■ELECTRONIC CONTROL SYSTEM

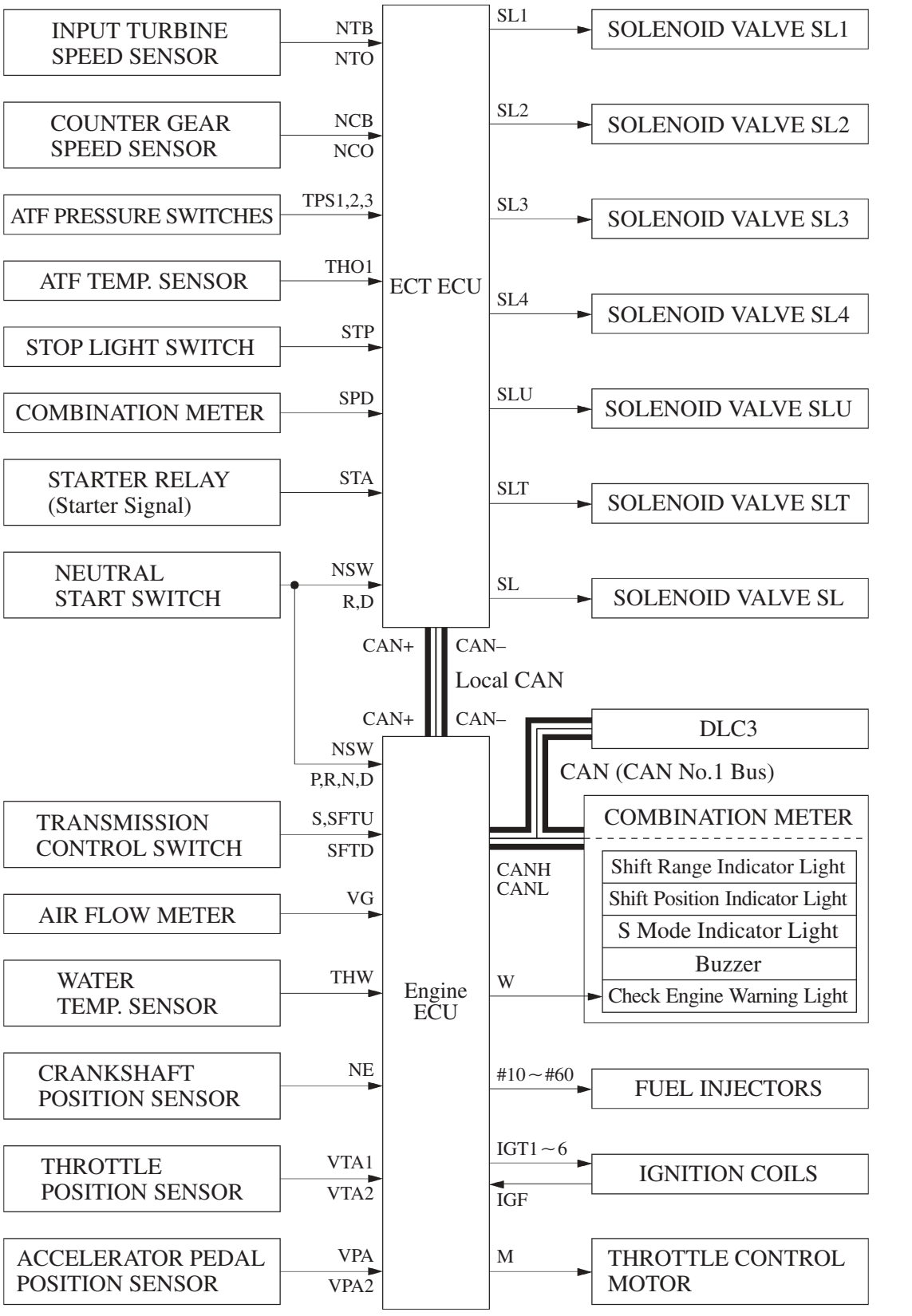
1. General

The electronic control system of the U660E automatic transaxle consists of the control listed below.

System	Outline
Shift Timing Control	The ECT ECU supplies current to 6 solenoid valves (SL1, SL2, SL3, SL4, SL and/or SLU) based on signals from each sensor to shift the gear.
Clutch to Clutch Pressure Control (See page CH-64)	Controls the pressure that is applied directly to the C1, C2 clutches and B1, B3 brakes by actuating the shift solenoid valves (SL1, SL2, SL3 and SL4) in accordance with ECT ECU signals.
Line Pressure Optimal Control (See page CH-65)	Actuates solenoid valve SLT to control the line pressure in accordance with information from the ECT ECU and the operating conditions of the transaxle.
Powertrain Cooperative Control (See page CH-66)	Controls both the shift control and engine output control in an integrated way, achieving excellent shift characteristics and drivability.
Lock-up Timing Control (See page CH-67)	The ECT ECU supplies current to shift solenoid valves SL and SLU based on signals from each sensor and engages or disengages the lock-up clutch.
Flex Lock-up Clutch Control (See page CH-68)	Controls solenoid valves SLU and SL, provides an intermediate mode between the ON/OFF operation of the lock-up clutch, and increases the operating range of the lock-up clutch to improve fuel economy.
Coast Downshift Control (See page CH-69)	The ECT ECU performs downshift control so that fuel cut control can continue for as long as possible during deceleration.
AI (Artificial Intelligence) -SHIFT (See page CH-70)	Based on the signals from various sensors, the ECT ECU determines the road condition and the intention of the driver. Thus, the shift pattern is automatically regulated to an optimal level, improving drivability.
Multi-Mode Automatic Transmission (See page CH-72)	The ECT ECU appropriately controls the automatic transaxle in accordance with the range position selected while the shift lever is in the S mode position.
Diagnosis (See page CH-74)	When the ECT ECU detects a malfunction, the ECT ECU makes a diagnosis and memorizes the malfunctioning part.
Fail-safe (See page CH-74)	Even if a malfunction is detected in the sensors or solenoids, the ECT ECU activates fail-safe control to prevent the vehicle's drivability from being significantly affected.

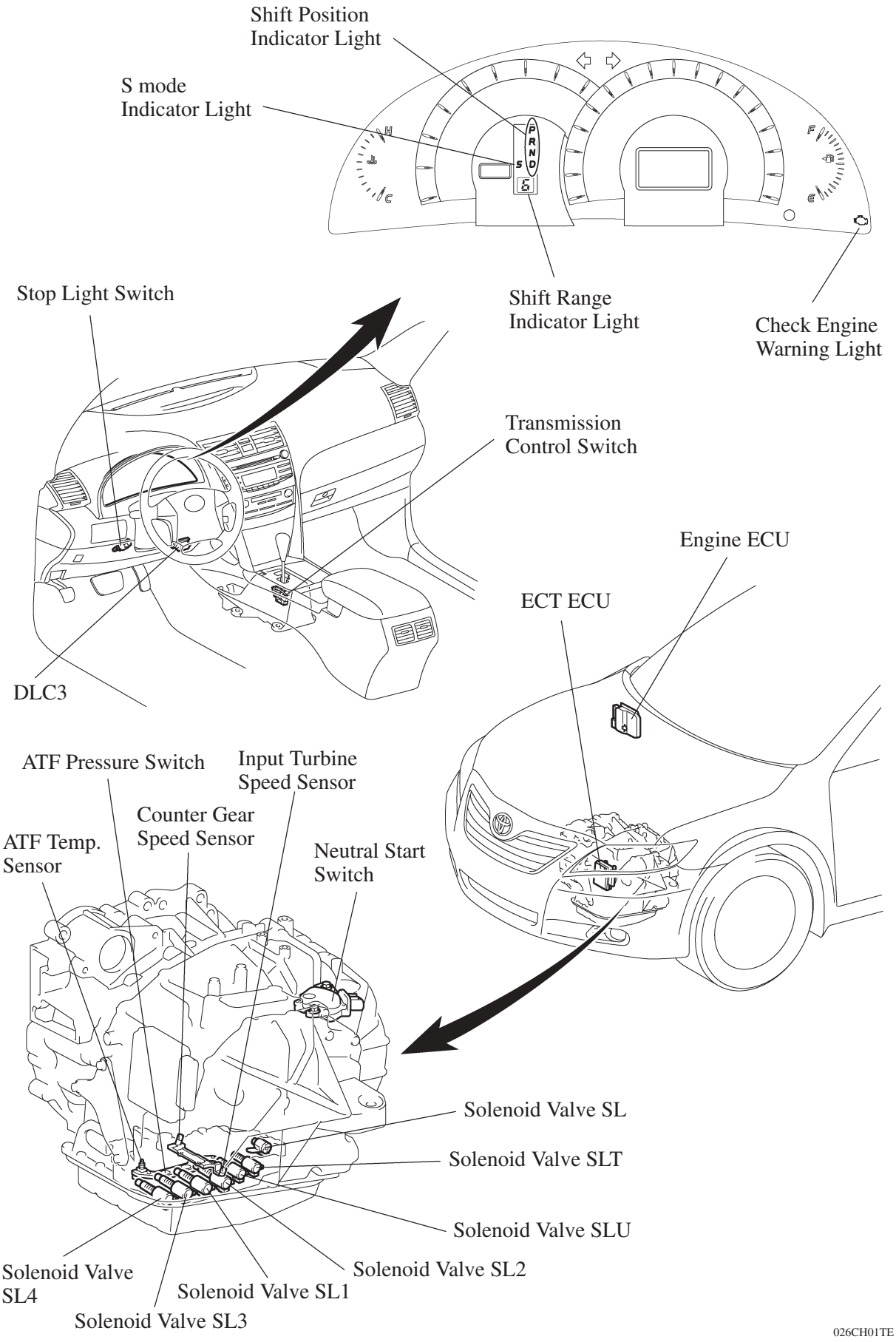
2. Construction

The configuration of the electronic control system in the U660E automatic transaxle is as shown in the following chart.



