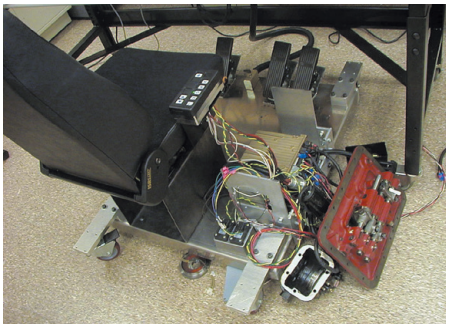
Eaton Tests an Automated Transmission Controller in Real Time Using xPC Target



Eaton's vehicle simulator.

The Challenge

Develop a flexible and cost-effective hardware-in-the-loop powertrain simulator for real-time testing of an automated transmission controller

The Solution

Build and run the simulator using xPC Target and off-the-shelf PC/104 I/O hardware

The Results

- Cost-effective testing and debugging
- Flexibility to adjust simulations as needed to optimize performance
- Reliable, thoroughly tested products

Automated mechanical transmissions are appealing options for truckers, since they combine the fuel economy and performance of manual systems with the easy-to-drive convenience of automatics. Testing automated transmissions for trucks can be costly and time-consuming, however, because of the many combinations of engines, clutches, transmissions, and driving conditions that must be tested.

Eaton Corporation, a producer of powertrain components for trucks, tests its Fuller AutoShift line of automated mechanical transmissions using a vehicle simulator. "The simulator enables us to develop and test AutoShift software and hardware in the laboratory," says Matt Busdiecker, principal systems engineer at Eaton. "We can play different scenarios back over and over for debugging." Eaton built the simulator using MATLAB®, Simulink®, Simulink Coder™, and xPC Target™.

The Challenge

An automated mechanical transmission is built by adding sensors, actuators, and an electronic control unit (ECU) to a manual transmission. The Eaton team set out to test and debug the AutoShift ECU in a timely and cost-efficient manner without sacrificing performance. This was challenging for several reasons. Unlike car manufacturing, where one development team usually controls the entire drivetrain for a particular make of car, truck OEMs combine and assemble parts built by several manufacturers. This meant that the ECU would have to be tested with several different combinations of drivetrain components.

In addition, the controller would need to be tested hundreds of times in the difficult terrains and varying environmental conditions in which trucks must perform, such as in mines, on mountains, or on logging roads, and in rain, snow, and ice.

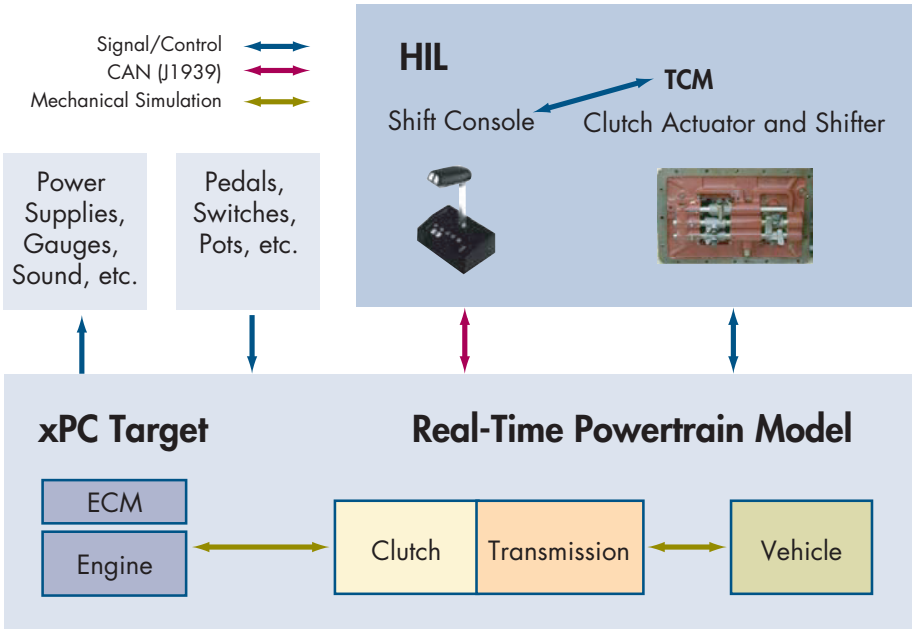
Finding an Alternative to Road Testing

To reduce the time, expense, and safety hazards associated with road testing, Eaton needed to develop a hardware-in-the-loop simulator. The simulator had to simulate the entire powertrain of both medium- and heavy-duty trucks (including the engine dynamics, master clutch, transmission, driveshaft, tires, and road) in real time. It also had to communicate electrically with the shift console, the transmission controller, and other vehicle systems; provide for signal injection and acquisition; and allow for automated testing using field data.

