the overwhelming majority of the signals never leave the chip – so they're not visible. Simulators give good visibility, since everything is modeled in software, but, as we've seen, they're too slow. Critically, emulators also provide the needed visibility. Veloce emulators from Siemens EDA, a part of Siemens Digital Industries Software, make it possible to peer into the circuits in the same way that simulation allows, but with far faster execution speeds.

The circuit that you build inside an emulator acts as a digital twin of the real circuit that you're designing. It allows you to develop a high-quality circuit much more quickly. This makes verification much more efficient, because you're testing the circuit before it's built. This means that there's no need to wait for actual silicon to do the verification. More critically, you can find any problems before committing to silicon, dramatically reducing the chances of an expensive and time-consuming mask re-spin and raising confidence when you move into production.

Importantly, scenarios and results can be traced back to requirements. This lets you converge on a complete, correct design more quickly, since the verification plan and results remain connected to the requirements that drove the design in the first place.

Finally, Veloce emulators can be installed in data centers, making them accessible by global design teams around the clock. This keeps the design and verification process going without requiring a break at the end of the day.

While Veloce emulators help to ensure that a silicon design is correct, there remains the challenge of testing production silicon to ensure that only fully-functional chips are used in safety-critical applications. Siemens EDA's Tessent TestKompress has been augmented with automotive-more thorough analysis of cell-to-cell interactions to increase defect coverage. Improved vector merging and compression keep test costs down and throughput high.

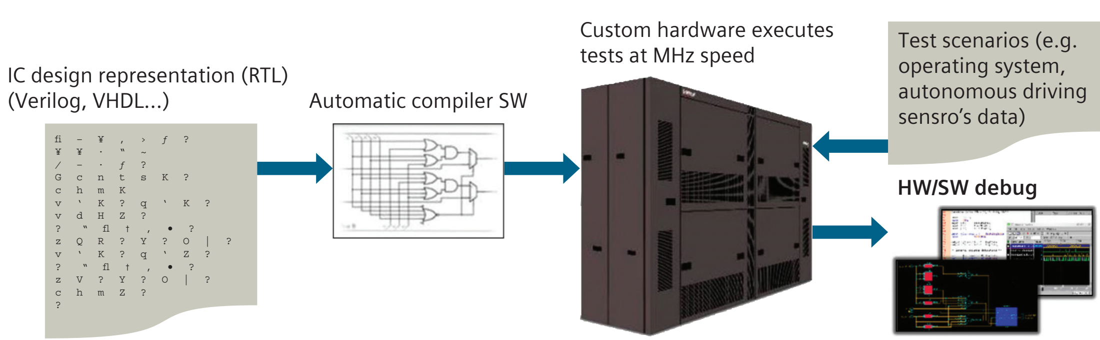

Figure 3: Veloce emulators take a design that's been compiled for the emulator, execute the design, and allow debugging of both hardware and software.

Verifying that your circuits are safe

In particular, Veloce emulators let you perform safety verification. Safety tests mean understanding what will happen with a vehicle when something goes wrong. There are two ways things can go awry, and they're called systematic faults and random faults.

Systematic faults are, by and large, design errors or bugs. If a condition occurs that uncovers some bug, then that bug will happen predictably every time those conditions crop up – hence it is deterministic. Random faults, on the other hand, don't represent an error in the circuit. They're caused by something external that's unexpected and probably not repeatable. The classic example is the single-event upset (SEU), where an energetic particle strikes a circuit somewhere and disrupts the state of the circuit.

Emulation helps with systematic faults by raising the level of verification coverage. It provides enough performance to put the circuit through all of its paces, ensuring maximal coverage.

Emulation helps with random faults by testing what happens when random faults are inserted. Unlike the situation with systematic faults, where you're fixing circuit bugs if you find them, there aren't bugs to fix with random faults. Instead, you're trying to prove that, if one of these unexpected events does occur, that the system can recover into a safe state. The vehicle won't suddenly be sent careening off the road, for instance.

