Improved Hybrid DCT Control

Authored by Pedro Zabala

A common approach when designing control system algorithms for Dual Clutch Transmission Systems (DCT) is to make use of fixed sequences (sequence-based) to perform specific actions, such as shifting. By implementing pre-defined steps on a given sequence, a robust and clear software execution flow is achieved. This approach also has validation and development benefits.

However, a fixed sequence becomes quite inflexible when presented with a 'change of mind', a request to change the event being executed and execute a different one. The solution for this is usually to neglect the new request until the existing one is completed (impacting time performance) or to add complex exceptions in the steps of the sequence. This can reduce the robustness of the system and introduce quality issues.

The introduction of electrification into the powertrain can aggravate the issue further as functionality becomes even more complex, with hybrid modules potentially becoming active during a driveline transient event. Considering, for example, a change of mind scenario occurring during a driving mode change from pure EV to Hybrid, the driveability could be hugely compromised with sequence-based implementation through the inability to abort the sequence smoothly and adapt to the driving mode change.

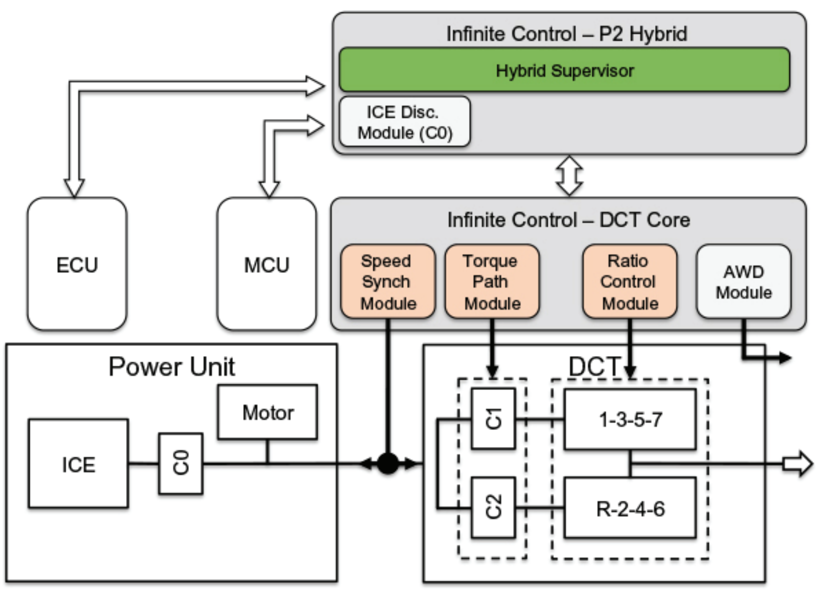
Furthermore, with many different potential electrification architectures (mild HEVs, self-charging HEVs, PHEVs, direct drive EVs, single speed EVs and multispeed EVs), developing generic control sequences for different system set ups may become unrealistic for an OEM, while legacy software may lack the functionality to deal with all configurations.

Recognising these challenges, Drive System Design developed a new solution called the "Infinite Control" platform which features non-sequenced architecture to achieve control of the HDCT unit. The architecture is based on self-coordinating independent functions that perform their activities (torque transfer, gear selection, speed synchronisation, etc) based on the targets and the status of the system. Like a high-performance team, rather than relying on a continuous high-level coordinator, each component executes the tasks assigned to them whenever they are required to achieve the common team goal.

The approach creates a very flexible architecture too, given that it is not restricted to a given shift sequence or technology, such as ICE AMT shift, P2 DCT shift, EV Dog shift, etc.

Infinite Control splits the control of events around the driveline by basic physical requirements: moving an actuator to achieve a ratio, control of torque level, synchronise a component. In this way, many actions can take place at the same time, as long as they maintain the right physical status of the system. When a ratio change is requested for example, the actuators will wait until time is right to move, the speed module will handle synchronisation to the new targets as soon as it is possible to do so and the toque module will hand over torque between clutches as soon as is physically possible, without waiting for further instructions. This can all happen while an ICE re-start is taking place and without issue if the ratio change is reverted before completing the first shift.

The software in Infinite Control is laid out in physics-based modules (torque, speed, ratio path) that collaborate among themselves to achieve a target:



Self-coordination of events allows seamless transient management during shifting (no need to initialise the entry to a different step), even in the event that the hardware behaviour is not as expected or a “change of mind” occurs.

For illustration, consider a DCT power-on upshift illustrated in Figure 1, with the circles showing where each function (torque, speed, actuation) takes an action (fill, synchronise, hand over, actuate) based on their own supervision of the system status.

