Advanced Prototyping

- **dSPACE Prototyper for new engine control concept**
- **System for full-pass engine control**
- **Power and scalability for the future**

For many years, PSA Peugeot Citroën used a self-developed rapid control prototyping tool, partly based on dSPACE hardware, to prototype new engine control functionalities. Then a new engine control concept with highly complex time processor unit functionalities called for a new prototyping tool offering even more performance. The dSPACE prototyping standard hardware provides the power to tackle the new tasks and at the same time offers scalability for future projects.

An engine controller is a very complex system, in which some calculations are time-based, and others are angular-based. Angular-based computation is very important since the injection and ignition pulses are defined to occur at certain angle positions of the engine. The engine's position and speed are calculated from the information coming from the crankshaft and camshaft sensors. The time processor unit's job is to calculate the position and the speed of the engine and then to correctly generate the injection and ignition signals at the right angle positions, at the right times, and taking into account the acceleration and deceleration of the engine.

When we decided to acquire a new prototyping tool that would handle the new engine control concept, the following requirements had to be met:

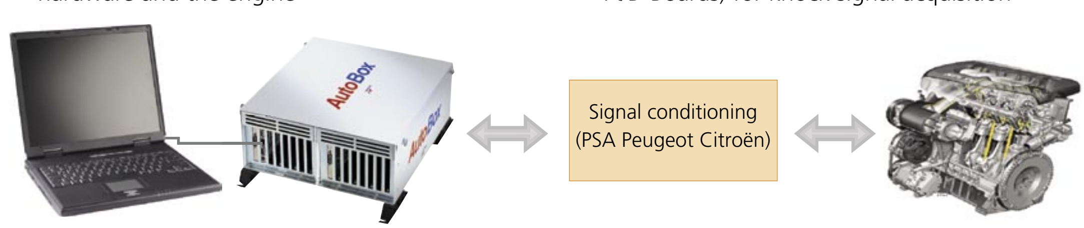
- Time processor unit (TPU) functionality (crankshaft/camshaft synchronization, multiple ignition and injection pulses) for up to 6 cylinders
- Knock signal acquisition and fast acquisition (up to 50 kHz) of relevant engine signals
- Compatibility with the working processes at PSA Peugeot Citroën, for example, full compatibility with MATLAB®/Simulink®
- Flexible hardware that will cope with whatever requirements the future may bring
- Signal conditioning for interfacing the real-time hardware and the engine

Our former prototyping tool was developed in-house, but we did not want to do that this time. Thus, we decided to consult 4 companies, specifying the above requirements. It is important to note that there was no specific requirement concerning the hardware solution. Solutions like VME-, CompactPCI, and dSPACE-based hardware were among the options, but none of them was specified as mandatory.