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3. Layout of Main Components



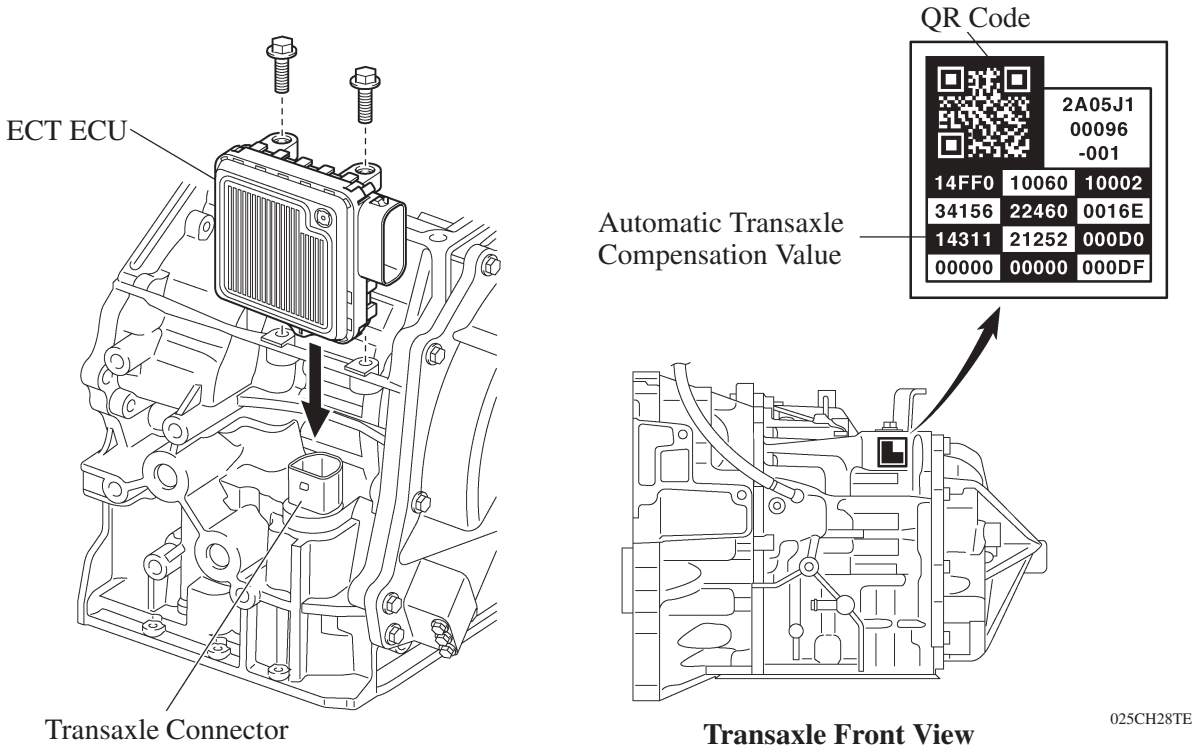
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4. Construction and Operation of Main Components

ECT ECU

- The ECT ECU has been isolated from the engine ECU and directly fitted to the transaxle. Thus, the wiring harness has been shortened allowing the weight to be reduced. All the solenoid valves and sensors used for automatic transaxle control are directly connected to the ECT ECU through the connector located in front of the automatic transaxle.
- The ECT ECU maintains communication with the engine ECU through the CAN (Controller Area Network). Thus, engine control is effected in coordination with ECT control.
- A label, on which the automatic transaxle compensation values and QR (Quick Response) code are printed, is attached on the top of the automatic transaxle. The label contains encoded automatic transaxle property information. When the automatic transaxle is replaced, allow the ECT ECU to learn the automatic transaxle property information by inputting the automatic transaxle compensation values into the ECT ECU using a intelligent tester II. In this way, the shift control performance immediately after replacement of the automatic transaxle is improved. For details, see the Camry Repair Manual (Pub. No. RM0260E).
- The QR code, which requires a special scan tool, is used at the vehicle assembly plant.



Transaxle Front View

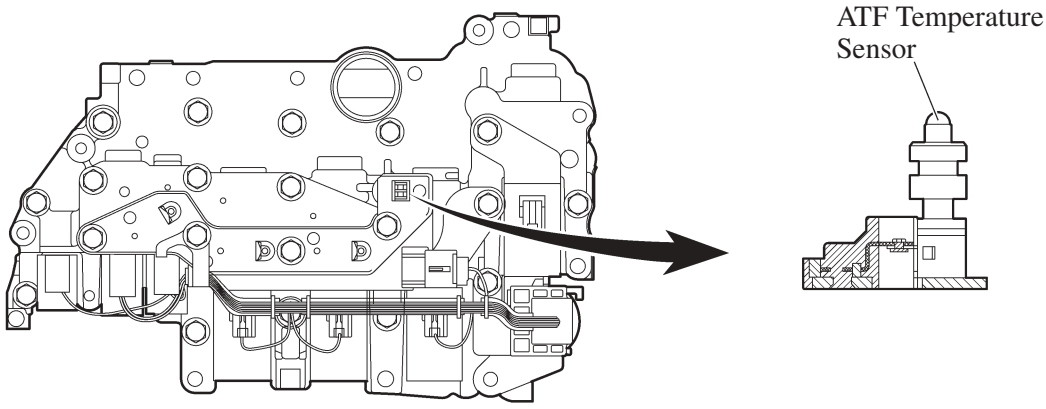
— REFERENCE —

What are QR (Quick Response) Codes?

- *QR code, a matrix symbology consisting of an array of nominally square cells, allows omni-directional, high-speed reading of large amounts of data.*
- *QR codes encode many types of data such as numeric, alphanumeric, kanji, kana and binary codes. A maximum of 7,089 characters (numeric) can be encoded.*
- *QR codes (2D code) contain information in the vertical and horizontal directions, whereas bar codes only contain data in one direction. QR codes (2D code) hold considerably greater volumes of information than bar codes.*

ATF Temperature Sensor

- The ATF temperature sensor is installed in the valve body for direct detection of the fluid temperature.
- The ATF temperature sensor is used for the revision of clutch and brake pressures to maintain a smooth shift quality every time.

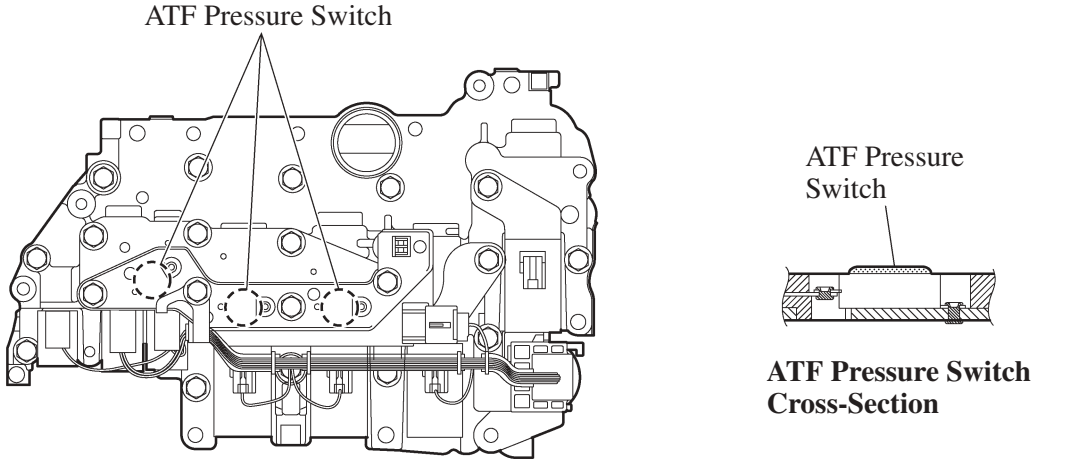


Lower Valve Body

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ATF Pressure Switch

- The ATF pressure switches are located in the output fluid passages of SL1, SL2 and SLU, and turn ON/OFF in accordance with the solenoid valve output fluid pressure.
- The ECT ECU detects malfunctions in solenoid valves SLU and SL used in lock-up control in accordance with the ON/OFF signals from ATF pressure switch 3 located in the SLU output fluid passage.
- When any of SL1 to SL4 malfunctions, the ECT ECU determines the appropriate fail-safe operation to be actuated in accordance with the ON/OFF signals from ATF pressure switches 1 and 2 located in the SL1 and SL2 output fluid passages.