Verifying the response to calculations

The integrated circuits process the sensor inputs and make decisions. It's important to verify that those decisions will have the intended effect. But the decisions affect mechanical systems that aren't available in an emulator. A different tool is required to take the Veloce emulator outputs the rest of the way through the system.

Siemens' Simcenter Amesim tool provides just such a capability, using functional mock-up units (FMUs) to simulate the effects of the emulator outputs. This is still a virtualized environment – you're driving digital twins of major mechanical components like the engine, the transmission, the brakes, and the steering.

So, for example, if a scenario in PreScan shows a pedestrian jumping unexpectedly in front of the car, the camera and other sensor signals that observe this happening are run through the emulator. The emulator will make a decision – say, to make an evasive steering maneuver, or to apply the brakes, or both. The logical signals indicating the decision can then be sent to Simcenter Amesim, where the steering wheel will turn by the requested amount, or the brakes will be applied the requested amount, or both.

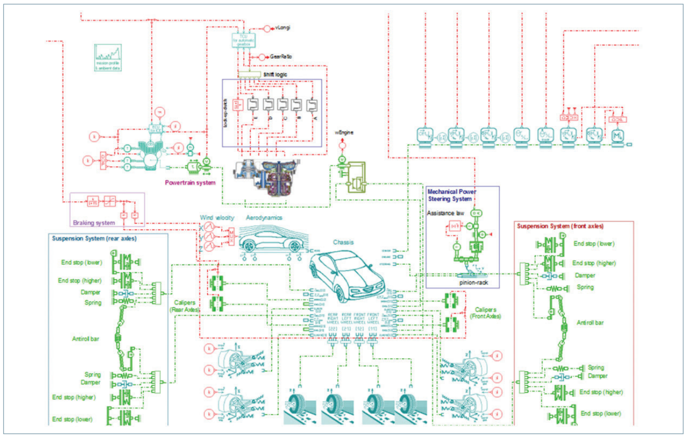

Figure 4: Siemens' Simcenter Amesiml allows simulation of mechanical systems in response to emulator outputs.

Verifying from stimulus to response

Together, these tools provide the end-to-end verification that's so critical for ensuring that your vehicle will perform correctly regardless of the scenario and regardless of which parts of the vehicle are affected. And it's done completely virtually, meaning no delays for building prototypes. One need only create models – and many of them already exist in the tool libraries.

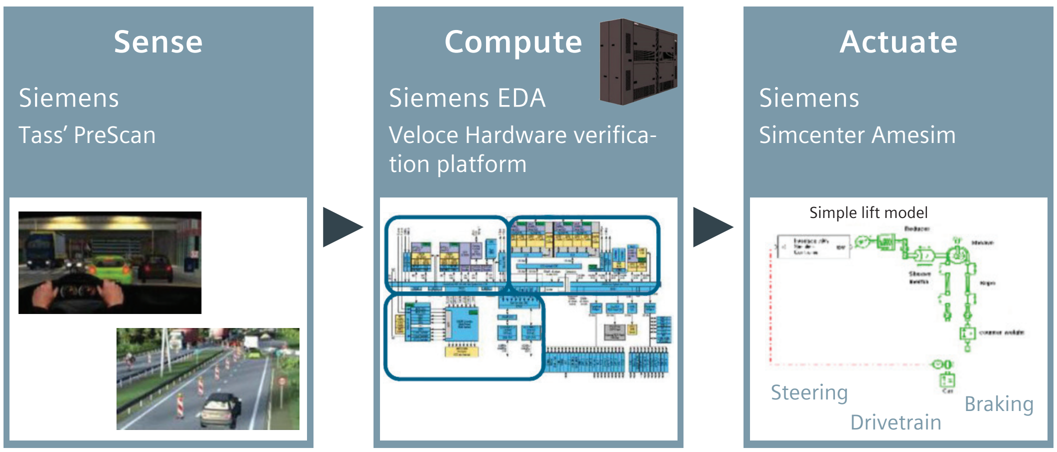

Figure 5: Together, PreScan, Veloce, and Simcenter Amesim provide end-to-end vehicle verification.

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