

The MathWorks tools help Toyota design for the future

- Toyota is taking full advantage of tools like MATLAB®, Simulink®, Stateflow® and Real-Time Workshop® to design, model, test and refine control strategies in an integrated design environment. This process has trimmed design times, as engineers create and test their ideas quickly and with few hardware prototypes. Now, in a development partnership with The MathWorks, Toyota engineers are taking their control designers' ideas from concept, through verification, to real production code in the same, seamless environment.

The Challenge: Traditional design methods fall short

Under increasing pressure to speed up design, increase quality, and reduce R&D costs, engineers at Toyota knew that they needed an alternative to traditional design methods. These methods were neither cost effective nor efficient, hampered as they were by costly or incomplete hardware prototypes and a design process that required re-engineering and reprogramming at several steps along the way. Toyota started looking for a way to bridge the gaps in traditional automotive electronics development and create executable specifications to consolidate the work of spec writers, control designers, and programmers.

The Solution: A development partnership with The MathWorks

Toyota adopted MathWorks tools like MATLAB, Simulink, Stateflow, and Real-Time Workshop as a total design solution.

Toyota's initiative—and their development partnership with The MathWorks—was set in motion ten years ago, when the auto maker first chose MATLAB, then Simulink. "Our use of [these tools] has been gradually increasing," says Toyota spokesperson Akira Ohata; "We now have more than 400 licenses for MATLAB, Simulink, and Stateflow, and they have become the de facto standard at Toyota for simulation, data processing, and controls design. It would be impossible to list all of the applications for these tools at Toyota."

The MathWorks tools have found a real home in the development of Toyota's electrical control units (ECUs), the under-dash controllers that run the software that runs the vehicles. Faced with stringent emissions standards and calls for improved performance, Toyota engineers are concentrating on improving such vital logic as fuel injection and transmission controls.

The Challenge

To speed up design, increase quality, and reduce R&D costs by finding an alternative to traditional design methods.

The Solution

Using the MathWorks tools for control design to prototype, model, test, and refine control strategies in an integrated design environment.

The Results

- A streamlined design process
- More accurate results
- Reduced R&D overhead

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— Akira Ohata, Toyota

Application Area

Automotive

MathWorks Products Used

MATLAB®

Simulink®

Stateflow®

Real-Time Workshop®

From design concept to integrated C code in a single environment

With design solutions from The MathWorks, Toyota engineers have the significant advantage of designing, modeling, simulating, testing and programming control strategies in a single environment. For example, specifications for Toyota's powertrain controllers now begin in the intuitive and self-documenting environment of Simulink and Stateflow, both powered by the industrial-strength computational, analytical, and visualization capabilities of MATLAB.

Controls engineers work directly in these executable specifications, refining control strategies and optimizing performance. The engineer's work is then just a step away from working C code through Real-Time Workshop, with software coded per the control engineer's intent.

Two types of simulation

Toyota engineers use the code in conjunction with hardware and implementation software manufactured by dSPACE of Germany for testing and virtual prototyping. Toyota takes advantage of two types of simulation: Hardware-in-the-loop (HIL) simulation, which allows testing of a prototype ECU on a "virtual engine" modeled in Simulink; and rapid prototyping ECU (RPE), which allows the simulator to replace all or part of the ECU while controlling an actual power plant.

Toyota uses HIL with the Simulink virtual engine to debug ECU hardware and software and for calibration. The HIL setup reduces costs, makes it easy to analyze performance, and allows duplication of operating conditions such as cold start and warmup. In RPE, Toyota engineers can calibrate the

parameters of control algorithms and quickly evaluate control logic. Developers build control logic in MATLAB and evaluate it with Simulink, finding the most promising candidates.

Through the use of dSPACE hardware, the changed parts of the engine control can be segregated as the ECU controls a real auto power plant. This allows the engineers to concentrate on areas being improved or developed.

The Results

- **A better product brought to market faster—and cheaper.** Already, the ECU development process has been streamlined and design cycles shortened as designers work with MathWorks tools to create and test their ideas quickly and with few hardware prototypes.
- **Reduced time to embedded code.** Toyota presented a chart at the Global Automotive Engineering Seminar in Troy, Michigan, in June 1998. The chart showed that Simulink/Stateflow/Real-Time Workshop, in conjunction with Toyota's own Integer Toolkit, generated code automatically that was just five percent larger and only 15 percent slower than Toyota's existing hand-written C code.
- **A pathway to innovation.** Toyota released a revolutionary hybrid electric vehicle in November 1997. "Simulink had a remarkable effect," on Toyota's HEV program, says Mr. Ohata. "It even allowed software developed in Simulink and autcoded with Real-Time Workshop to be used on a real ECU well into the development cycle."



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