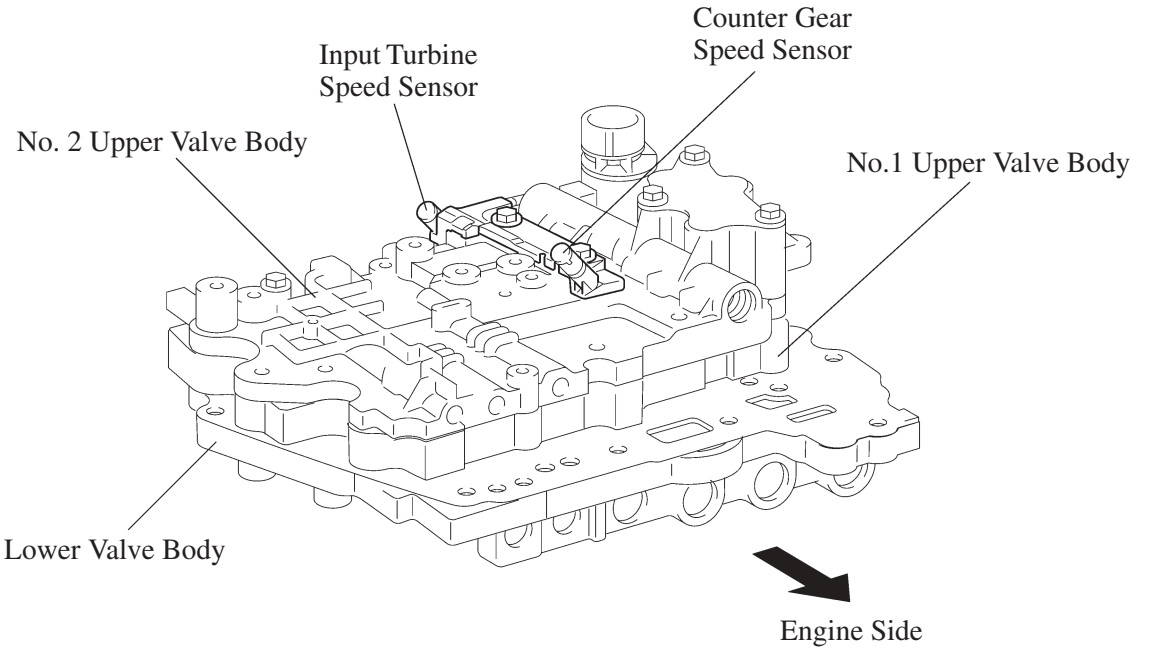
Lower Valve Body

ATF Pressure Switch Cross-Section

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Speed Sensors

- The U660E automatic transaxle uses an input turbine speed sensor (for the NT signal) and a counter gear speed sensor (for the NC signal). Thus, the ECT ECU can detect the timing of the shifting of the gears and appropriately control the engine torque and hydraulic pressure in response to the various conditions. These speed sensors are the Hall type.
- The input turbine speed sensor detects the input speed of the transaxle. The No.2 clutch piston is used as the timing rotor for this sensor.
- The counter gear speed sensor detects the speed of the counter gear. The counter drive gear is used as the timing rotor for this sensor.
- The Hall type speed sensor consists of a magnet and Hall IC. The Hall IC converts the changes in the magnetic flux density that occur through the rotation of the timing rotor into electric signal, and outputs the signal to the ECT ECU.

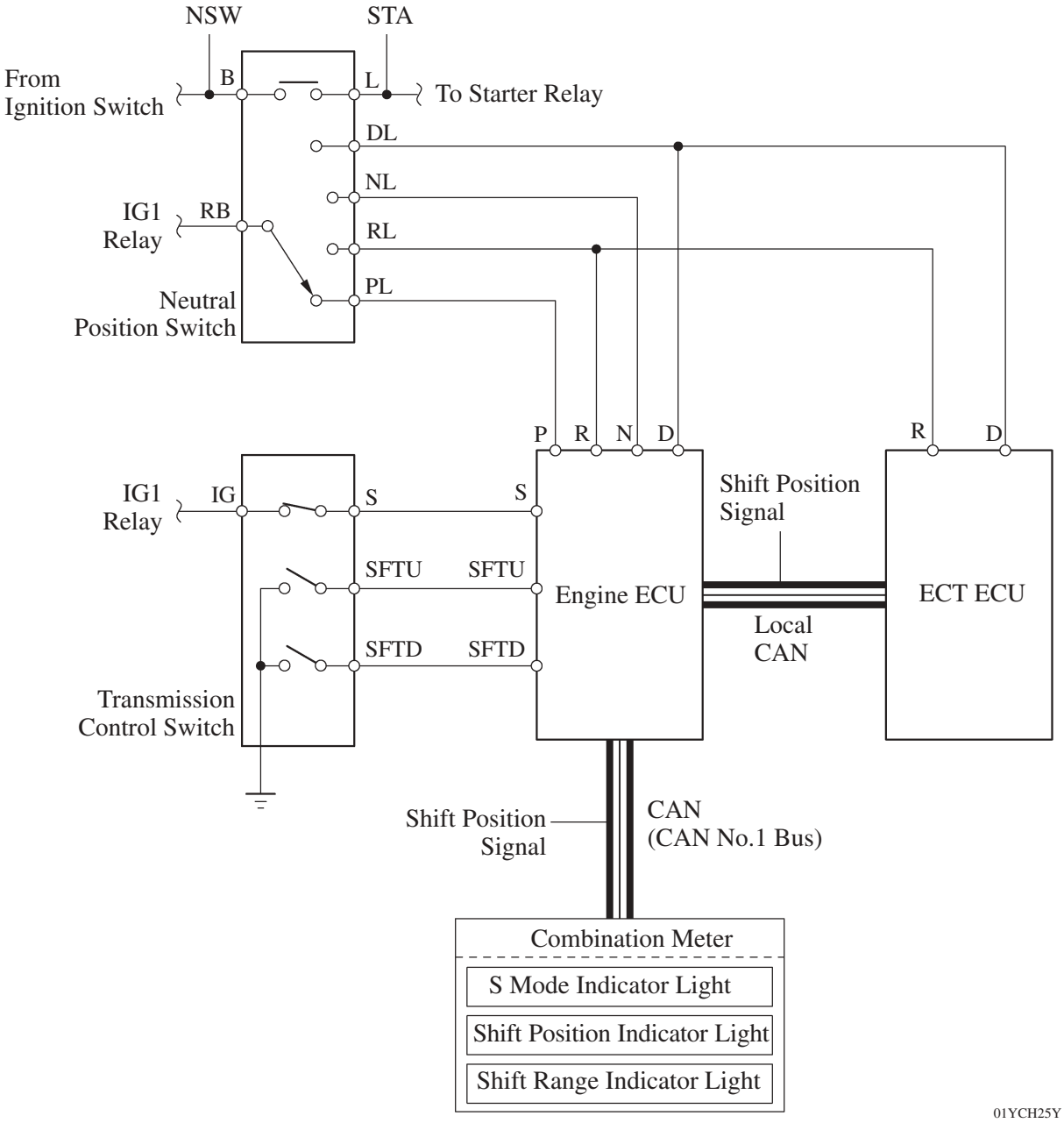


Transmission Control Switch and Neutral Start Switch

The ECT ECU and engine ECU use these switches to detect the shift lever position.

- The neutral start switch sends the P, R, N and D position signals to both the engine ECU and ECT ECU. The engine ECU transmits signals to the combination meter for the shift position indicator light (P, R, N and D) in response to the signal it receives from the switch.
- The transmission control switch is installed inside the shift lever assembly. Switch terminal S is used to detect whether the shift lever is in the D position or S mode position, and terminals SFTU and SFTD are used to detect the operating conditions of the shift lever (front [+ position] or rear [– position]) if S mode is selected. By transmitting signals to the engine ECU, the transmission control switch turns on both the shift range indicator light and S mode indicator light when the shift lever is moved to the S mode position, and indicates the selected range position through shift range indicator light.

