Real-time and Performance Aspects of Hardware-in-the-Loop (HiL) Testing Systems

Introduction

HiL systems facilitate the testing of hardware, such as electronic control units (ECUs), in a closed-loop application. As regards automotive applications, this means that the entities of driver, vehicle, and environment are simulated by a single model in real-time. On the one hand, the advantage inherent in this approach provides the user with reproducible test cases, along with the attendant extensive coverage of functions. On the other hand, it facilitates hazard-free testing of functions that are critical to safety. Furthermore, the multiple use - or reuse - of existing models and test cases significantly increases the overall economy of the development process.

As automotive electronics continue to evolve, their ever-increasing system complexity calls for powerful HiL systems possessing the high degree of flexibility needed to adapt testing systems to future demands. Also required are high real-time performance in concert with excellent signal quality and accuracy. This article presents an overview of the referenced characteristics as they relate to PT-Labcar by Etas - a powerful, preconfigured HiL system for powertrain development.

PT-Labcar system

The power of PT-Labcar is based on the interaction of a variety of components (Figure 2). The I/O to the ECU and external measurement equipment is realized by means of flexible plug-in cards. This configuration allows
for system adaptations accommodating customer requirements. The Breakout Box with its rugged connectors provides the user with taps and/or routing options for up to 300 ECU signals.

At the core of PT-Labcar is the real-time target - its hardware being a standard off-the-shelf PC in an industrial enclosure - that computes the real-time model. In conjunction with the Labcar-RTPC software, it becomes a Labcar real-time simulation target. Labcar-Operator software provides the user interface for handling the system as well as project management. Additional Labcar-Automation software handles test implementation, automatic execution and management.

**Real-time performance**
As a prerequisite to obtaining realistic test results from the HiL simulation for time-critical functions, the HiL system must provide high-performance signal handling. This includes short real-time model execution times and low signal latency between hardware and real-time model. To ensure high overall system performance, it is therefore necessary to provide high real-time computing power and intelligent real-time data management.

**Real-time data management**
An example of this is the angle-synchronous signal measurement card. By sending signals only when required (e.g., upon a change of signal level), the card optimizes the data transfer between the hardware and the computing unit. Another example is the new PWM I/O card. This card is equipped with a powerful field programmable gate array (FPGA), which allows fast and intelligent preprocessing and a reduction of data traffic. The resulting segregation between the computing unit and the FPGA reduces latency times.

CAN communications performance has also been increased. The CAN card communicates with a PC-PCI bus (inside the RTPC) in parallel with the VME bus. Measurements taken by means of the Labcar HiL system on a complex 8-cylinder engine ECU confirm that the cycle time is less than 500 µs.

**Real-time computing power**
To make full use of available computing power, PT-Labcar supports PCs with Core 2 Duo processors. The intelligent distribution of the computing load across both processors increases the calculation performance on real-time systems. In addition, the deployment of a Reflective Memory card - enabling high-speed and low-latency communications between several Labcar-RTPCs, serves to increase computing power for multiprocessor usage.

All semiconductor devices generate heat while operating, and high-performance processors in particular are characterized by high current draws requiring adequate thermal management. A frequent consequence of poor heat dissipation is the reduction of a CPU's clock frequency in an attempt to prevent overheating. For this reason, the Labcar-RTPC is housed in a specially designed industrial PC enclosure, ensuring that the rated computing power can actually be exploited.

**Real-time signal quality**
Beyond system performance, the electrical signal quality is essential to obtaining accurate and reproducible HiL simulation results. Labcar systems guaranty a good signal quality, which is also true of high-speed signals. The accuracy of real-time timing, duration, and the correctness of the electrical signal shape - both measured and generated - are only a few of the relevant quality objectives.
Real-time error simulation

In HiL testing, electrical failure simulation (e.g., short-circuits) is steadily gaining importance. For this reason, contact pins are typically connected by means of electromechanical switches (relays). Although the benefit of this solution lies in its low cost, the downside is that the real-time timing of the switching event is inaccurate. To ensure real-time capable switching, "electronic switches" (e.g., transistor, Mosfet) and a real-time control unit are indispensable. The ES4440 Compact Failure Simulation Module is designed to meet all of these requirements. In combination with the Labcar-RTPC, real-time capable electrical failure simulation tests can be implemented. And finally, automated electrical failure simulations have become easy with Labcar-Automation.

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