

7-XDCT: Compact and Cost-Efficient Dual Clutch Transmission for Small and Mid-Size Vehicles

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ABSTRACT

The automotive industry continues to develop new powertrain technologies aimed at reducing overall vehicle level fuel consumption. The ongoing trends of “downsizing” and “down speeding” have led to the development of turbocharged engines with low displacement and high torque density. In order to meet the launch response requirements with these engines as well as fuel economy needs, transmissions with large ratio spreads will need to be developed. Due to the lack of torque amplification from the torque converter, the next generation of dual clutch transmissions (DCT) will need to have larger launch ratios and ratio spreads than currently available in production today. This paper discusses the development of a new family of DCT (called “xDCT”) for use in front wheel drive vehicles, aimed at meeting some of these challenges.

The xDCT family features two innovative concepts, the idea of “gear generation” and “supported shifts”. A combination of these features results in the development of a highly compact and efficient family of DCTs. The paper will begin with a definition of the xDCT concept followed by a layout of the gear sets for 7 and 10 speed versions of this transmission. Simulation results are used to show the powershift capability as well as efficiency of the developed transmission concept. Finally, a 3D design study is utilized to demonstrate key features of the transmission concept that will result in a highly efficient and compact transmission with low mechanical complexity and full powershift capabilities.

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INTRODUCTION

The ongoing trends “downsizing” and “downspeeding” have led to the introduction of a large number of turbocharged engines with small displacement, high torque and significant disadvantages in response compared to previous generations of naturally aspirated engines. This trend will grow even stronger in the future, creating a huge demand for ratio spread, on the one hand in order to improve launch behavior, on the other hand to reduce fuel consumption. Especially dual clutch transmissions (DCT) without the advantage of torque amplification by a torque converter will require launch ratios in the area of 20 and ratio spreads larger than 10. In order to maintain acceptable ratio steps, this will lead to an increasing demand for DCT concepts with a large number of gears [1]. On the other hand,

small vehicles and especially cost-sensitive markets will require concepts which maintain today's number of gears with significantly reduced complexity. Current production DCTs feature a maximum of seven speeds, which can be realized using three main shafts and four shift sleeves. With conventional gear set concepts this complexity cannot be reduced, as each gear requires a separate switchable connection. To even increase the number of gears, more gear wheels, shift sleeves and shafts have to be added thus increasing size, weight, and cost.

The solution developed by FEV is the “xDCT” family, a series of DCT concepts for transverse installation, which effectively minimize mechanical complexity for any given number of gears by combining two non-conventional ideas: “gear generation” and “supported shifts” (Figure 1). In order

to “generate gears”, at least one switchable connection between the two input shafts is included which allows for use of all gears inside the transmission with both clutches. This approach has first been presented previously by other authors [2] [3] [4].

Although the use of a single switchable connection theoretically doubles the number of gears, the remaining challenge is to effectively use these gears in a shift schedule without torque interruption. The solution introduced by FEV for the xDCT family is to incorporate one or two “supported shifts” into the shift schedule. For these shifts, two adjacent gears are assigned to the same clutch which usually requires a gear change with torque interruption. For a supported shift however, torque fill is provided with the second clutch using the next higher gear. The energy which is stored in the engine inertia and released during the upshift compensates for the smaller torque amplification of the supporting gear. It is this combination of the two ideas, i.e., “gear generation” and “supported shift” that allows for effective use of the theoretically available gears without torque interruption.