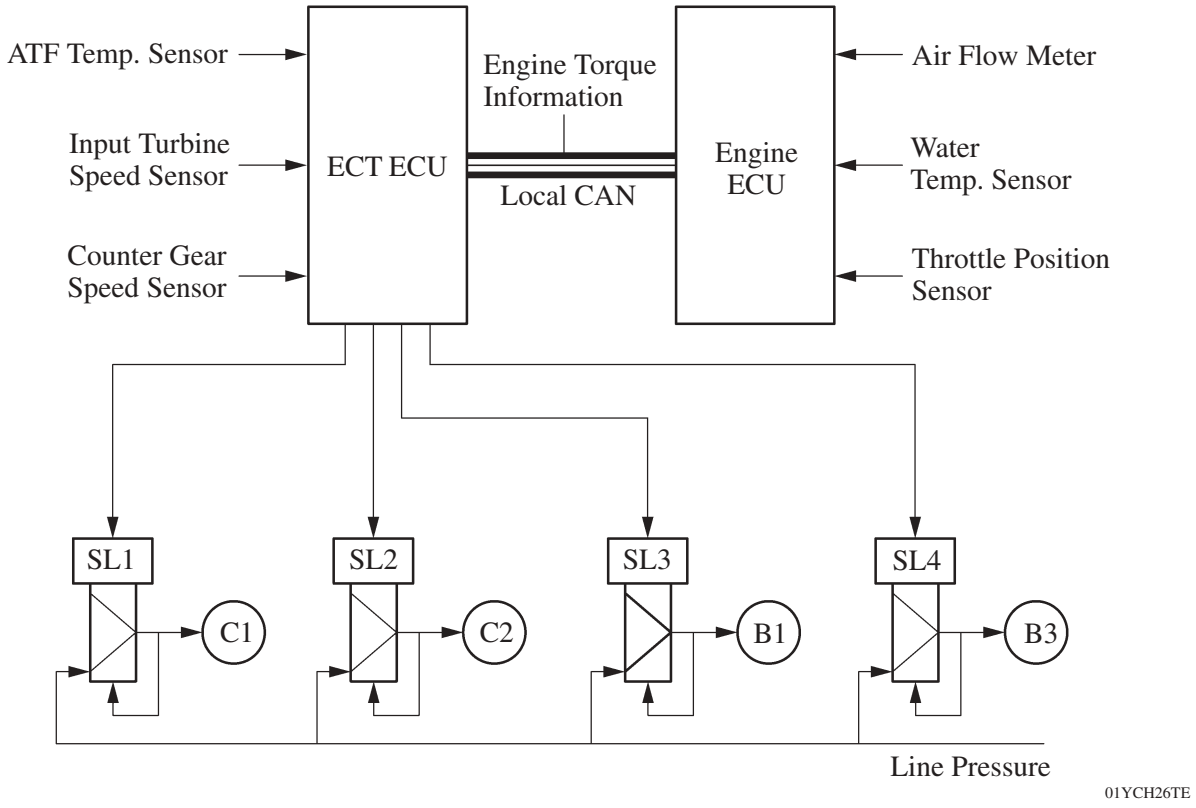
▶ Wiring Diagram ◀



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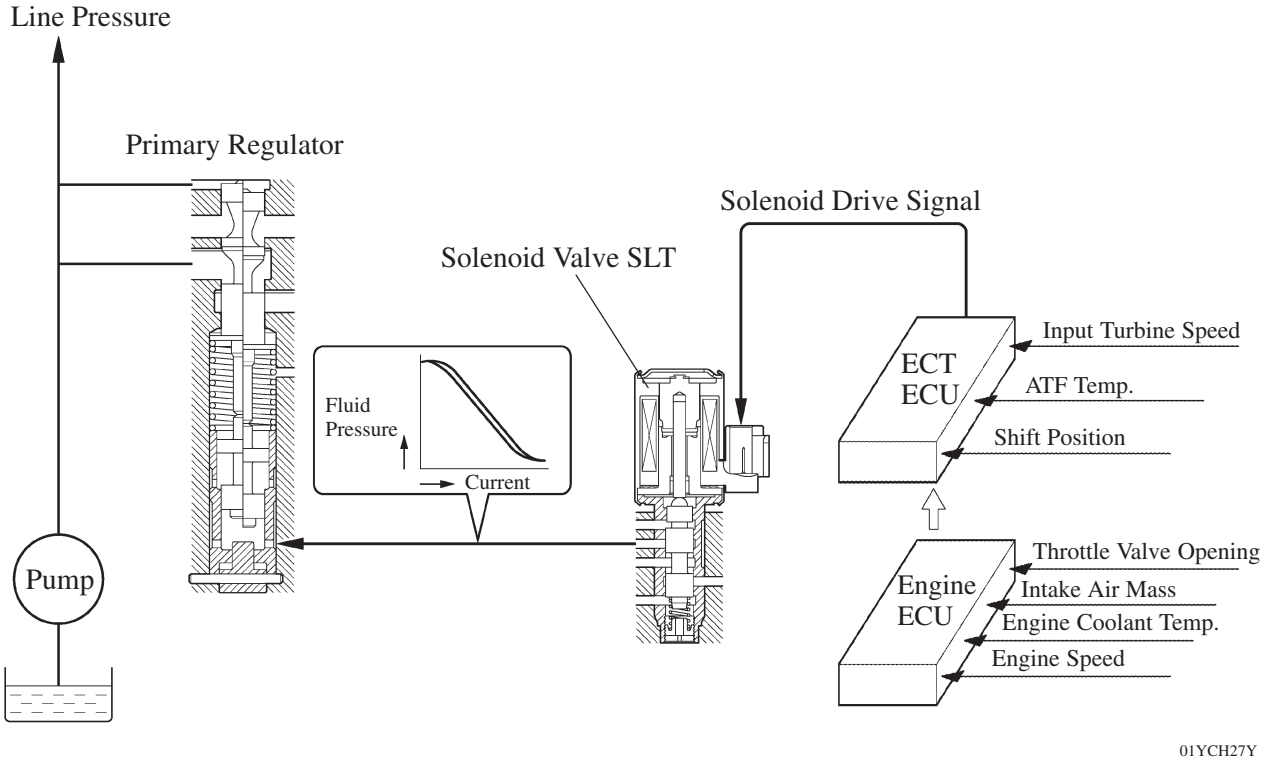
5. Clutch to Clutch Pressure Control

- Clutch to clutch pressure control is used for shift control. As a result, shift control in the 2nd gear or above is possible without using the one-way clutch, and the automatic transaxle has been made lightweight and compact.
- Using the fluid pressure circuit, which enables the clutches and brakes (C1, C2, B1 and B3) to be controlled independently, and the high flow SL1, SL2, SL3 and SL4 linear solenoid valves, which directly control the line pressure, the ECT ECU controls each clutch and brake accordingly with the optimum fluid pressures and timings in accordance with the information transmitted by the sensors, and then shifts the gears. As a result, highly responsive and excellent shift characteristics have been realized.



6. Line Pressure Optimal Control

The line pressure is controlled by using solenoid valve SLT. Through the use of solenoid valve SLT, the line pressure is optimally controlled in accordance with the engine torque information, as well as with the internal operating conditions of the torque converter and the transaxle. Accordingly, the line pressure can be accurately controlled in accordance with the engine output, traveling condition, and the ATF temperature, thus realizing smooth shift characteristics and optimizing the workload of the oil pump.

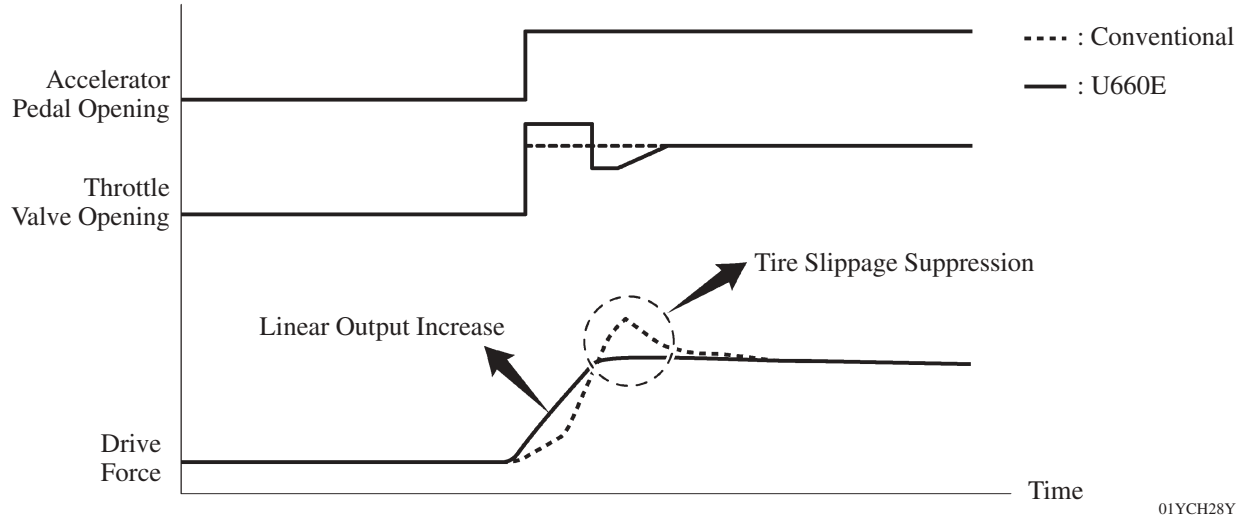


*: This diagram illustrates the fundamentals of Line Pressure Control. The valve shapes differ from the actual ones.