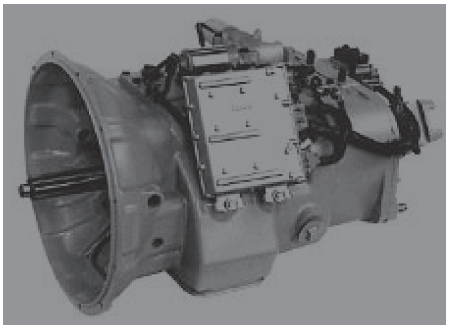
Eaton had built powertrain simulators in the past using various computer and I/O hardware, but the simulation code, GUI, and I/O handlers for these simulators were handwritten in C. Modifying or enhancing this handwritten code for various vehicle combinations would be costly and time-consuming. They needed a better way.

The Solution

Eaton began by considering three options for the powertrain simulator: hand-coding using RTKernel (a real-time operating system); using Simulink vehicle models with Simulink Coder and dSPACE® software and hardware; and using Simulink vehicle models with Simulink Coder, xPC Target,



The powertrain simulator system (right).
An automated truck transmission (below).



and standard off-the-shelf PC-ISA, PCI, and PC/104 I/O hardware.

Evaluating Options

After evaluating each option in terms of cost, development time, risk, availability of I/O hardware, maintainability, flexibility, special driver requirements, and connectivity, they concluded that xPC Target would provide the best solution. It would enable them to use standard ISA, PCI, and PC/104 I/O hardware, thereby significantly reducing their overall development costs and time. This standard equipment would also offer the most flexibility, provide for special driver requirements and connectivity, and be easy to maintain.

Real-Time Testing

In building the vehicle simulator, Eaton engineers added I/O blocks from xPC Target to their Simulink drivetrain model to interact with the transmission controller. They wrote several S-functions to handle conversion of SAE-J1939 messages to and from parameters in engineering units. Using xPC Target enabled Eaton to test the transmission controller in real time.

By adding I/O blocks to their existing Simulink models, generating code with Simulink Coder, and downloading the code to the simulation PC that runs the xPC Target real-time kernel, they significantly reduced development time and costs.

The Test Environment

The test setup consists of two tower PCs, one for the host and one for the target. The target contains both PCI and ISA boards. These include an A/D board, a digital I/O board, a timer/counter board, and a CAN board.

A portable bench contains the two computers, the power supplies, a BNC I/O panel, interface circuitry, and dashboard components.

The system is powered with a 12-volt power supply. The dashboard panel contains a truck speedometer, a tachometer, an ignition switch, trailer brake switches, a speaker, a

"Using xPC Target with inexpensive PC computer and I/O hardware enabled us to build an HIL simulator that helped us develop, test, and debug the ECU and software used in our automated transmission products." —Matt Busdiecker, Eaton Corporation

J1939 connector, and other switches and potentiometers. Engine and gearbox sounds are generated using digital recordings that are stored in memory and clocked by xPC Target timer/counters.

The driver platform contains the clutch, brake, and throttle pedals, as well as a seat and the transmission controller under test. The electrical components on the driver platform are connected to the interface board through an umbilical cable. This setup is also used to connect to the transmission controller while it is installed in the environmental chamber. Potentiometers and position feedback sensors connected to the transmission shift actuators provide feedback to the virtual transmission simulation.

Simulating the Driving Experience

The simulated vehicle can be "driven," tested, and run repeatedly in an environmental chamber where road conditions are quickly created. A driver starts the simulated engine, selects gears through the AutoShift console, and then drives the simulated vehicle using the pedals and gauges. Sound, such as engine noise, is generated to give the driver an authentic driving experience.

The xPC Target powertrain simulator provides all the electrical signals that the transmission controller "sees" in a real vehicle, enabling Eaton to test the powertrain under virtually all the conditions that it will face on the road.

The Results

Cost-effective testing and debugging. The xPC Target–based simulator provides quick, repeatable testing and debugging in the laboratory at a fraction of the cost of using other third-party solutions.

Flexibility to adjust simulations as needed to optimize performance. Using xPC Target, Eaton engineers are now able to adjust and run an unlimited number of different simulations to optimize vehicle performance. Control algorithms can be developed, tested, and modified quickly while the hardware is in a "real" environment.

Reliable, thoroughly tested products. By using Simulink, Simulink Coder, and xPC Target, Eaton engineers can see how their simulated vehicle and powertrain components interact in real time. "This kind of observation is key when you are creating different false signals and want to see what happens to your controller when you get that false signal," says Busdiecker. "Because our engineers could immediately see the cause-and-effect reactions of certain signals, they were able to build a better product that is fully tested and reliable."

Industry

- Automotive

Application Areas

- System design and simulation
- Verification, validation, and test
- Embedded systems
- Control systems

Products Used

- MATLAB®
- Simulink®
- MATLAB Coder™
- Simulink Coder™
- xPC Target™

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