

General Motors Front Wheel Drive Seven Speed Dry Dual Clutch Automatic Transmission

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ABSTRACT

General Motors has introduced a new front wheel drive seven speed dry dual clutch automatic transmission in 2014. The 250 Nm input torque rated gear box was designed and engineered for a global market in both front wheel drive and all-wheel drive configurations. The transmission has integrated start/stop capability enabled by the use of an electric motor driven pump and a pressurized accumulator.

The architecture selected was chosen for optimization of packaging, fuel economy, mass, shift pleasability, and NVH. High mileage durability and world class drivability were the cornerstone deliverables during the engineering and design process

Fuel efficiency is estimated to be 3% - 10% improvement over a conventional six speed automatic transmission. FWD variant wet mass of 78.1 kg was achieved through the rigorous engineering processes used to optimize the transmission system.

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INTRODUCTION

The dry dual clutch transmission, dDCT, uses dual concentric input shafts and two counter shafts which are in constant mesh with the final drive ring gear on the output axis with the differential assembly. Engine power is transferred to the transmission using a dual mass flywheel, DMF, with interface drive tangs to the dual dry clutches, DDC. Power flow from the DDC to the concentric input shafts is handled by a high pressure, direct acting dual concentric slave cylinder, CSC. All transfer pinions and gears are in constant mesh, with gears on the countershafts achieving power transfer through appropriate synchronizer assembly engagement between the gear and splined synchronizer hub. Four synchronizer assemblies are incorporated to achieve the reverse and seven forward gear ranges. Synchronizers are applied using hydraulic power from the control system. Power flow from the countershaft final drive pinion is routed to the final drive ring gear mounted to the differential assembly. Final drive ratio flexibility is achieved by matching final drive ring gear with the integrated final drive pinions on the countershafts. Lubrication of the gear box components is achieved by directed splash lubrication methods, incorporating troughs and dams, using fluid engineered for minimal spin loss throughout the operating temperature range. Creative engineering solutions, such as routing the power flow for reverse gear through both countershafts, enabled reduced packaging length and elimination of a separate axis for a reverse idler gear.

A separate hydraulic fluid is used in the control system, referred to as the powerpack, for the electronically controlled shift events. The fluid is engineered to maximize pump efficiency across the operating temperature range, specifically cold temperature. A high pressure, axially compensated pump, driven by an electric motor, coupled with a gas charged accumulator, supplies the hydraulic power for the synchronizers and CSC. The accumulator enables the electric motor to be cycled as demand pressures require, as well as engine start / stop for fuel efficiency. The control system utilizes a direct mounted external controller to coordinate all shift events. Five pressure control solenoids, and four flow control solenoids are utilized in the hydraulic circuitry.

Design for manufacturability methods were incorporated into the components and architecture of the transmission throughout the engineering and design process. Manufacturing flexibility for customer specific component interface requirements, sediment control, and error proofing methods significantly contribute to achieving the transmission durability, cost, and reliability goals. System integration of the transmission into the vehicle environment has resulted in noise, vibration, and handling characteristics competitive with conventional automatic transmission based vehicles.

A summary of the dDCT transmission specifications are shown in [Table 1](#).

Table 1. Specification table

Number of gear ratios	7 Forward, 1 Reverse
Maximum input torque, Nm	250
Maximum output torque, Nm	3800
Wet mass, kg	78.1
Input to output axis center distance, mm	196.93
Input to output axis vertical drop, mm	75

KINEMATIC ARRANGEMENT

The transmission has a four axis, seven speed power-flow as shown in the stick diagram in Figure 1. The odd and even input shafts have a co-axial arrangement. The odd input shaft connects the engine node through the odd clutch to the pinions of 1st, 3rd, 5th and 7th gear states. The even input shaft connects the engine node through the even clutch to the pinions of 2nd, 4th, 6th and reverse gear states. The driven gears have been placed on the two countershafts. The driven gears for 3rd, 5th, 4th and reverse gear states have been placed on the upper countershaft whereas the driven gears for 1st, 7th, 6th and 2nd gear states have been placed on the lower countershaft. The arrangement has four double synchronizers. The gears are in constant mesh. To select a gear state, the corresponding synchronizer and the input clutch must be engaged. The upper and the lower countershafts have integral final drive pinions which are in constant mesh with the final drive ring gear. The kinematic arrangement has two gear dependencies: 4th and 6th gears are driven by a common pinion, similarly 5th and 7th gears are driven by a common pinion. The power-flow has a two plane reverse, the reverse pinion is coupled to the 2nd driven gear. The reverse ratio results from the 2nd gear ratio multiplied by the reverse plane ratio.