7. Powertrain Cooperative Control

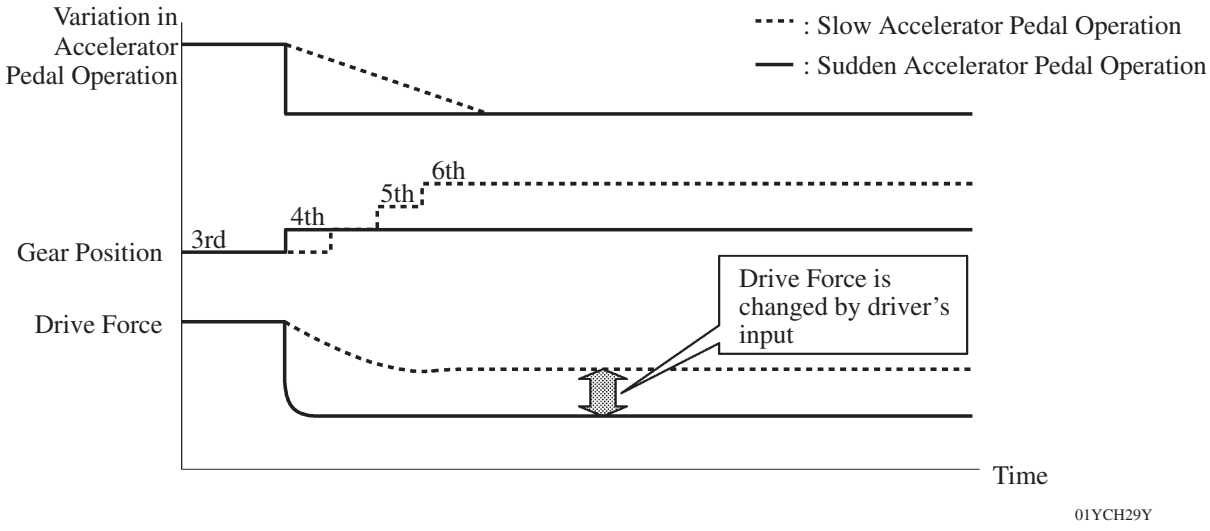
Throttle Control at Launch

By controlling the engine output in cooperative control with ETCS-i (Electronic Throttle Control System-intelligent) when the vehicle is launched, excellent launch performance (improved response and suppression of tire slippage) is ensured.



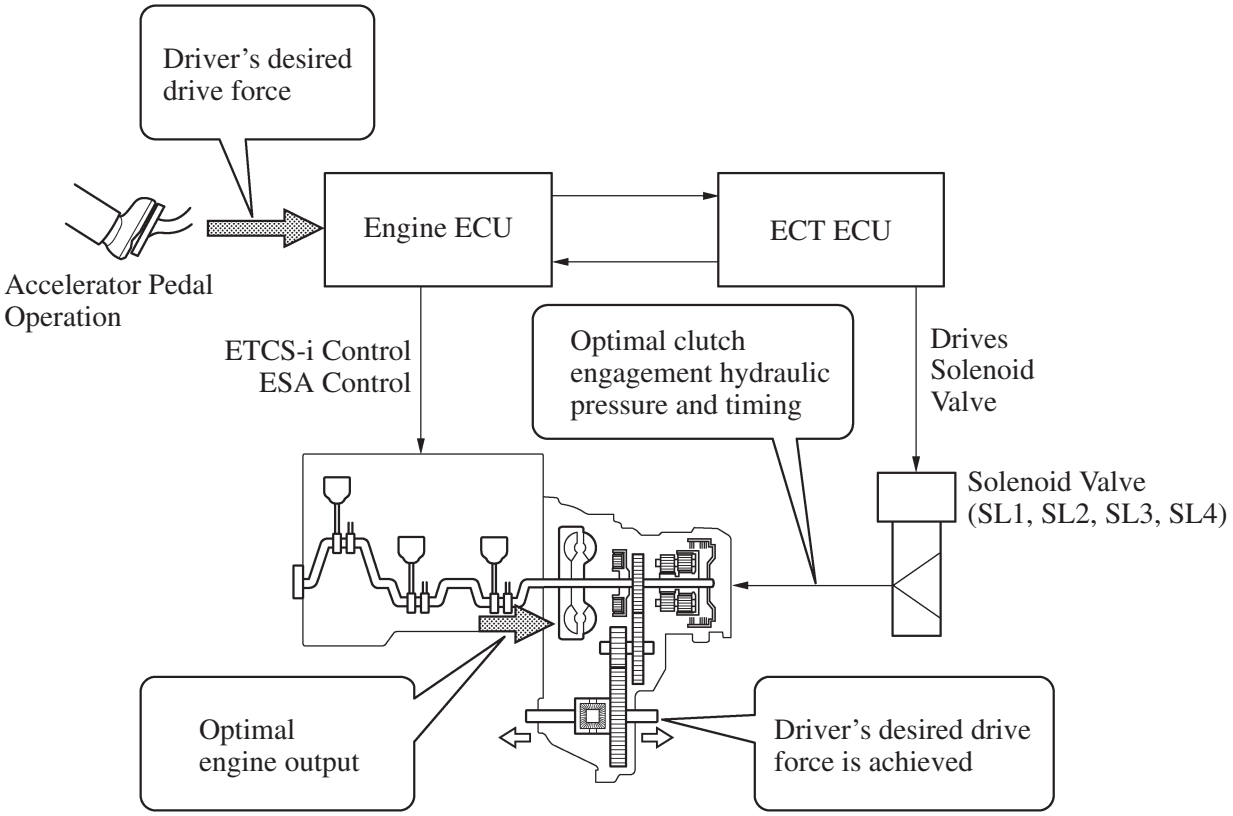
Deceleration Force Control

The ECT ECU determines the gear position when the accelerator pedal is OFF (released completely) in accordance with the operation of the accelerator pedal (released suddenly or slowly) during deceleration. In this way, preventing unnecessary upshifts and downshifts when the accelerator pedal is OFF and ensuring smooth acceleration when the vehicle needs to accelerate again.



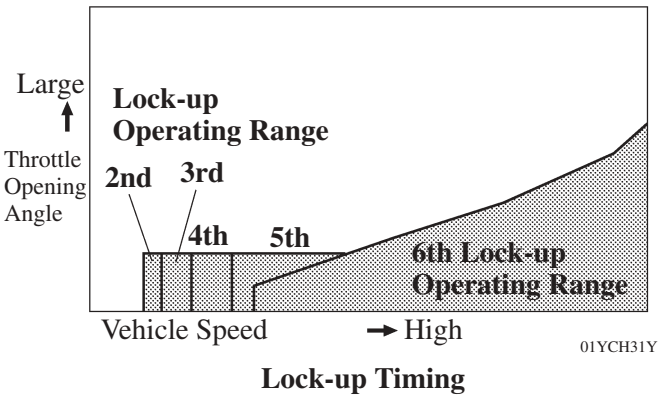
Transient Shifting Control

Through cooperative control with ETCS-i (Electronic Throttle Control System-intelligent) and ESA (Electronic Spark Advance), and electronic control of the engagement and release speed of the clutch and brake hydraulic pressures, excellent response and shift shock reduction have been achieved.



8. Lock-up Timing Control

The ECT ECU operates the lock-up timing control in order to improve the fuel consumption while in the 2nd gear or above with the shift lever in the D, S6, S5, S4 range.