The shift is triggered by the yellow marker when a new ratio is set. There are actions to be taken and none of them is commanded by a higher coordinator:

Gear Engagement Module:

- Disengage previous ratios when there is no more torque coming through the path
- Engage new ratios when the actuator is free

Torque Module:

- Activate new clutches
- Hand over the torque to new clutch when the new clutch can deliver the torque requested (power on/ power off)

Speed Module:

- Synchronise the power unit to the new input speed when there is no risk of creating a shift quality issue at the wheels.

Now consider a simple change of mind, where the system requests an upshift but reverts the action in the middle of the torque hand over, illustrated in Figure 2.

In this scenario, the speed module will never take any action as the conditions for changing speeds on the system never occur. The torque module will revert the hand over as soon as the target changes.

On top of the ratio management, the hybrid supervisory controller will usually require a certain load torque or slip on a friction component from the transmission to perform the required hybrid management functions. Having a speed module independent of the clutch torque module allows the transmission load or slip to be adjusted while hand overs are taking place without any conflicts. The torque module does not set the torque level, it distributes the torque level set by the speed module among the different friction components. So while the speed module is handling requests from the hybrid module, the torque and gear actuation modules can be handling requests of a ratio change. This can all be done without conflict whether a change of mind occurs or not.

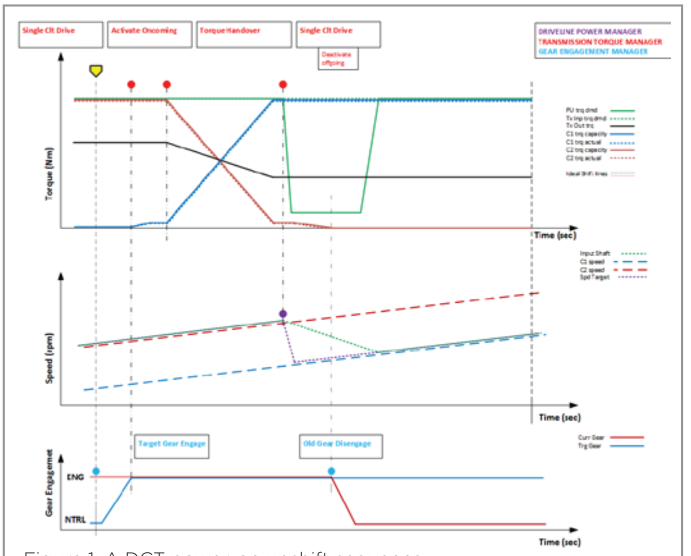


Figure 1: A DCT power-on upshift sequence,

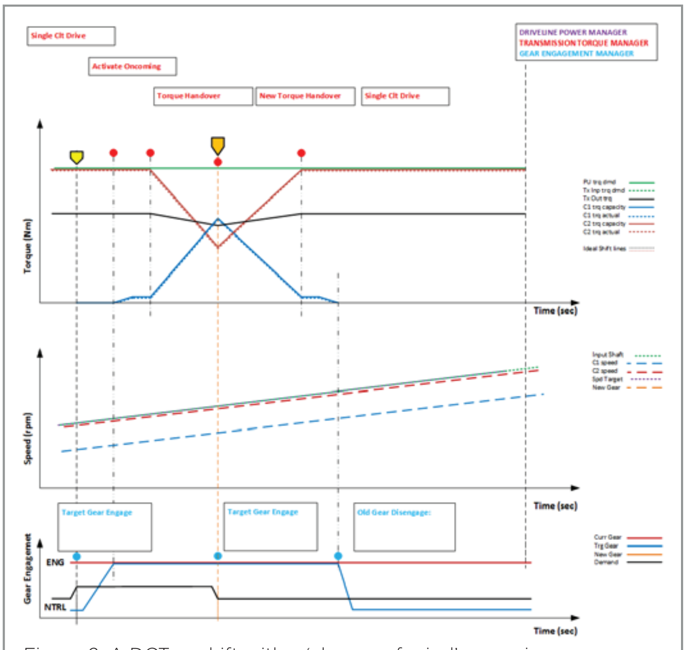


Figure 2: A DCT upshift with a ‘change of mind’ scenario.

Infinite Control has been designed to be flexible so it can be adapted to suit different technologies, such as DCT, AT, AMT or the “Powershift” typically found in commercial vehicle and off-highway applications. It can also be adapted to any level of electrification. It enables the same control software to be used across applications, reducing development time and accelerating tome to market.

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Drive System Design, Berrington Road, Leamington Spa, UK
WWW.DRIVESYSTEMDESIGN.COM