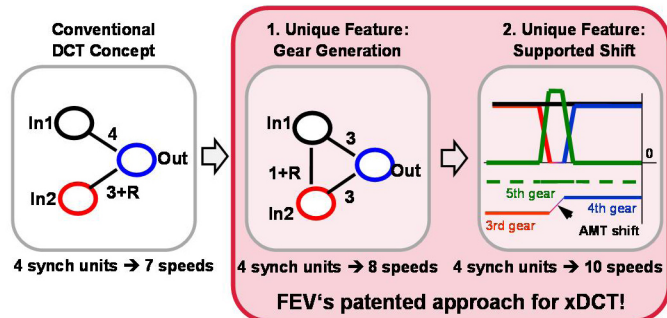


Figure 1. Gear Generation and Supported Shifts

CONCEPT DEFINITION

The need for a large number of well-stepped gear ratios without increasing the mechanical complexity of current transmissions requires new ways of gear set synthesis and optimization. Therefore new gear sets at FEV are developed using a systematic, computer aided synthesis process. During this process, all theoretically possible solutions are analyzed until the optimum solution considering all boundary conditions has been found (Figure 2).

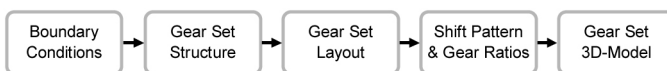


Figure 2. Steps for Systematic Gear Set Development

The visualization of gear set structures shown in Figure 3 allows a very simple and fast analysis of the functionality possible with a certain transmission layout. It illustrates the degrees of freedom and the number of switchable connections between them for a given gear set [5]. The total number of gears is the sum of “direct gears” (direct connection between input and output) and “generated gears” (gears in which the

switchable connection between the inputs is active). All possible arrangements of switchable connections can be evaluated, e.g., with respect to the theoretical number of gears and the number of efficiency-optimum direct gears. The right part of Figure 3 shows the gear set structures of “10-xDCT” (b) with ten usable forward gears using a total of eight switchable connections (e.g., four synchronizer units/four shift sleeves) and the gear set structure of a smaller version, the “7-xDCT” (c), which features seven forward gears using only six switchable connections (e.g., three synchronizer units and three shift sleeves).

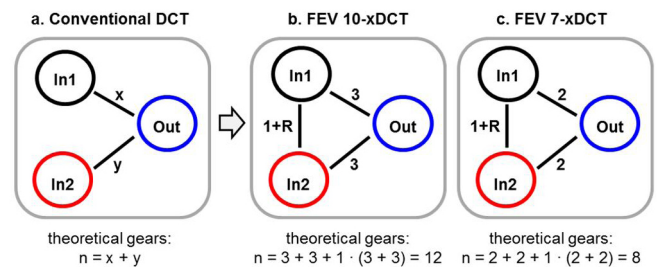


Figure 3. Development of Gear Set Structures

Figure 4 shows the complete FEV 7-xDCT gear set structure with the arrangement of all gear ratios. Gears 3 and 6 (III., VI.) are direct gears on the first clutch (In1) while Gears 2 and 5 (II., V.) are direct gears on the second clutch (In2). The transfer connection (T) between the two inputs has a selectable ratio step and will create a shorter gear if the transfer is used from In1 to In2. Conversely, if the transfer is used from In2 to In1, the ratio step will create longer gears. Gears 1, 4 and 7 are generated gears and combine the transfer gear ratio (T) with different direct gear ratios. The connection for reverse (R) is installed between the inputs (In1, In2). Thus, reverse gear is assigned to the first clutch and uses the connection “R” and direct gear ratio II. The connections used in a certain gear and the upshift sequence are shown in the right part of Figure 4. In the upshift sequence, only the generated Gear 4 has to be engaged using a supported shift.

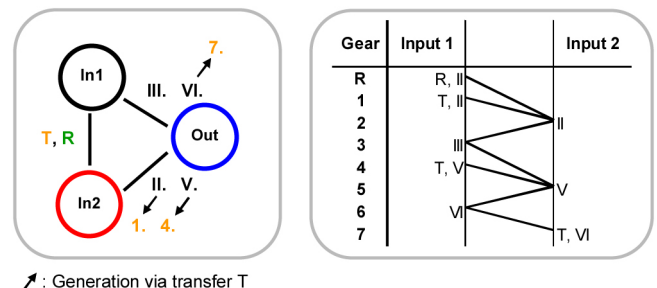


Figure 4. 7-xDCT Gear Set Structure