Lock-up Timing

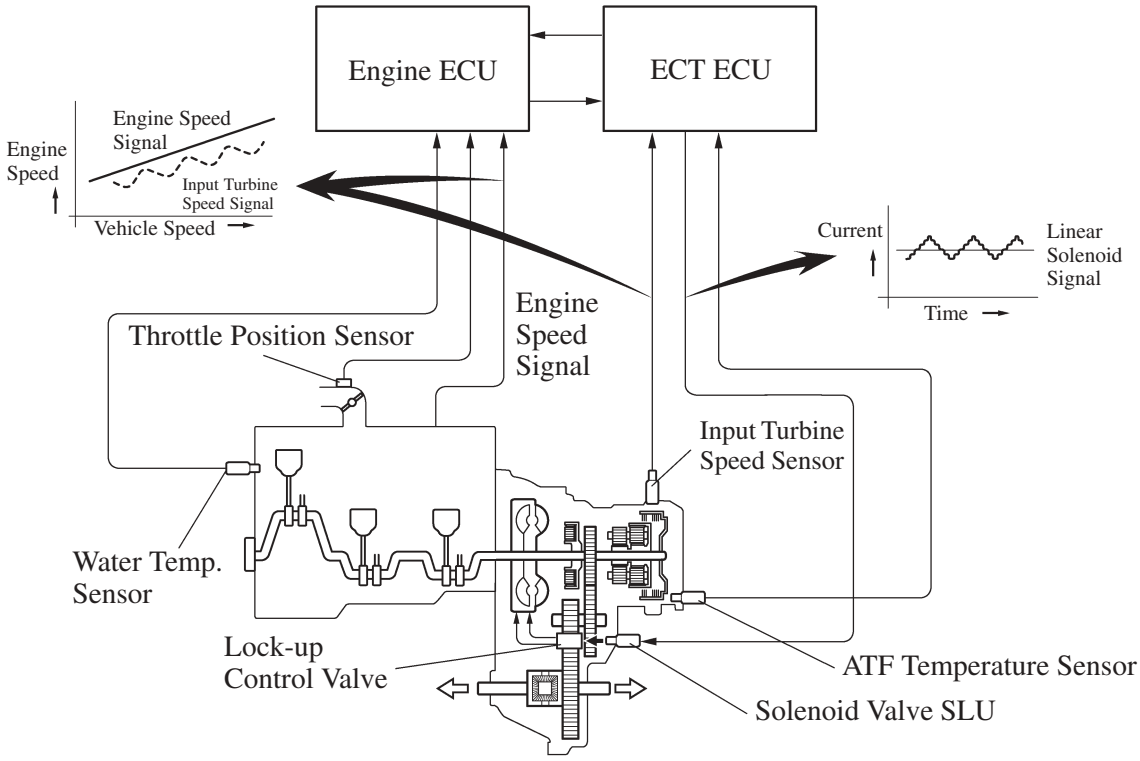
▶ Lock-up Operation ◀

Gear \ Position or Range	D or S6	S5	S4
1st	X	X	X
2nd	○	○	○
3rd	○	○	○
4th	○	○	○
5th	○	○	—
6th	○	—	—

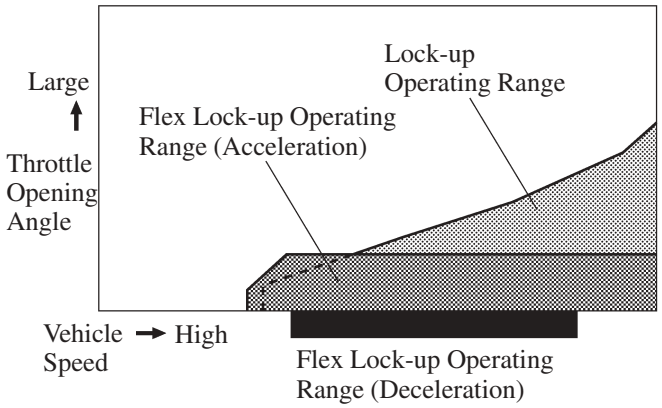
○: Operates X: Does not operate —: Not applicable

9. Flex Lock-up Clutch Control

- In addition to the conventional lock-up timing control, flex lock-up clutch control is used.
- This flex lock-up clutch control regulates solenoid valve SLU as an intermediate mode between the ON and OFF operations of the lock-up clutch.
- During acceleration, flex lock-up clutch control operates when the gear position is the 2nd or higher and the shift lever is in the D, S6, S5 or S4 range position. During deceleration, it operates when the gear position is the 4th or higher and the shift lever is in the D, S6, S5 or S4 range position.
- During acceleration, the partition control of the power transmission between the lock-up clutch and torque converter greatly boosts the transmission efficiency in accordance with the driving conditions, improving the fuel economy.
- During deceleration, the lock-up clutch is made to operate. Therefore the fuel-cut area is expanded and fuel economy is improved.
- By allowing flex lock-up clutch control to continue operating during gearshift, the smooth torque transmission has been obtained. As a result, the fuel economy and drivability have been improved.



▶ Flex Lock-up Operation ◀



Flex Lock-Up Timing in 6th Gear

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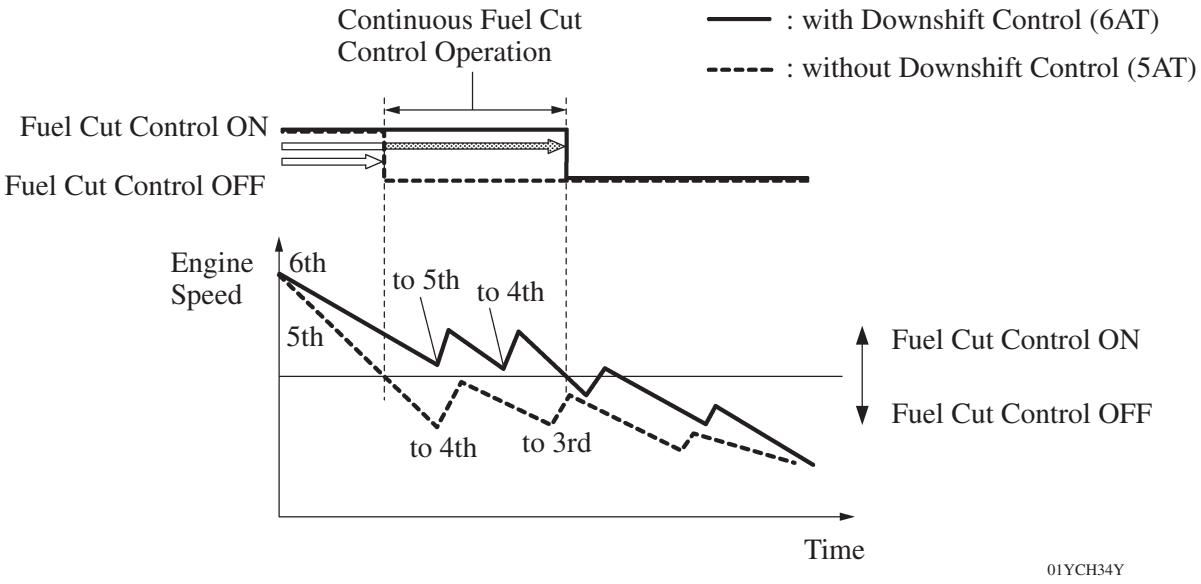
Gear \ Position or Range	D, S6	S5	S4
1st	X	X	X
2nd	○	○	○
3rd	○	○	○
4th	○*	○*	○*
5th	○*	○*	—
6th	○*	—	—

○: Operates X: Does not operate —: Not applicable

*: Flex Lock-up Clutch Control also operates when the vehicle is decelerated.

