Nissan: RapidPro for Engine Control

- Pilot project with RapidPro hardware for engine control
- Successful in-vehicle tests on Nissan Maxima
- RapidPro to be used in further Nissan projects

The Nissan Motor Corporation, Japan, used the new signal conditioning and power stage hardware RapidPro in a pilot project, as part of a fullpass rapid control prototyping (RCP) application for control of Nissan's well-known VQ engine. The control functions were tested on a Nissan Maxima. The pilot project was completely based on the dSPACE hardware and software tool chain. Nissan continues to use the RapidPro units under real conditions in its projects.

Nissan's VQ Engine

To evaluate the RapidPro System with its signal conditioning and power stage features (presented in dSPACE NEWS 3/2004) under real conditions, Nissan chose the Maxima as the test vehicle in the pilot project. The Maxima was powered by the latest 3.5L VQ engine. The VQ engine series is Nissan's mainstream V6 engine lineup, which has been in Ward's "Ten Best Engines" for 11 years in a row. (Ward's Auto World magazine annually recognizes outstanding engine performance in this way). Following constant improvement, the engine is now in its 3rd generation and has a new engine management system (EMS). The EMS supports numerous variable devices, such as continuously variable valve timing and a variable air induction system. System function redundancies are reduced by reading multiple information from one sensor (for example, the cam position sensor), so fewer sensors are needed. Another special feature of the EMS is that it efficiently controls emission reduction using an advanced air/fuel mixture control strategy and lambda probes.

"We are very satisfied with the results. The system has worked reliably and was able to start our engine at once. Frankly speaking, I was very surprised to see that the RapidPro started the engine so easily and smoothly, because I predicted that this project would be very difficult."

Shigeaki Kakizaki, Nissan Motor Corporation, Japan

◀ *Nissan's VQ engine – powering the Nissan Maxima – was selected for the pilot project with RapidPro.*

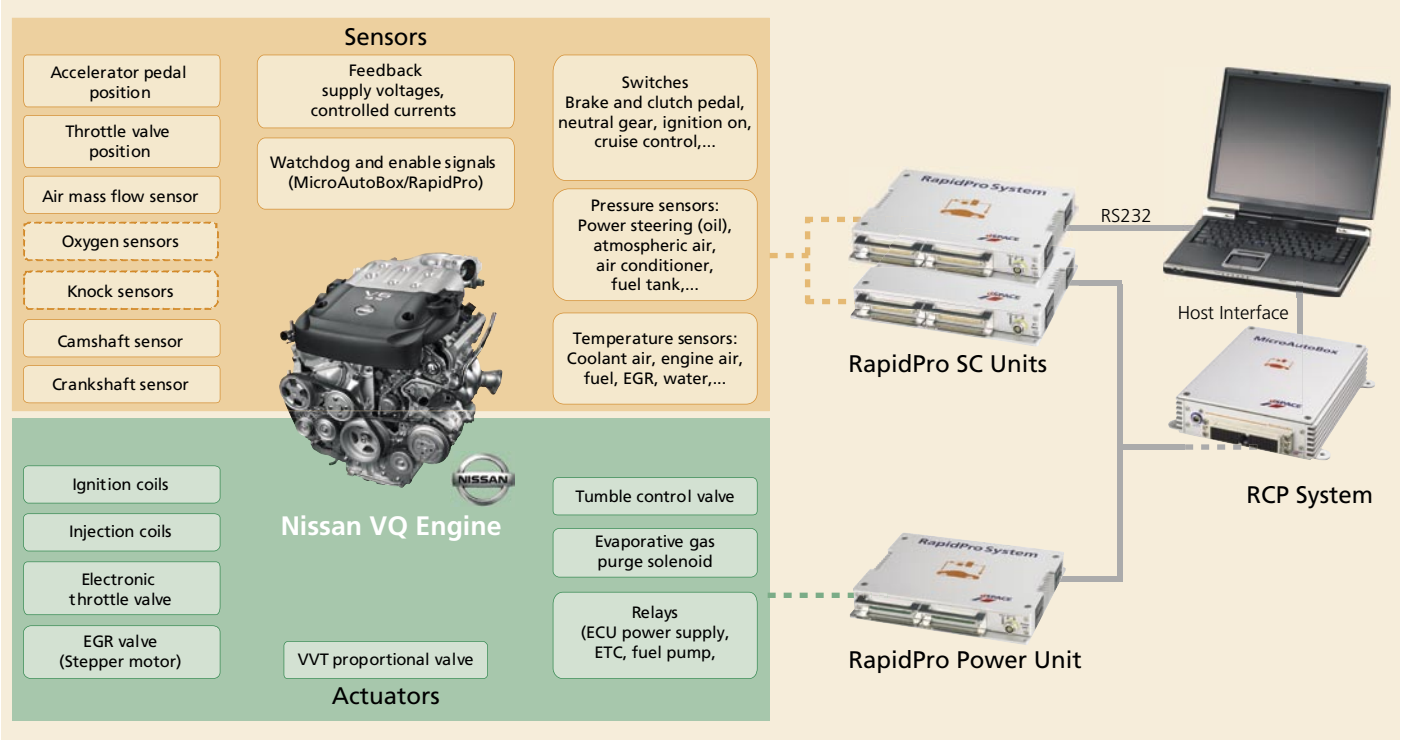
Nissan's RCP System for the VQ Engine

In a fullpass approach to controlling the VQ engine, Nissan employed dSPACE's MicroAutoBox prototyping system and two RapidPro SC Unit prototypes plus one RapidPro Power Unit prototype, equipped with the appropriate signal conditioning and power stage modules. The RapidPro units adapted the required sensor and actuator signals to the MicroAutoBox (see pictures on next page). An engine controller model running on the MicroAutoBox was available from previous projects at Nissan. A proven software tool chain was used: MATLAB®/Simulink®, dSPACE Real-Time Interface (RTI) for basic I/O and Extended Engine Control, and the experiment software ControlDesk. Nissan's RapidPro hardware was configured with a terminal application, as the new ConfigurationDesk configuration software was not available at the time of the pilot project.