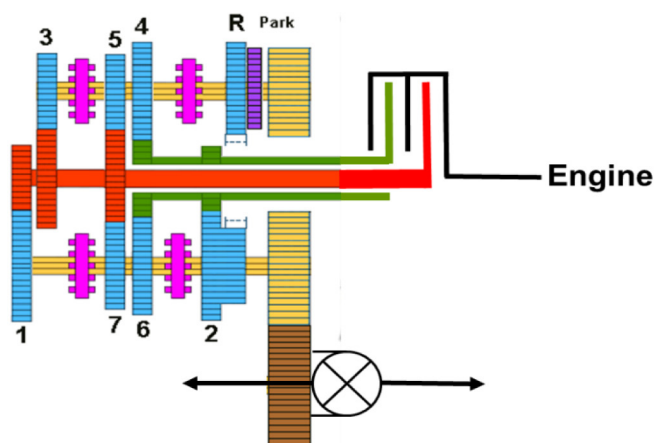


Figure 1. Stick diagram

There are three sets of final drive ratios available, providing an effective launch ratio from 16.67 to 19.29. Table 2 provides the clutching table, with example of 7.42 overall ratio spread between 1st

and 7th gear ratios, and the overall forward effective launch ratio of 19.29 using final drive ratio set 1. Pre-synchronization strategies of non-torque carrying gears can also be incorporated to achieve vehicle performance metrics.

Table 2. Gear clutching table

Gear	Gear Ratio	Final Drive Set 1 Overall Ratio	Ratio Step	C246R Input Clutch	C1357 Input Clutch	1st Gear Synchro	2nd Gear Synchro	3rd Gear Synchro	4th Gear Synchro	5th Gear Synchro	6th Gear Synchro	7th Gear Synchro	Rev Gear Synchro
R	-3.88	-20.21		X									X
N			-0.92										
1	4.23	19.29			X	X							
2	2.47	11.26	1.71	X			X						
3	1.38	7.19	1.79		X			X					
4	0.93	4.85	1.48	X					X				
5	0.75	3.91	1.24		X					X			
6	0.71	3.24	1.06	X							X		
7	0.57	2.60	1.25		X							X	
Overall Spread	7.42												

X - On, carrying torque

The cross section of the gear box is shown in Figure 2, with the transmission interface for all wheel drive configuration shown in Figure 3. Ship with oil capability is maintained in both the FWD and AWD variants.

LAUNCH DEVICE

One of the unique devices to a dDCT is the dry dual clutch, DDC, shown in Figure 4 and 5. The function of the DDC is to allow power transfer from the engine to the transmission odd gear or even gear shafts for the staged, or preselected, gear state change.

The launching clutch is dry, meaning no lubrication fluid is used to cool the clutch. Air convection and conduction is used to dissipate heat generated thru shift events and operation. During a shift event, torque flow changes from one friction disc to the other disc, which requires controlled timing and clutch slip. Heat is generated during this torque exchange. Air inlet and outlet passages are in the clutch housing to provide a path for air flow. A thermal model, developed by the General Motors Propulsion Systems Research Laboratories, predicts the clutch temperature after a shifting event or a series of events. The control algorithm utilizes this model to predict clutch temperature. The clutch utilizes a specifically developed friction material for a dDCT that is bonded to a more conventional cushion disc. The friction material offers a more stable coefficient of friction at temperatures up to 350C, and more judder resistant at low torque.