10. Coast Downshift Control

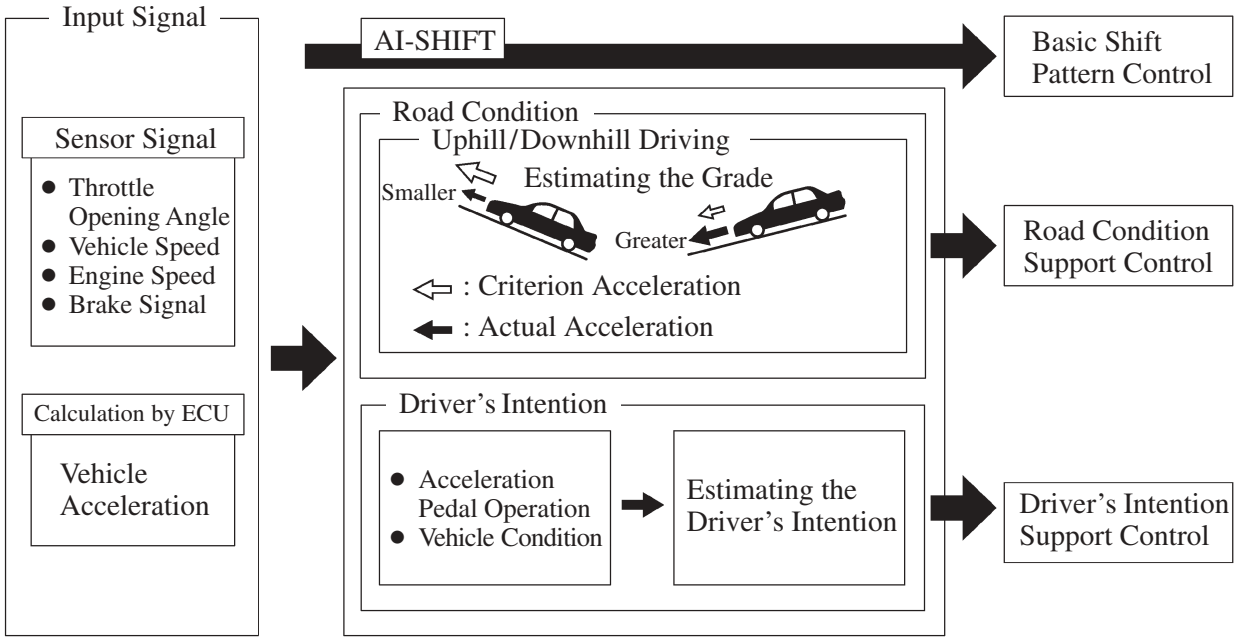
- The ECT ECU performs downshift control to restrain the engine speed from decreasing, and keeps fuel cut control operating for as long as possible. In this way, the fuel economy is improved.
- In this control, the transaxle downshifts from 6th to 5th and then 5th to 4th before fuel cut control ends when the vehicle is decelerated in the 6th gear, so that fuel cut control continues operating.



11. AI (Artificial Intelligence)-Shift Control

General

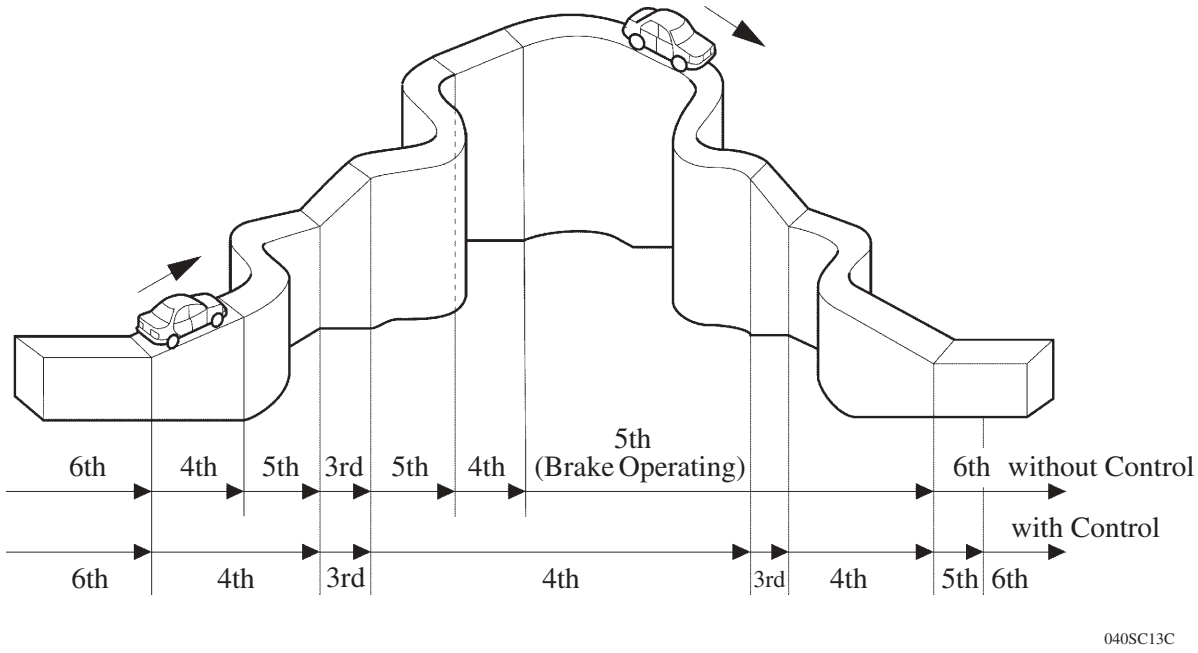
AI-SHIFT control enables the ECT ECU to estimate the road conditions and the driver's intention in order to automatically control the shift pattern in the optimal manner. As a result, a comfortable ride has been achieved.



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Road Condition Support Control

Under road condition support control, ECT ECU determines the throttle valve opening angle and the vehicle speed whether the vehicle is being driven uphill or downhill.
To achieve the optimal drive force while driving uphill, this control prevents the transaxle from up shifting to the 5th or 6th gear. To achieve the optimal engine brake effect while driving downhill, this control automatically downshifts the transaxle to the 5th or 4th or 3rd gear.



Driver's Intention Support Control

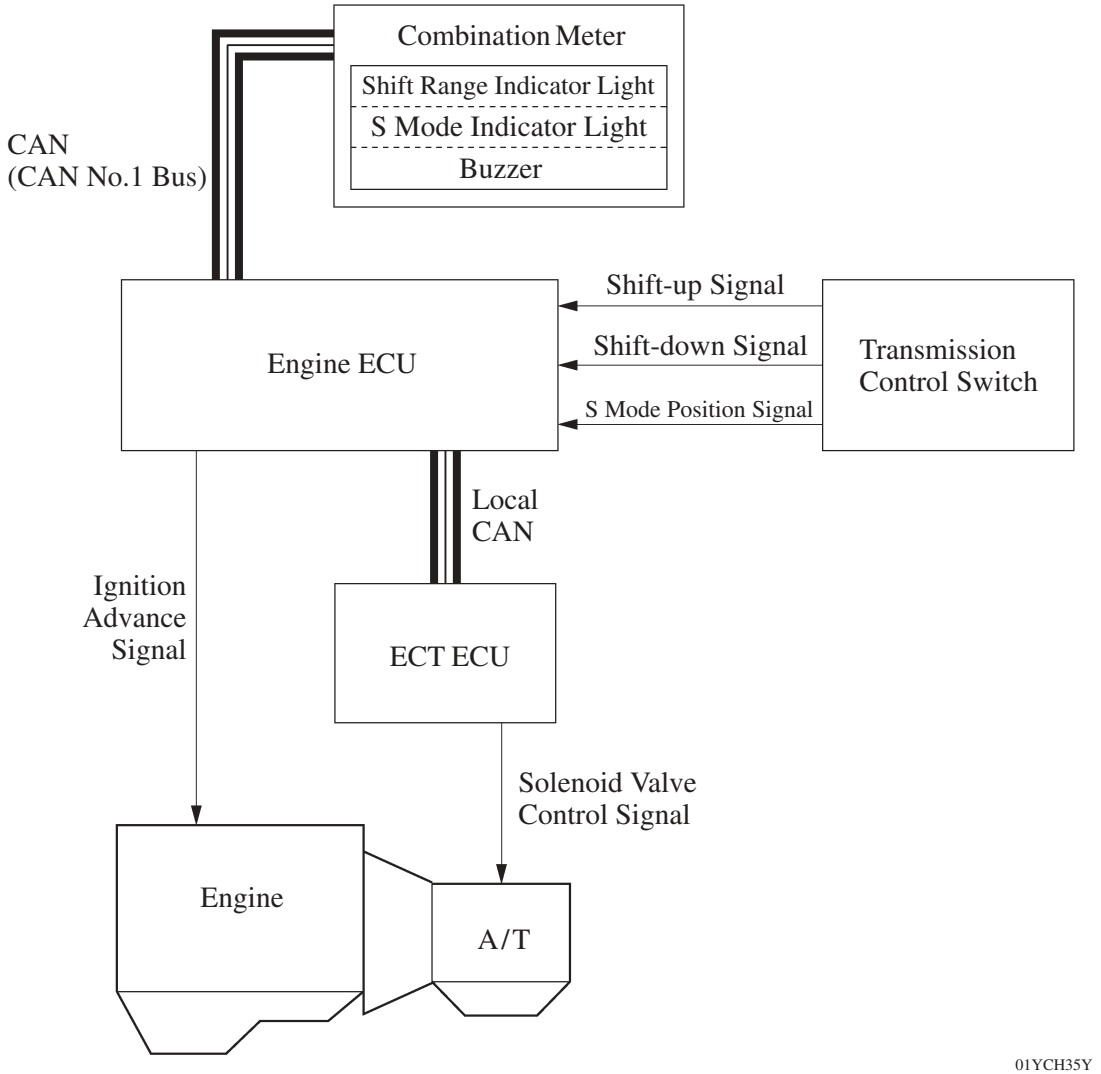
Estimates the driver's intention based on the accelerator operation and vehicle condition to switch to a shift pattern that is well-suited to each driver, without the need to operate the shift pattern select switch used in the conventional models.