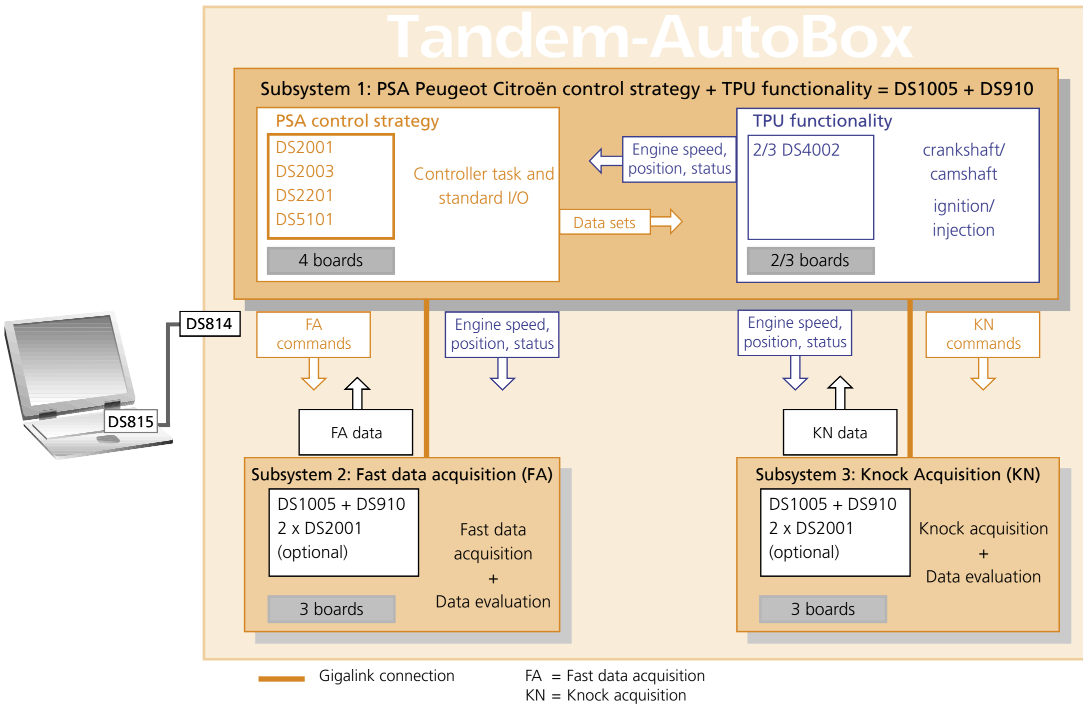
The Decision for a New Prototyping Tool

Finally, we decided on the dSPACE hardware because of its power and scalability, which we felt would be useful in future projects. And it met our requirements within budget.
The real-time hardware configuration is based on the dSPACE modular hardware in multiprocessing mode:

- One subsystem (mainly based on one DS1005 PPC Board and several DS4002 Timing and Digital I/O Boards) for the heart of the engine control: TPU functionality like ignition, injection, and cranking; and control strategy by PSA Peugeot Citroën
- One subsystem (based on one DS1005 PPC Board and several DS2001 High-Speed A/D Boards) for fast acquisition of relevant engine signals
- One subsystem (based on one DS1005 PPC Board and several DS2001 High-Speed A/D Boards) for knock signal acquisition



▶ *The rapid control prototyping system for full-pass engine control.*



▲ *The modular hardware system with multiprocessing configuration is the core of the advanced rapid control prototyping system.*

A multiprocessor system was chosen for the project because:

- With the fiber optic communication module DS910 running at 1.25 Gbit/s between the processor boards, we have high performance for exchanging data between the subsystems.
- The multiprocessor hardware provides very good modularity: adding or removing one of the subsystems is straightforward.
- While the main functions execute on the master processor with a sampling time of up to 100 µs, intelligent I/O subsystems perform the acquisition tasks with a sampling time of up to 16 µs.

The entire real-time hardware configuration is based on standard dSPACE products. No further hardware development was needed, which was important to limit the cost and the risks.The signal conditioning hardware was developed by PSA Peugeot Citroën.

