CASE STUDY - Toyota Motor Corporation, Hybrid Vehicle Management System Development Division

Dramatically Improved efficiency of Advanced Development for Hybrid Vehicle (HV) Motor Controls. From design "idea" to actual implementation into hardware within a single day

The problem up until now...
For the advanced development team working on HV motor controls, to conduct an actual hardware evaluation, a control spec written in C language has to be converted to a hardware design. However, in a not uncommon scenario, Toyota's control systems engineers couldn't easily convert C language to Verilog HDL themselves.

Solution provided...
"We adopted Veltronix's high-level synthesis tool 'Veltronix Accelerate'. Ease of use by our control systems engineers themselves directly and (unlike other high-level synthesis tools) the fact that Verilog HDL and FPGA expertise is not required, were the main reasons for our choice, stated Mr Kenji Yamada from the Hybrid Vehicle Management System Development Division."

Headquarters of Toyota Motor Corporation, Toyota City, Aichi Prefecture, Japan

OVERVIEW

Toyota Motor Co. adopts Veltronix's high-level synthesis tool 'Veltronix Accelerate' for their HV vehicle motor controls development. Toyota's control system engineers can now develop control algorithms in C and then, without any Verliog HDL expertise, implement an accelerated algorithm on to an FPGA themselves. Previously the time taken from the development of a new control system spec through to actual evaluation in hardware, would be months. Additionally, there would be the added cost of out sourcing the Verilog code generation, normally to a different hardware engineer with this specific skill set. The Veltronix Accelerate tool allowed conversion from C into Verilog to happen in hours not months and the operation was completed by Toyota's control system engineers themselves.

RESULTS & FUTURE USE

Complete in 1 Day, previously took 25 Days

"Previously the conversion to FPGA took about 200 hours, and was outsourced. Now, our motor control systems engineers do it using 'Veltronix Accelerate' and this time is reduced to about 8 hours. New control specs created by our control systems engineers can be promptly verified, which accelerates advanced development. We expect this to directly improve the performance of our customer vehicles".

Kenji Yamada
Toyota Motor Corp.

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◆ Electric-powered vehicles promote the development of more advanced motor controls

The rise of electric-powered vehicles is a major trend taking effect in the car industry. There are many types under development; Plugin in Hybrid Vehicles (PHV) which can be externally charged; Mild HV assisted by a small motor at engine start and during acceleration only; Series HV run by electricity generated by a petrol engine; Electric Vehicle (EV) run only by electricity; and Fuel Cell Hybrid Vehicles (FCHV) with electricity generated by hydrogen.

"One of technical issues we are facing with electric-powered vehicles is how to develop effective drive control systems for motors that co-operate control with engines.

One example is a synchronous motor often used for HV. If the electric current of the motor is not appropriately controlled according to the rotor position, the required torque cannot be obtained or a synchronization loss (step-out state) can occur. Extremely advanced control methods are required to run these motors efficiently. As such we are working to continually improve and develop their performance".

◆ The issue will be the advanced development of motor control algorithms

The HV Management System Development Division oversees the advanced development of HV motor controls for Toyota Motor Corporation.

Mr. Kenji Yamada, the group leader of this division talked about their issues: "When we verify a new algorithm for motor control on an actual machine, a microcomputer doesn't necessarily have good enough performance to represent the behaviour. To deal with this issue, we used to convert the control algorithm into hardware. The implementation of the algorithm on fast FPGA has been the conventional method for verification on an actual machine. However, even though they can write algorithms in C language, engineers for motor control don't have detailed knowledge of hardware languages, such as Verilog HDL. Therefore, we had to outsource the porting to Verilog HDL. Trying out only one idea could sometimes take 6 months."

It was such a time-consuming process, as a complex and advanced motor control algorithm has to be explained to, and understood by, FPGA developers. On top of that, the control systems engineers had to verify that the logic was correctly implemented on FPGA.

Mr. Yamada tried other high-level synthesis tools which can convert C language to Verilog HDL. He said "other tools are made for ASIC and FPGA engineers and require detailed settings, such as timing requirement. That requires knowledge of Verilog HDL or ASIC. So, it was not designed for 'Control system engineers'".

◆ More efficient FPGA development with Veltronix Accelerate

Mr Yamada said, "Veltronix Accelerate' doesn't require any settings for C source codes or circuits. So we do not have to think about the differences between software processed by lines or routines and hardware synchronized and processed in parallel by a clock. 'Veltronix Accelerate' converts C language to Verilog HDL by one simple click, which is the biggest advantage of this tool. This is the ideal tool that we (control systems engineers) were looking for."

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◆ The implementation of a new idea is reduced to 8 hours from 200 hours

Veltronix Accelerate has improved the process of advanced development as follows: First, a new algorithm written in C language by a motor control engineer is converted to Verilog HDL via Veltronix Accelerate. Then it is implemented onto an FPGA with an FPGA development tool (such as Intel 'Quartus(R) Prime'). Finally, the algorithm is evaluated by operating an actual motor. A specific evaluation platform is used with Intel (R) Stratix (R), IV developed by a supplier, so it doesn't have to be affected by resources such as FPGA processing performance or logic capacity.

Mr. Yamada says, "Veltronix Accelerate greatly reduces the time taken to evaluate a new motor control design idea." He continues, "Eight hours is all it takes to implement a new idea on FPGA, including common processes such as C syntax checking and writing on FPGA. When we outsourced the same task, it used to take about 200 hours to start running the motor. On top of that, we also had to spend time checking if the algorithm was correctly implemented on FPGA. So, there are great advantages in using Veltronix Accelerate."

Mr. Yamada regards Veltronix's technical support highly by saying, "Veltronix staff always deal with our enquiries and requests quickly and accurately. Aaron and some of their staff are familiar with Japanese language and have deep knowledge about vehicle development processes, so they have been really helpful."

The case study for Veltronix Accelerate described in this article is for advanced development of motor control algorithms, so it doesn't mean that output Verilog HDL code is used for production vehicles. However new ideas for motors are now tried and evaluated in a significantly shorten time. As such the performance of future Toyota HVs will be directly improved because of their, now accelerated, motor control development process.

Kenji Yamada - GM, Hybrid Vehicle Management System Development Division, Toyota Motor Corporation, Japan.

"We have utilised Veltronix's Accelerate Tool and expertise on the advanced development of our Hybrid Motor Control Systems. The main attraction was the ability for a Control Systems Engineer to put his ideas and algorithms written in C and convert them into hardware without Verilog HDL or FPGA expertise. It has made it possible for us to efficiently evaluate the acceleration of complex algorithms in hardware. This tool is exactly what we "Control Systems Engineers" were looking for. We are looking forward to future developments from Veltronix."

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