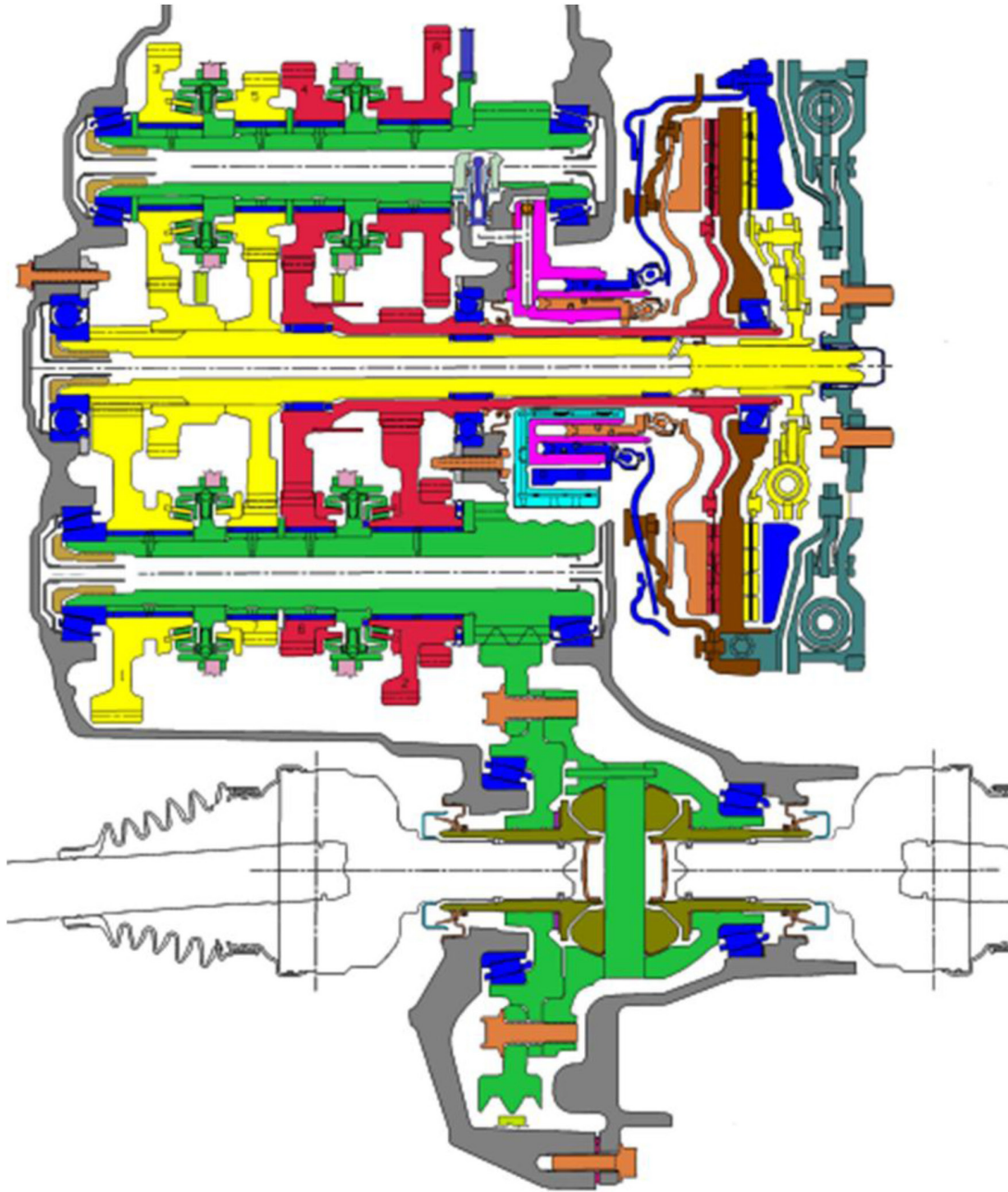


Figure 2. Cross section of gear box

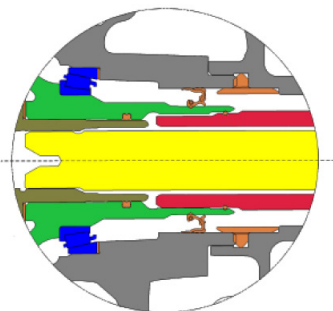


Figure 3. All wheel drive interface

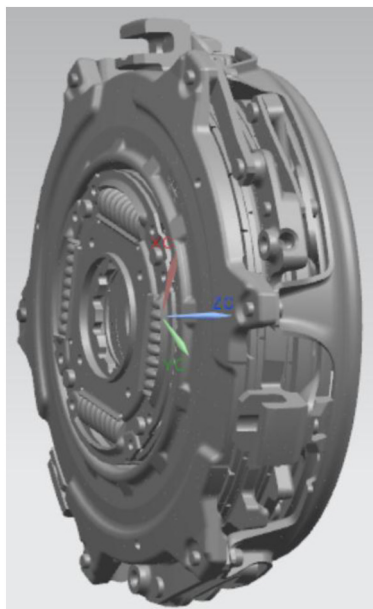


Figure 4. Dry dual clutch

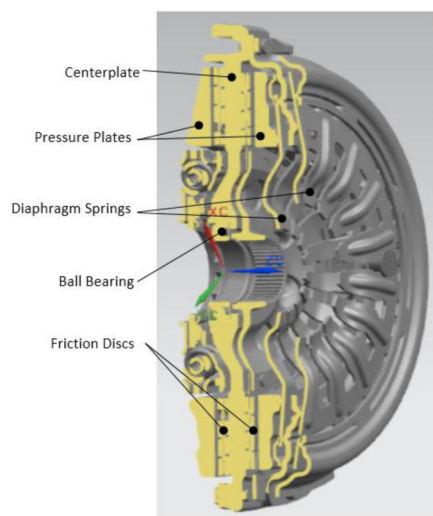


Figure 5. Dry dual clutch cross section

Additional features of the DDC include manufacturing operations and tolerance control which reduce the sensitivity to judder. Judder is a common stick slip phenomena in all types of clutches which results in a jerky, or lurching, motion to the vehicle, which can be a customer complaint issue. Strategic measures have been taken in the design, manufacturing, and calibration to avoid the onset of judder in under-torque and launch conditions. To provide an added defense against judder, a 100% inspection process in manufacturing is used to measure and compare to specification limits for the DDC.

Balancing of the DDC is another special manufacturing operation developed from the beginning of the dDCT program. The DDC architecture does not offer a simple method to correct for imbalance. Balancing is accomplished by several operations involving multiple sub-assemblies throughout manufacturing. These operations helped to eliminate the need to add balancing mass to the DDC and achieve specification.

The clutch centerplate is connected to the flywheel, which is directly connected to the engine crankshaft. The centerplate is a common interface to both clutch friction disc 1 and disc 2, and rides directly on a ball bearing pressed onto the hollow, or even, input shaft. The ball bearing allows the clutch center plate to spin freely without torque transfer when the vehicle is in a neutral condition. The dual concentric slave