Newly Developed Twin Clutch SST (Sport Shift Transmission)

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Abstract

This paper describes the newly developed Twin Clutch Sport Shift Transmission (TC-SST) used in the LANCER EVOLUTION X. In the Twin Clutch SST (the first transmission of its kind to be used by Mitsubishi Motors Corporation (MMC)), a six-speed automated manual transmission in which two automatic clutches are used to realize (a) quick gearshifts and a concomitantly good acceleration feeling and (b) highly efficient torque transmission and concomitantly good fuel economy. MMC plans to include the TC-SST in the transmission lineups of future front-engine, front-wheel-drive passenger cars.

Key words: *Transmission, Power Train, Clutch, Hydraulic System*

1. Objective of the development

The Twin Clutch Sportronic Shift Transmission (hereinafter referred to as TC-SST) was developed with the following as key concepts:

(1) Quicker gear shifting than conventional automatic transmissions (A/Ts) with the same or better gearshift smoothness
(2) Fuel economy as good as in manual transmissions (M/Ts)
(3) Off-the-line acceleration performance as good as in M/Ts

For each of these concepts, the objectives for achievement in the development were set based on the needs and benchmarks of the vehicles that were slated to be equipped with the TC-SST.

The TC-SST has two electro-hydraulically controlled clutches; one connects to an odd-number gear set, i.e., the 1st, 3rd and 5th gears and the other to an even-number gear set, i.e., the 2nd, 4th and 6th gears. Either of these two clutches is used at any given time to connect power to a selected gear. Before the working clutch is switched from one to the other, the control system determines the gear to be used next and engages that gear (pre-shift gear engagement). The system then disengages the first clutch and engages the second clutch at the most appropriate timing while controlling the engine torque so that the gear shifting will take place most smoothly and the fuel economy and off-the-line acceleration performance will be made high enough to be comparable to or better than those offered by five-speed M/Ts (**Table 1**).

Table 1 Adopted technologies and their purposes

Items \ Purpose	Shift Q up efficiency	High fuel	Driveability up weight	Small or light	NVH decrease
Cooperation with engine	Yes	Yes	Yes		
Wide gear spread		Yes	Yes		
Short length with multi shaft				Yes	
Use ball or roller bearing as much as possible		Yes	Yes		
Floating of center bearing of the shaft supported with 3 points		Yes	Yes		
Press fit of gear and shaft				Yes	Yes
Variable control of line press		Yes			
Use many linear solenoids	Yes				
Optimization of clutch slip control	Yes				Yes
Optimization of Pre-shift	Yes				
Precise adaptive control of the piston engagement point or pre-filling	Yes	Yes			

2. Basic structure

Table 2 compares the specifications of the TC-SST and those of the five-speed A/T used in an MMC vehicle model. Despite its larger coupled engine's torque compared with the five-speed A/T, the TC-SST is shorter in overall length and lighter in weight, meaning that it has improved characteristics for installation on vehicles.

Fig. 1 shows a cross-sectional view of the TC-SST. **Fig. 2** is a skeleton diagram of the TC-SST.

There are two hydraulically controlled, wet type multiple-disc clutches of the same diameter. They are coaxially arranged, the one being installed on a hollow shaft that drives the odd-number gears and the other on a solid shaft that drives the even-number gears. Compared with A/Ts and continuously variable transmissions (CVTs) using torque converters, the TC-SST gives less feel of slip and offers direct response to accelerator operations comparable to M/Ts.

Another feature of this clutch system is the use of long-travel damper springs. By properly setting the inertia working on both ends of the springs, the clutches operate smoothly with low vibration noise.

The gear unit of the TC-SST has a total of six speed gears; the three (1st, 3rd and 5th) of them and the reverse gear are installed on the odd-number gear shaft

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Table 2 TC-SST specifications

Model name		W6DGA (TC-SST)	W5A5A (A/T for LANCER EVO wagon MR)
Overall length (mm)		385	418
Power transmission system (Engine to transmission)		Wet multiple-disc clutch (two clutch sets)	Torque converter
Coupled engine's torque (N·m)		422	343
Gear ratios	1st	3.655 (14.848)	3.789 (12.633)
	2nd	2.368 (9.621)	2.057 (6.860)
	3rd	1.754 (7.127)	1.421 (4.737)
	4th	1.322 (5.372)	1.000 (3.333)
	5th	1.008 (4.097)	0.731 (2.437)
	6th	0.775 (3.148)	–
Final reduction ratio		4.062	3.333
Mass (dry) (kg)		98	108

