HIL in Formula One

- dSPACE HIL simulation for Formula One teams

- Used by almost all racing teams

- Ideal for tough requirements

Almost all Formula One teams use hardware-in-the-loop (HIL) simulators from dSPACE to develop and test their electronic control units, both individually and when networked. To simulate racing car models in real time, powerful and flexible-to-adapt hardware and software from dSPACE is used as a basis for real-time applications. Working closely with customers, dSPACE develops application-specific systems that are precisely tailored to the requirements of Formula One.
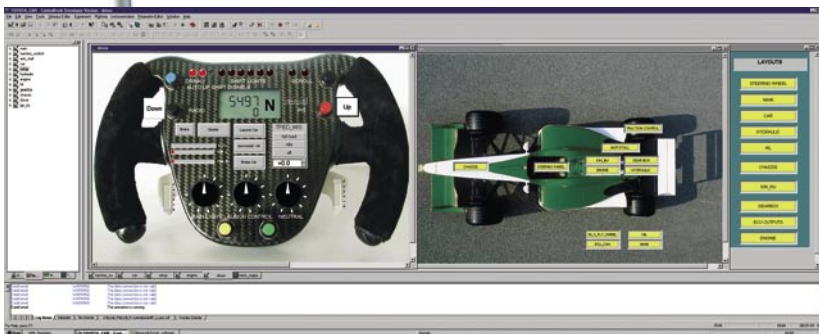
HIL Simulation in Motor Sports

Formula One teams produce new versions of their electronic control units (ECUs) on an almost daily basis, relying on hardware-in-the-loop simulation to test how the ECUs interact with the other components and software versions. Almost all teams use dSPACE simulators to calculate and simulate the racing car models. These virtual real-time tests ensure that both hardware and software are of the greatest possible quality before test drives are made with the expensive vehicles themselves. In many cases, HIL simulation is a fixed part of a team's testing processes. Only software versions that have passed the HIL tests are validated on test bench and test track. Cornering speeds and gear-change speeds can be increased only if the control systems for transmission,


▲ Graphical user interface for motor sports in ControlDesk.

differential, and throttle are sufficiently fast. Gear changes take less than 20 ms, for example, and top speeds of 350 km/h demand very fast control loops. A high data transmission rate is enormously important, so the CAN buses always use the highest baud rate of 1 Mbit/s.

Model Calculation and I/O Signals

The DS1006 Processor Board with a clock rate of 3 GHz is ideal for calculating the complex models of racing cars. If necessary, developers can combine several DS1006 boards to make a multiprocessor system with very short computation times, for example, to calculate a mean-value engine model, a brake hydraulics model, and a vehicle dynamics model, including the entire I/O for engine and vehicle dynamics control. The DS2211 HIL I/O Board implements the application-specific engine signals. For example, it calculates the crankshaft and camshaft signals synchronously with the engine angle, and simultaneously measures the injection times and the ignition angle synchronously with the crankshaft angle. In the automotive industry, the board is widely utilized for passenger vehicles and trucks. With a 4 MHz update rate for the angular processing unit (APU) bus, it fits the requirements of Formula One perfectly. It provides all the necessary I/O connections for a combustion engine with a maximum engine speed of +/- 29,296 rpm, and up to 8 cylinders, including signal conditioning. Higher counts of 10, 12, or 16 cylinders can be achieved by cascading DS2211 boards. The dSPACE simulator can be extended by an arbitrary number of CAN interfaces. Capturing all CAN messages from the ECU network, and CAN restbus simulation for emulating unavailable network nodes, are typical tasks. This is particularly important if the chassis and the engine are being developed at separate locations, as is currently the case with world champion Renault, for example (see dSPACE NEWS 2/2005).