Software Development Adjustments

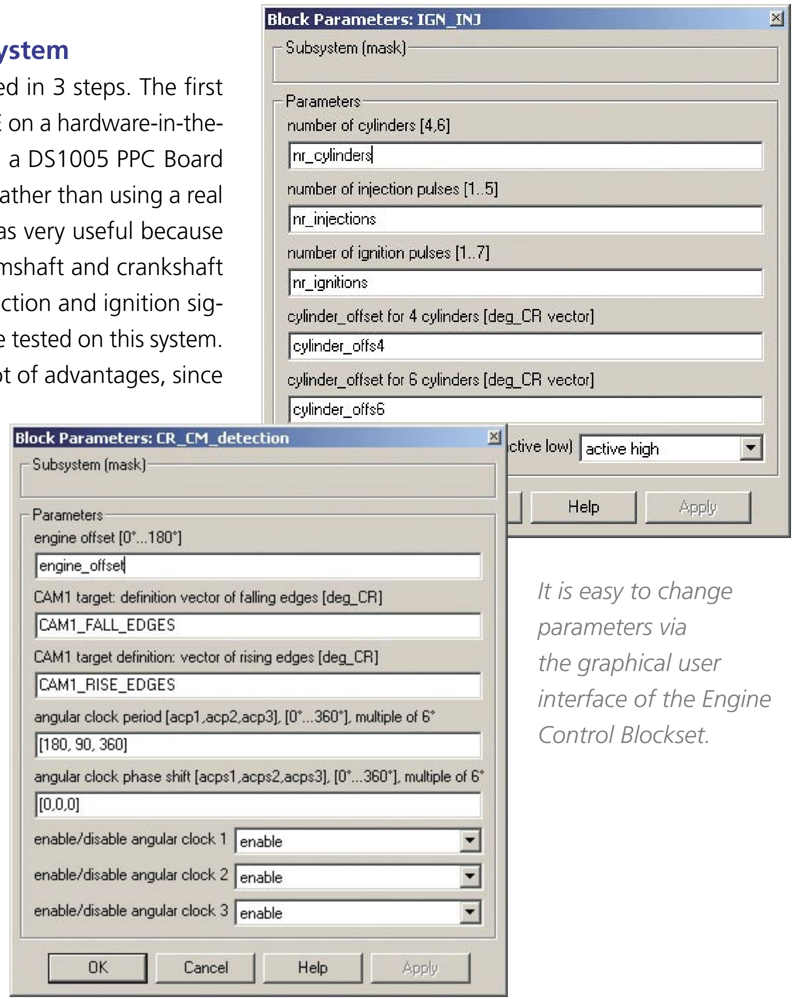
Only software development was necessary to integrate some specific requirements in the Simulink model, by means of S-functions written in C code. These included the TPU functionality on the DS4002 Timing and Digital I/O Boards and knock and fast signal acquisition on the DS2001 High-Speed A/D Boards. These engineering tasks were performed by dSPACE GmbH in Germany and by dSPACE Sarl in France. Although theoretically, we could do this ourselves at PSA Peugeot Citroën, we preferred to ask dSPACE because of their expert knowledge of I/O board programming.

All the TPU functions specifically developed for us can be conveniently parameterized by means of a comprehensive Engine Control Blockset, which provides a graphical user interface to the C functions directly in the Simulink model. It is thus very easy to change parameters like the shape of the camshaft or the number of injection or ignition pulses per cylinder. It also allows us to optimize the hardware configuration: depending on the requirements for different engine control projects, it is possible to use 1, 2 or 3 subsystems, so the costs are scalable. It is even possible to scale the first subsystem (4 or 6 cylinders) by removing some boards and selecting the appropriate option in one of the Blockset dialogs.

Validation with a Hardware-in-the-Loop System

The development was validated in 3 steps. The first step was carried out by dSPACE on a hardware-in-the-loop (HIL) simulator (based on a DS1005 PPC Board and a DS2210 HIL I/O Board), rather than using a real engine. The DS2210 board was very useful because it allows the generation of camshaft and crankshaft signals and the capture of injection and ignition signals. All the functionalities were tested on this system. Using an HIL simulator has a lot of advantages, since it allows:

- Testing the TPU functionality implemented in the Engine Control Blockset in real time without risking damage to a real engine
- Configuring tests with a lot of flexibility, thanks to the DS2210's capabilities and to ControlDesk
- Performing systematic tests using ControlDesk TestAutomation (now replaced by AutomationDesk)



It is easy to change parameters via the graphical user interface of the Engine Control Blockset.

Finally, we performed the two last steps: Running the tests on our own test bench followed by successful tests on a real engine, to study the effects of its actual environment (noisy signals, for example).

Ready for Future Projects

The new rapid control prototyping system allows us to develop advanced engine functionalities – now and in future projects.

Natalia Lestrée, Laurent Genelot
PSA Peugeot Citroën
France

Highly complex TPU functionalities for gasoline direct injection are integrated in the new engine control concept at PSA Peugeot Citroën:

- Multiple injection (up to 5 pulses) and ignition (up to 7 pulses) for up to 6 cylinders
- 0.1° resolution
- Engine speed range: 40-10,000 RPM
- Pulse overlap management
- Knock and fast signal acquisition (~20 signals up to 16 µs sampling time)
- Full compatibility with MATLAB/Simulink