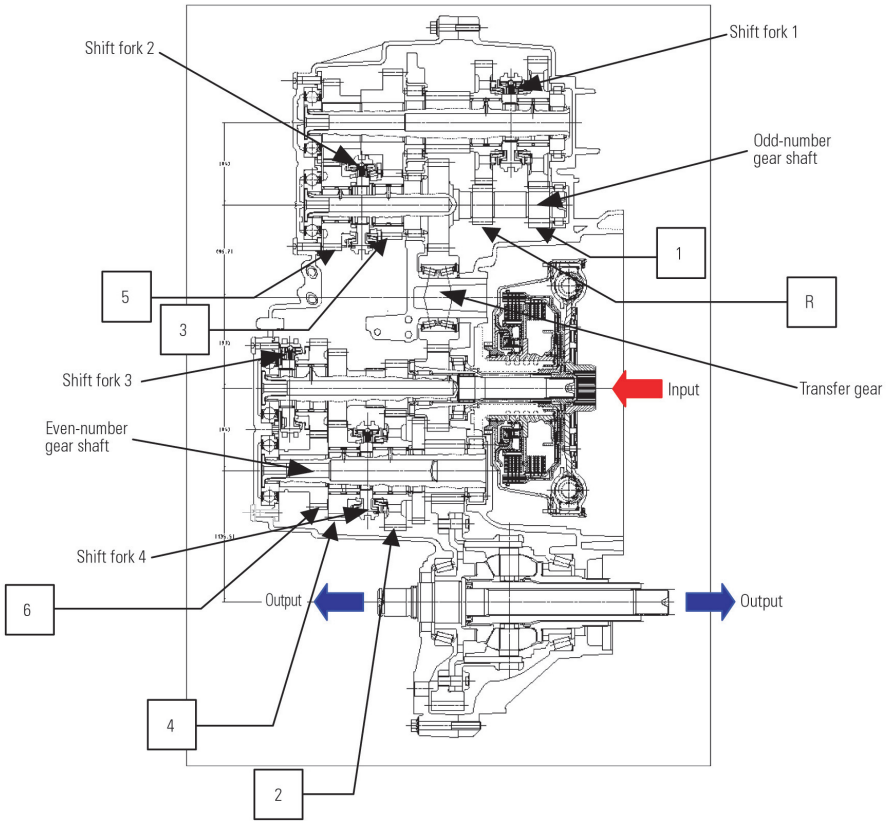

Fig. 1 TC-SST cross-sectional view

and the remaining three gears (2nd, 4th and 6th) are installed on the even-number gear shaft, forming a combination of two three-speed M/Ts. This arrangement with the odd-number speed gears installed on a shaft different from the shaft for the even-number gears with a transfer gear in between significantly reduces the overall length of the transmission. Like conventional M/Ts, a synchromesh mechanism using the shift fork to slide the synchronizer sleeve is employed for shifting gears. The shift fork is operated hydraulically through the hydraulic pistons on both of its ends.

Conventional A/T systems have the control unit located inside the cabin, separately from the A/T unit. With the TC-SST, the control unit forms an integral part of the TC-SST unit together with various sensors, solenoids and its hydraulic valve body. This contributes to substantial reduction in physical wiring. Furthermore, this makes it possible for the control unit to undergo the process for calibrating the clutch strokes and other unit specific characteristics before the TC-SST leaves the transmission manufacturing factory, which significantly helps to ensure the stable gearshift feeling of the TC-SST (**Fig.3**).

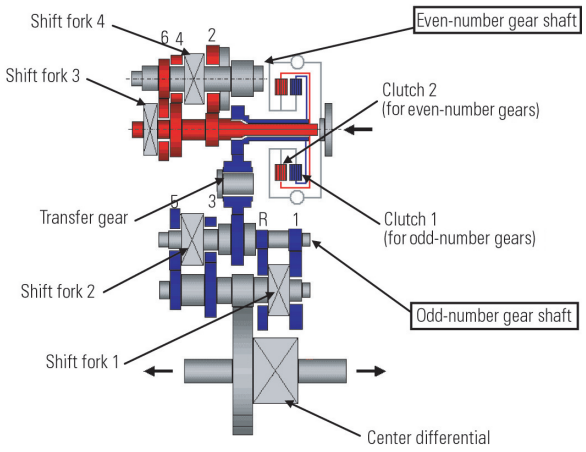

Fig. 2 TC-SST basic structure (1)