Phases of the Pilot Project

When the rough concept had been worked out, the pilot project was divided into four major phases:

1. Detailed specification and configuration
2. Commissioning and real load tests
3. Hardware-in-the-loop (HIL) tests on a test bench
4. In-vehicle tests



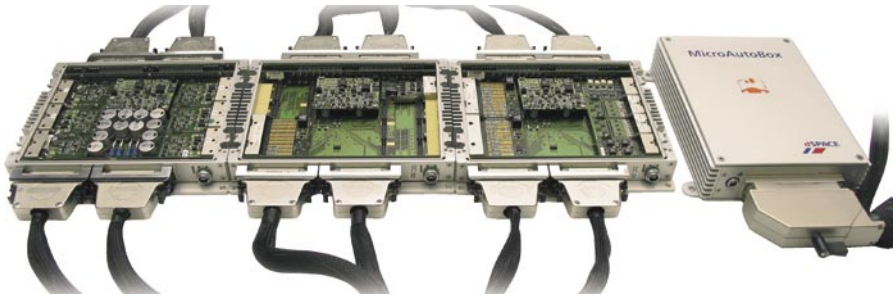
▲ *Sensor and actuator signals of the VQ engine were adapted to the MicroAutoBox prototyping system via the RapidPro prototypes with signal conditioning and power stages.*

Phase 1: Detailed Specification and Configuration

To detail the concept design, Nissan provided the specifications for sensor inputs and actuator outputs, which were investigated and mapped against the RapidPro modules (see table on next page). dSPACE then configured the modules and assembled the two wiring harnesses between the sensors/actuators and RapidPro, and between RapidPro and the MicroAutoBox. The resulting system includes some spare signals, which can be used to connect additional sensors and actuators as the engine evolves in the future. The maximum configuration uses all the I/O channels of the MicroAutoBox.

Phase 2: Commissioning and Real Load Tests

dSPACE ran initial tests with Nissan's real loads connected to RapidPro in the laboratory. Synchronization to crankshaft and camshaft, and correct ignition and injection, were tested by hardware-in-the-loop simulation (HIL). All these tests made use of a pure stimulus model running on the MicroAutoBox. During the commissioning of the system, especially the wiring harness, the need for a compact and easy-to-handle RapidPro break-out box (BOB) was obvious. In addition to typical features like closing/opening all the relevant signal connections, inserting stimulus signals, and signal measurement, the RapidPro-specific BOB has



◀ *A powerful tool combination: RapidPro hardware and MicroAutoBox.*

Quantity	Module Description	Example Application
1	SC-AI4/1 (4-channel differential analog input module)	Throttle position and pressure sensor signals which must be amplified
3	SC-AI10/1 (10-channel analog input module)	Accelerator pedal position, pressure sensors, temperature sensors, air mass flow sensor, sensor supply and battery voltage measurements
2	SC-DI8/1 (8-channel digital input module)	Crankshaft/camshaft sensors, switches (e.g., brake, neutral gear, etc.)
1	SC-DO8/1 (8-channel digital output module)	Relays, ignition coils
1	SC-SENS4/1 (4-channel sensor supply module)	Supply for sensors and ignition coils
1	PS-FBD2/1 (2-channel full-bridge driver module)	Throttle valve, tumble control valve
5	PS-LSD6/1 (6-channel low-side driver module)	Evaporative gas purge solenoid, VVT valve solenoids, EGR stepper motor, fuel injectors, heater, O_2 sensor

▲ *Project-related RapidPro signal conditioning (SC) and power stage (PS) modules.*

the advantage of using RapidPro Sub-D connectors. If wiring errors are detected during commissioning, they can be temporarily corrected by rewiring directly on the BOB. At the end of the commissioning phase, the RapidPro BOB can be removed, and the corrected wiring harness can be connected directly to the RapidPro System.

Phase 3: HIL Tests on a Test Bench

Next the RapidPro System was shipped to Nissan, where it was connected to an existing dSPACE HIL simulator which matches the actuators and sensors of the real engine. The final configuration of the RapidPro System was done via software during the HIL tests. For example, engineers adjusted the upper and lower threshold values of some channels on the 8-channel digital input modules and the cut-off frequencies of some channels on the 4-channel analog input module. The overall system passed the test without the hardware having to be changed. After this success, Nissan decided to start in-vehicle tests with the Maxima immediately.

Phase 4: In-Vehicle Tests

With the RapidPro System integrated into the vehicle, the signals were checked in two steps, without the engine running and with the engine running. Nissan tested all the sensors, actuators, and signals successfully for functionality, plausibility, and noise. The input signals were validated by measurements done with an oscilloscope and compared to the input signals of the model measured with ControlDesk. The engineers from Nissan were also trained in using and configuring the RapidPro System during phase 4.

Nissan's Experience with the RapidPro System

Nissan's objectives were to evaluate the RapidPro prototype and to develop new functions for engine control. RapidPro is still being used under real conditions and to great effect. The RapidPro prototype will be replaced with units of the upcoming release version. The fullpass approach to controlling the VQ engine will soon have to be expanded by adding lambda control and knock detection. dSPACE will provide the necessary modules for use in a successor project. Because MicroAutoBox's I/O resources were stretched to capacity in the pilot project, a Control Unit will be used to expand the I/O functionality. If the Control Unit performs the entire I/O, no customer specific wiring harness is needed between MicroAutoBox and the RapidPro System, and only the high-speed serial link is used for communication.

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