Hardware-in-the-Loop Testing of Safety-Relevant Functions in the Context of ISO 26262

Dr. A. Himmler
dSPACE GmbH, Paderborn, Germany

Hardware-in-the-loop (HIL) simulation is today an integral part in the vehicle development process as a method for testing electronic control unit (ECU) software. HIL simulation is used for all aspects of development, naturally including safety-relevant functions and systems. This applies to all test tasks (from function testing to release tests, testing a single ECU or an ECU network, and so on) and also to different vehicle domains: The drivetrain, vehicle dynamics, driver assistance systems, interior/comfort systems and infotainment are all tested by HIL simulation.

This paper describes the role of HIL simulation in the development of safety-relevant systems. It explains the requirements defined by ISO 26262 for HIL testing and for HIL systems used in developing safety-relevant systems, and how these requirements can be met.

HIL in the context of ISO 26262 – test objects and methods
Concerning HIL systems the most relevant phases and parts of ISO 26262 are the phases *software unit testing, software integration testing* and *verification of software safety requirements* of part 6 "Product Development: Software Level" and *item integration testing* contained in part 4 "Product Development: System Level".

For example, part 6 of ISO 26262 explicitly names HIL testing as a suitable environment for software unit testing and integration testing, as well as for verification of safety requirements on component level.

Part 4 names HIL testing as a suitable environment for the test of single electronic control units and component tests as well as testing of networks of electronic control units up to a entire vehicle networks.

HIL Systems for ISO 26262 conformal development
To use a HIL system to test safety-relevant functions and systems according to ISO 26262 the confidence in the complete system is the key factor. However, ISO 26262 does not contain guidelines to ensure the confidence in a HIL system. Nevertheless, guidelines can be deduced from the experience gained by developing and using HIL technology over the years and while it became an industry proven technology.

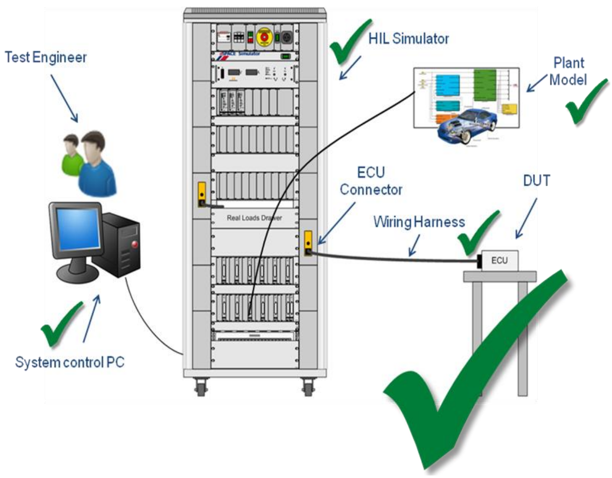

Figure 1: Components of a HIL system

The confidence in a HIL system needs to be ensured during the whole lifetime the HIL system is in use including minor or major modifications of the system. Thus the total life cycle of a HIL system needs to be considered.

The life cycle of a HIL system can be considered to consist of several phases:

- HIL project work to build the HIL system (including hardware, I/O software and experiment software)
- HIL usage
- Modification or rebuilding of HIL system (may affect hardware, software, or both)

These phases are separated by quality gates to test and ensure the confidence in the HIL system. To do this appropriate measures and tests are required that need to be documented. The compliance of each test needs to be checked.

Tests are depending on the specific quality gate. For instance, after building a HIL system the very first tests may even be simple connection tests of the internal wiring. These are followed by tests of the I/O channels including the related I/O software. More elaborate tests are open-loop and closed-loop tests including an ECU. On the other side, a reduced test set is sufficient after a software update. Another test set may be required for maintenance of a HIL system (periodically or required by certain milestones of the development project).

A life cycle model like this is also applied for test systems that are to be used for safety related systems in other industries than the automotive industry. For example, the ECSS describes a similar life cycle model for test systems to be used for satellites.

The measures and tests that are necessary and sufficient to ensure the confidence in an HIL system are described in this paper. In addition, reasons and motivations are given for each of the tests.

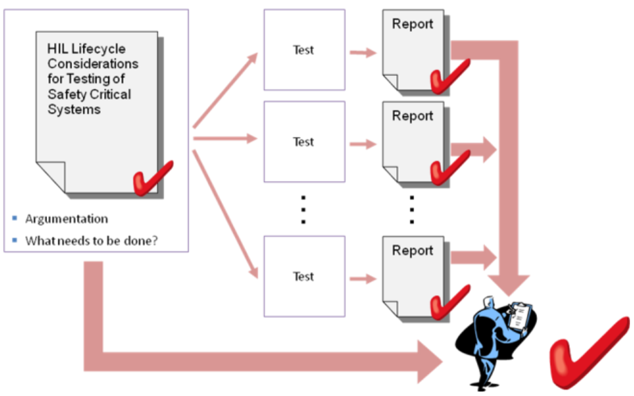

Figure 2: Quality gate ensuring confidence in a HIL system

Author

Dr. Andreas Himmler is Product Manager for hardware-in-the-loop simulators at dSPACE GmbH. He is responsible for dSPACE's PHS-bus based systems, safety topics such as ISO 26262 in the HIL context, and the aerospace market.