# Smooth Gear Changes with Dual Clutch
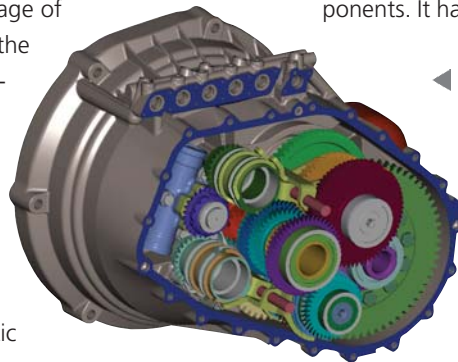
- Centro Ricerche Fiat (CRF) uses dSPACE Prototyper

- Development of a dual clutch transmission (DCT) control

- MicroAutoBox for in-vehicle tests

During the past fifteen years, the Fiat Research Centre (CRF) has acquired considerable experience in the design, analysis, testing and validation of automatic manual transmission control applications, for cars with different kinds of motorization: gasoline, diesel, natural gas, and electric. With dSPACE Prototyper and ControlDesk we at CRF were able to set up different dual clutch transmission (DCT) applications in a notable time, concentrating on the control strategies and the system design. DCT represents the evolution of automated manual transmission (AMT), as it overcomes the loss of comfort due to the torque transient.

## Dual Clutch Transmission

Dual Clutch Transmission (DCT) is a six-speed gearbox with two standard dry clutches (electro-hydraulically actuated) and a sequential electro-hydraulic engaging actuator. The two dry clutches transmit the engine torque through the two input shafts at the wheels, while the engaging actuator manages the disengaging/engaging operations during the gear-shift transient. The advantage of the mechanical architecture of the gearbox is that it allows the gearbox to manage the power shift operations between the two ratios without a longitudinal acceleration change. The drivers can use the gearbox in the manual mode via a joystick lever, or they can choose an automatic function type from the economy, standard or sport mode. DCT significantly increases the driving comfort during gear-shift operations due to the smooth torque transient.

## Control Requirements

Designed completely under MATLAB®/Simulink®/Stateflow®, DCT ensures a higher level of comfort by managing the torque shifting with the two dry clutches. The core concept of the transmission control is a model-based control able to handle the

complexity of four main actuations: the engine torque, the clutches' torque and the disengaging/engaging operations. The power shift operations calculate the references for the two clutches and the reference torque for the engine control unit, in order to have null longitudinal acceleration losses during the gear change. The main control task also needs to recognize faults of sensors, and hydraulic and mechanical components. It has to preserve the synchronizer's
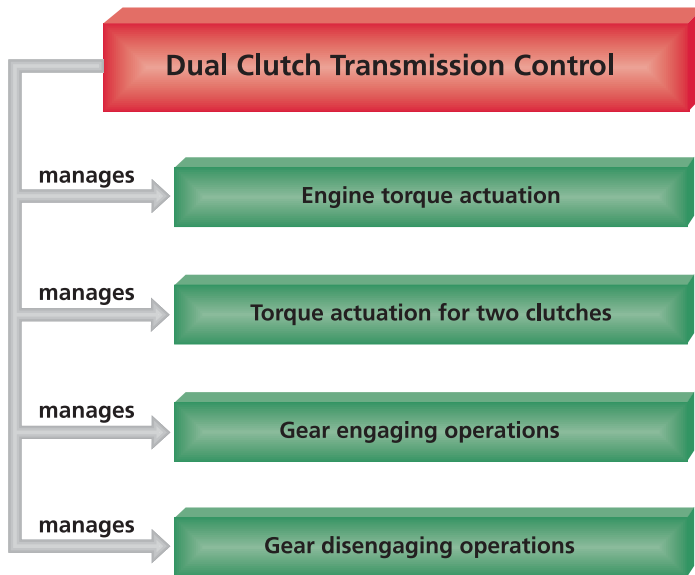


◀ *The mechanical architecture of the Dual Clutch Transmission (DCT) gearbox manages powershift operations between two ratios without a longitudinal acceleration change.*

integrity during the gear-shift transient, and adopt opportune recovery strategies to guarantee the system safety and functionality. The control also includes automatic mode strategies with the possibility to have low consumption gear change strategies, sport control strategies, and a personalized mode which can be automatically tuned to any personal guiding style. The basic automatic mode control strategies choose the gear ratio, using low consumption or performance power-based rules in order to optimize

**Dual Clutch Transmission Control**

manages → **Engine torque actuation**

manages → **Torque actuation for two clutches**

manages → **Gear engaging operations**

manages → **Gear disengaging operations**

▲ *Four complex main actuations are handled by the control system of the Dual Clutch Transmission (DCT). Driving comfort during gear shifts is increased significantly, and gear changes during turning maneuvers are safer.*

implemented in MATLAB/Simulink with the real sensors and actuators field, and we automatically generated the code with Real-Time Workshop. It was easy to install and use the dSPACE MicroAutoBox inside every standard production vehicle because of its high number of input and output channels, various hardware configurations, and compact size. We well appreciated ControlDesk's capabilities to change parameters, visualize and acquire data, because these features supported the DCT calibration. Thus ControlDesk is well integrated inside our calibration process, which uses a MATLAB procedure in order to help the engineers fine-tune and optimize the DCT application.

the engine's working set points and the vehicle's desired behavior. The development tool chain based on MATLAB/Simulink and dSPACE tools allowed the experiment team's engineers to easily design and test the application, change parameters and acquire main data signals.

## Control Implementation

The DCT control strategies and the support control functions, realized with MATLAB/Simulink/Stateflow, were verified with the software-in-the-loop (SIL) approach before going on the bench and on the road. We successfully customized the dSPACE tools to our needs in order to adjust the system with the on-board vehicle testing and perform fine tuning. dSPACE MicroAutoBox and the related tool kit libraries fulfilled our requirements. The tool environment helped reduce development time and minimize safety-critical testing during the validation procedures of the DCT application. The dSPACE Real-Time Interface Library let us effortlessly link the control strategies

## Results

The DCT control ensures gear-shift operations without significant longitudinal acceleration losses, especially during increasing gear-shift operations. The smooth load torque transient during a gear-shift maneuver not only improves comfort but also lets the driver manage safe gear changes during turning maneuvers. Using dSPACE Prototyper and ControlDesk significantly reduced the development time.

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◄ *The Dual Clutch Transmission (DCT) control has been successfully implemented on a Lancia Thesis prototype car. For in-vehicle tests, the Fiat Research Centre (CRF) used dSPACE MicroAutoBox.*