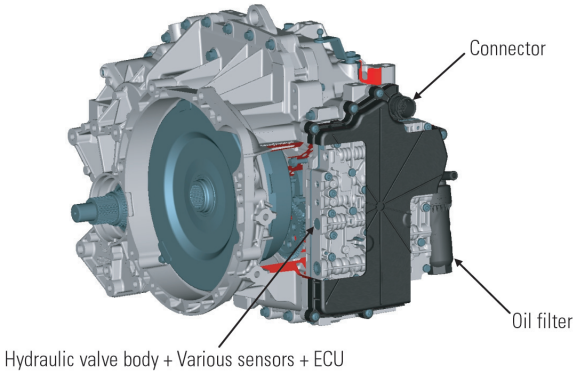

Fig. 3 TC-SST basic structure (2)

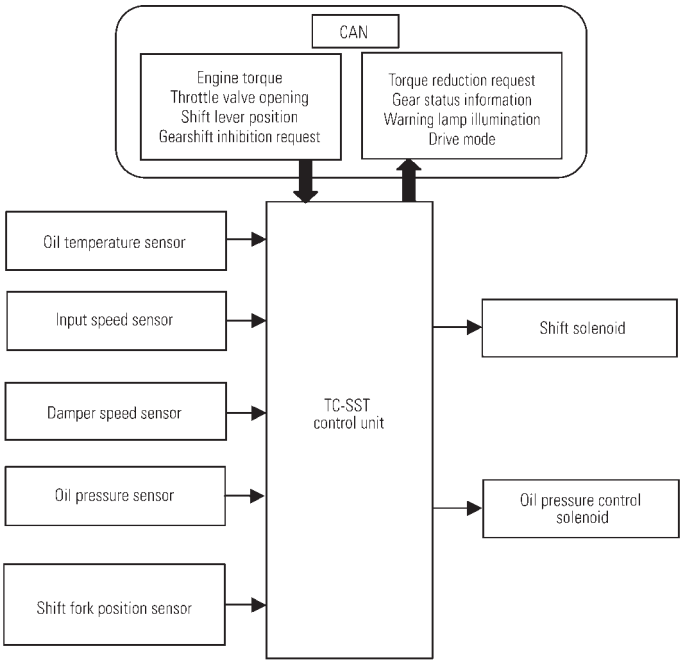

Fig. 4 Control system

3. Outline of TC-SST operation

When the vehicle is to be started in 1st, for example, the 1st gear is brought in mesh with the output shaft by the synchromesh mechanism and then the odd-number gear clutch is engaged to cause the engine torque to be transmitted to the output shaft through the 1st gear. While this process is taking place, the 2nd gear on the even-number gear shaft is brought in mesh with the output shaft by the corresponding synchromesh mechanism. When the conditions for shifting up to 2nd are met, the even-number gear clutch is engaged simultaneously with the disengagement of the odd-number gear clutch in such a way that transmission of engine torque is not interrupted. Likewise, before a shift from 2nd to 3rd takes place, the synchromesh mechanism causes the 3rd gear to mesh with the output shaft while the vehicle is running in 2nd and the 2nd to 3rd gearshift completes when the odd-number gear clutch is engaged simultaneously with disengagement of the even-number gear clutch.

4. Electronic control system

Fig. 4 is a block diagram showing the control system of the TC-SST. Vehicle and engine status data are transmitted through the control area network (CAN), an international standard intra-vehicle communication network, to the TC-SST control unit. The control unit uses these data together with TC-SST internal data to control the TC-SST in a way most suitable for the vehicle condition. When controlling the TC-SST, the control unit adjusts the supply of hydraulic pressures to the four shift forks and two clutches to make these shift forks and clutches operate most appropriately in order to ensure both smooth gear change and quick gearshifts without causing interruption of engine torque transmission.

(1) Creep control

Like A/Ts with a torque converter, the TC-SST allows the vehicle to creep through minute control of the clutch pressure to create a slip-engagement state. The TC-SST control unit makes this control in coordination with the engine control to prevent engine stalls.

The control unit also takes control to reduce the torque transferred through the clutch to the minimum while the driver is stepping on the brake pedal. This control is effective to improve fuel economy and reduce clutch engagement shock that would result from shift lever operation.