BUSINESS

Graphical Animation

The real-time model of the racing vehicles are implemented on the real-time test hardware via dSPACE's Real-Time Interface (RTI). RTI provides extensive Simulink® block libraries for defining analog and digital I/O connections, and for more complex systems such as CAN communication and crankshaft-angle-based I/O functions. dSPACE's 3-D animation software MotionDesk shows the vehicle behavior on screen, for example, if the car skids on a bend or how it brakes on different road surfaces. Several simulations can be played back synchronously in multi-track mode, so developers can compare them directly and choose the best control strategy. Users can even drive the simulated vehicle themselves, by connecting a real steering-wheel and real pedals to the simulator. They are also given visible and audible feedback such as engine noise. To reproduce specific operating points precisely, testers can take data recorded during actual drives and run it in lab tests. This helps them to reproduce and study specific critical situations. The test system is handled via ControlDesk's graphical interface, which users can adapt to fit specific projects. To allow comparison, simulated test drives must be precisely reproducible, and must preferably also run automatically. Both goals are achieved by
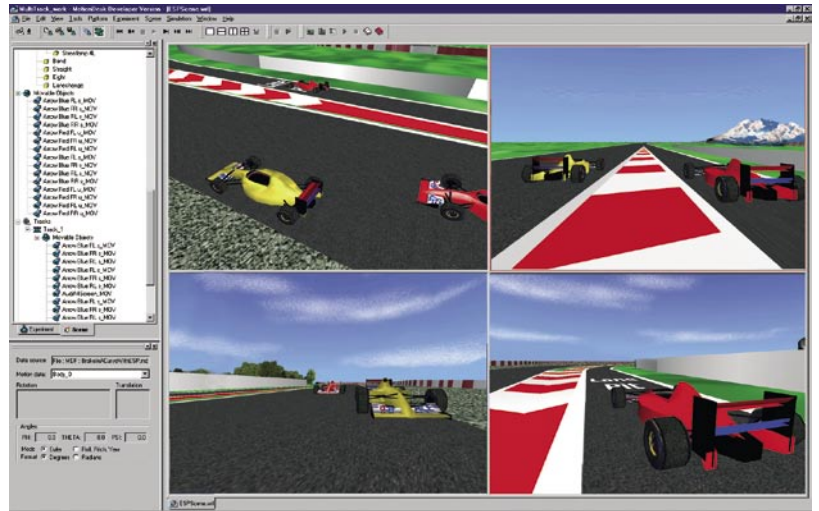
▲ *MotionDesk shows the driving maneuver on screen.*

AutomationDesk, the test management and automation software. This enables users to create test runs graphically without needing particular programming knowledge. Further advantages are integrated test management, a powerful tool for creating customer test libraries, results management, and integrated reporting.
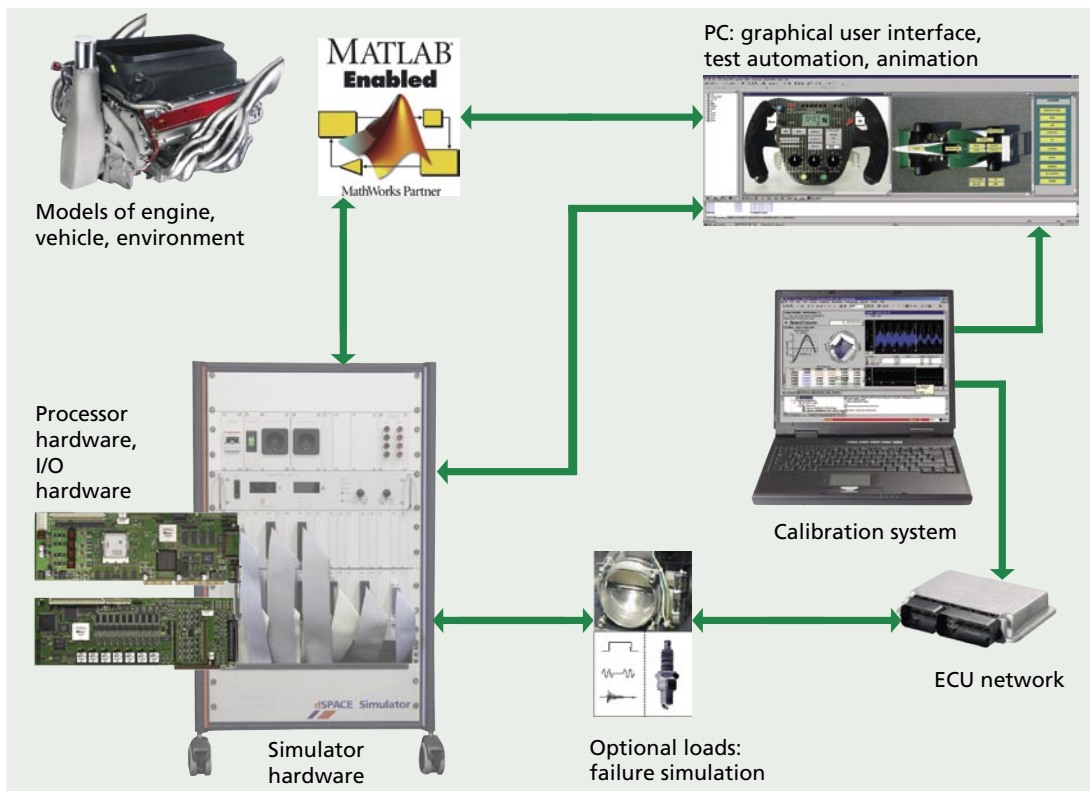
▲ *Typical structure of a hardware-in-the-loop test system for racing cars.*