cylinder also has a set of bearings which allow rotation of the clutch, and apply load to rotating diaphragm springs for disc 1 or disc 2. Hydraulic pressure actuates the concentric slave cylinder piston to lock a friction disc between the centerplate and pressure plate through the diaphragm springs. A mechanical advantage through the diaphragm lever of 2.25 for clutch 1, and 3.05 for clutch 2, increases the clamping load on the friction discs. Clutch torque capacity and control is made by position control of the concentric slave cylinder pistons.

DUAL CONCENTRIC SLAVE CYLINDER

The concentric slave cylinder, CSC, has 2 independent cylinders, one for each clutch actuation motion as described in the DDC section, [Figure 6](#). The cylinders share a common aluminum forged housing which has been anodized for friction and wear performance. The cylinder for clutch 2 is mounted concentrically inside of the cylinder for clutch 1. Independent hydraulic circuits are provided for control of fluid pressure and flow, which is necessary for a clutch to clutch shift pleasability. Mounted in the cylinder bodies are small samarium cobalt magnets which create a field intensity and pattern orientation consistent enough for the elastomagnetic position sensor to read the travelled position of the cylinder. The sensed position is proportional to the clutch torque capacity through calibration and algorithm learning. A key learning during the dDCT development was the need to shield the sensor from magnetic field interference. This was accomplished with the use shielding made from high nickel content mu-metal.

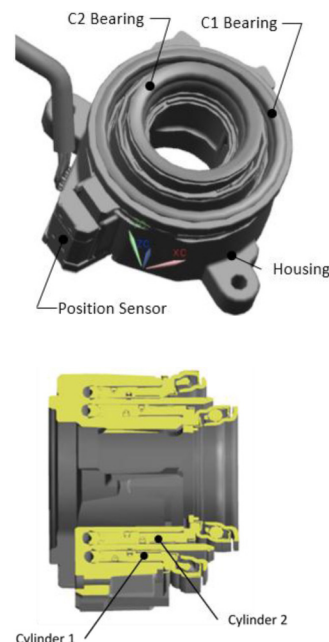


Figure 6. Concentric Slave Cylinder



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