(2) Variable control of line pressure

The TC-SST uses a variable line pressure control system that allows it to precisely adjust the line pressure to the minimum levels necessary for the control of the clutches, as well as lubrication of the clutches and control of gear shifting, while also adjusting it according to oil temperature and other similar conditions. This control keeps the total energy loss of the transmission to a minimum and contributes to

Table 3 TC-SST control modes

Mode	Gear change timing	Gear change time	Accelerator response
Normal	At low engine speed	Standard	Moderately responsive
Sport	At medium engine speed	Short	Responsive
S-Sport	At high engine speed	Very short	Very responsive

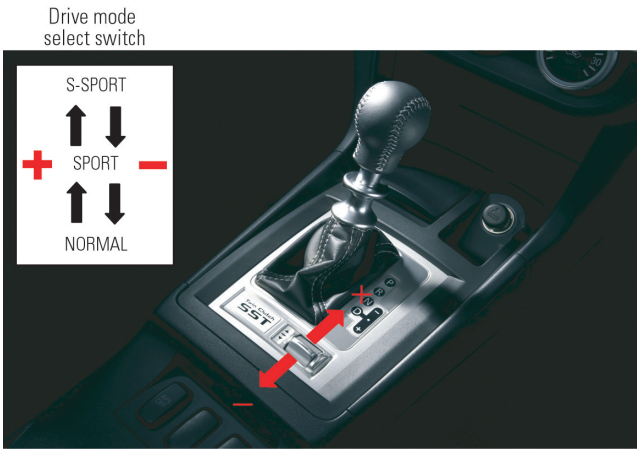

Fig. 5 TC-SST control modes

improvement in fuel economy.

(3) Clutch slip control

The TC-SST is capable of controlling the clutch slip speed using the selected drive mode, vehicle speed, accelerator position and other factors as parameters. By employing this control, the TC-SST can simultaneously satisfy such contradicting requirements as fuel economy, direct response to accelerator operation and reduced vibration noise.

(4) Pre-shift control (bringing a gear in mesh before clutch engagement)

Pre-shift control is programmed in a way consistent with the gearshift characteristics intended by each drive mode. The control logic reflecting the result of the analysis on the data collected through a series of test drives has enabled a natural and quick shift response of the transmission.

(5) Other control features

The TC-SST control incorporates a function of automatically memorizing the best clutch engagement points through learning. This function offsets the unit specific deviation resulting from part variations, thereby ensuring the TC-SST's original high gearshift quality. It also includes a function of pre-pressurizing a clutch hydraulic piston circuit under certain conditions for quicker gear shifting.

5. Control modes

In the case of the TC-SST used in the LANCER EVOLUTION X, three drive modes, i.e., "Normal," "Sport" and "Super Sport" can be selected using the TC-SST control mode select switch located next to the shift lever. The timing of a gear change as well as how quickly the gear change takes place and how the gear change is responsive to accelerator operation is made different between the control modes so that the user can enjoy driving in all scenes (**Table 3** and **Fig. 5**).

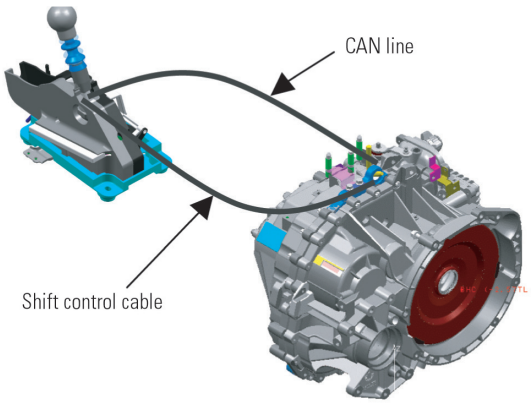

Fig. 6 Communication with shift lever

6. Shift lever

The shift lever system of the TC-SST accommodates CAN communications and is the first of its kind to be used by MMC. Shift lever position data, TC-SST control mode select switch status data and paddle shift data are transmitted through the CAN line from the shift lever control unit to the TC-SST control unit. The use of the CAN communication system substantially reduces the amount of in-vehicle wiring (**Fig. 6**).

7. Conclusion

In the development and production of the TC-SST, the latest simulation technologies are applied to a variety of analyses that are conducted, digital modeling technologies are used extensively and latest types of production equipment are introduced, all to assure the highest possible quality of the new transmission.

Using this opportunity, we wish to extend our sincere thanks to all of those who helped make this development possible.


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