12. Multi-Mode Automatic Transmission

General

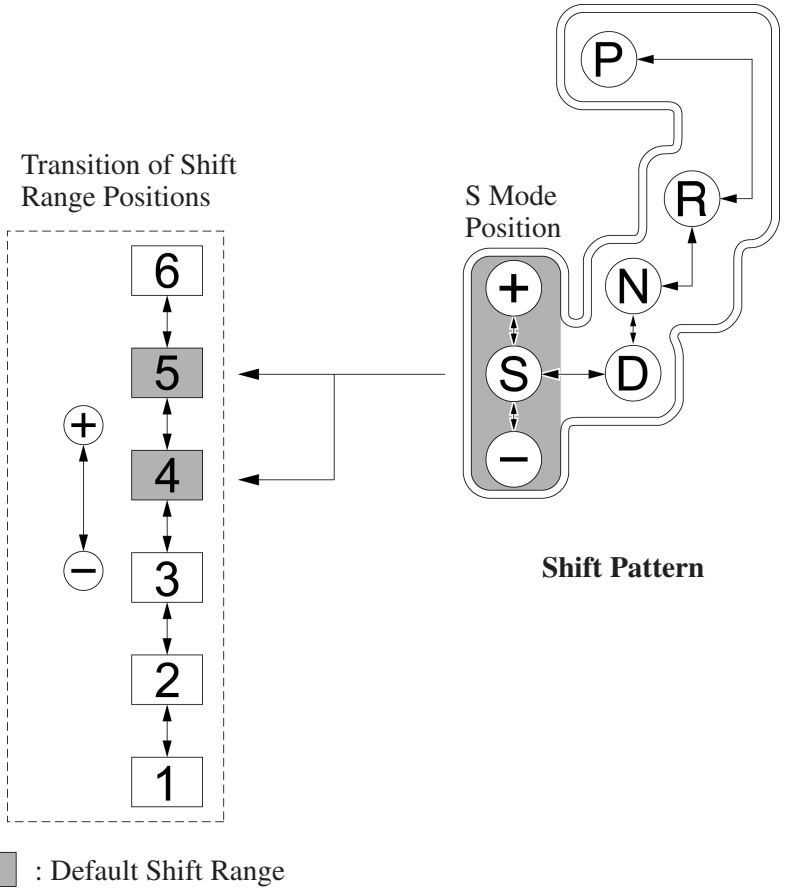
By moving the shift lever to the front ("+" position) or to the rear ("–" position), the driver can select the desired shift range position. Thus, the driver is able to shift gears with a manual-like feel.

- This Multi-mode automatic transmission is designed to allow the driver to switch the gear ranges; not for manually selecting single gears.
- An S mode indicator light, which illuminates when the S mode position is selected and a shift range indicator light, which indicates the range position, have been provided in the combination meter.
- When the vehicle is being driven at a prescribed speed or higher, any attempt to shift down the range by through the operation of the shift lever will not be executed, in order to protect the mechanism of the automatic transaxle. In this case, the engine ECU sounds the buzzer in the combination meter twice to alert the driver.



Operation

- The driver selects the S mode position by engaging the shift lever. At this time, the shift range position selects the 4th or 5th range according to the vehicle speed. (During AI-Shift control, the shift range that has the currently controlled gear position as the maximum usable gear position is displayed.) Then, the shift range positions change one at a time, as the driver moves the shift lever to the front ("+" position) or to the rear ("–" position).
- Under this control, the ECT ECU effects optimal shift control within the usable gear range that the driver has selected. As with an ordinary automatic transmission, it shifts to the 1st gear when the vehicle is stopped.
- When the shift lever is in the S mode position, the S mode indicator light in the combination meter illuminates. The shift range indicator light indicates the state of the shift range position that the driver has selected.



▶ Usable Gear Chart ◀

Shift Range Indicator Light Indication	Shift Range	Usable Gear
6	6	6th ↔ 5th ↔ 4th ↔ 3rd ↔ 2nd ↔ 1st
5	5	5th ↔ 4th ↔ 3rd ↔ 2nd ↔ 1st
4	4	4th ↔ 3rd ↔ 2nd ↔ 1st
3	3	3rd ↔ 2nd ↔ 1st
2	2	2nd ↔ 1st
1	1	1st

13. Diagnosis

- When the ECT ECU detects a malfunction, the ECT ECU makes a diagnosis and memorizes the information related to the fault. Furthermore, the check engine warning light in the combination meter illuminates or blinks to inform the driver of the malfunction.
- At the same time, the DTC (Diagnosis Trouble Code) are stored in the memory. The DTC stored in the ECT ECU are output to a intelligent tester II connected to the DLC3 via the engine ECU.
- For details, see the Camry Repair Manual (Pub. No. RM0260E).

14. Fail-safe

This function minimizes the loss of operation when any abnormality occurs in a sensor or solenoid.

▶ Fail-safe Control List ◀

Malfunction Part	Function
Input Turbine Speed Sensor	Shifting to only either the 1st or 3rd gears is allowed.
Counter Gear Speed Sensor	● The counter gear speed is detected through the signals from the skid control ECU (speed sensor signals). ● Shifting between the 1st to 4th gears is allowed.
ATF Temp. Sensor	Shifting between the 1st to 4th gears is allowed.
ECT ECU Power Supply (Voltage is Low)	When the vehicle is being driven in 6th gear, the transaxle is fixed in 6th gear. When being driven in any of the 1st to 5th gears, the transaxle is fixed in 5th gear.
CAN Communication	Shifting to only either the 1st or 3rd gears is allowed.
Knock Sensor	Shifting between the 1st to 4th gears is allowed.
Solenoid Valve SL1, SL2, SL3 and SL4	The current to the failed solenoid valve is cut off and operating the other solenoid valves with normal operation performs shift control. (Shift controls in fail-safe mode are described in the table on the next page. For details, refer to Fail-Safe Control List)

▶ Solenoid Valve Operation when Normal ◀

Gear Position		1st	2nd	3rd	4th	5th	6th
Solenoid Valve	SL1	○	○	○	○	X	X
	SL2	X	X	X	○	○	○
	SL3	X	○	X	X	X	○
	SL4	X	X	○	X	○	X

▶ Fail-safe Control List ◀

	Gear Position in Normal Operation	1st	2nd	3rd	4th	5th	6th
SL1	OFF Malfunction (without Fail-safe Control)	1st → N	2nd → N	3rd → N	4th → N	5th	6th
	ON Malfunction (without Fail-safe Control)*1	1st	2nd	3rd	4th	5th → 4th	6th → 4th
	Fail-safe Control during OFF Malfunction	Fixed in 3rd or 5th*2					
	Fail-safe Control during OFF Malfunction (ATF Pressure Switches 1 or 2 Malfunctions)	Fixed in 3rd or 5th*2					
SL2	OFF Malfunction (without Fail-safe Control)	1st	2nd	3rd	4th → 1st	5th → N	6th → N
	ON Malfunction (without Fail-safe Control)*1	1st → 4th	2nd → 4th	3rd → 4th	4th	5th	6th
	Fail-safe Control during OFF Malfunction	1st	2nd	3rd	3rd*3	3rd*3	3rd*3
	Fail-safe Control during OFF Malfunction (ATF Pressure Switches 1 or 2 Malfunctions)	Fixed in 2nd or 3rd*3					
SL3	OFF Malfunction (without Fail-safe Control)	1st	2nd → 1st	3rd	4th	5th	6th → N
	ON Malfunction (without Fail-safe Control)*1	1st → 2nd	2nd	3rd	4th	5th	6th
	Fail-safe Control during OFF Malfunction	1st	3rd	3rd	4th	5th	5th*3
	Fail-safe Control during OFF Malfunction (ATF Pressure Switches 1 or 2 Malfunctions)	Fixed in 3rd*3					
SL4	OFF Malfunction (without Fail-safe Control)	1st	2nd	3rd → 1st	4th	5th → N	6th
	ON Malfunction (without Fail-safe Control)*1	3rd	3rd	3rd	4th	5th	5th
	Fail-safe Control during OFF Malfunction	1st*4	2nd*4	4th*4	4th*4	6th	6th
	Fail-safe Control during OFF Malfunction (ATF Pressure Switches 1 or 2 Malfunctions)	Fixed in 2nd*3					

*1: Fail-safe control is not actuated when the ON malfunction occurs.

*2: If malfunctions already exist in any of the P, R or N range positions and a malfunction is detected when the gear is shifted to the 1st gear, the gear position is fixed in the 5th gear. After that, if any of the P, R or N range positions is selected, the gear is fixed in the 3rd gear position.

*3: The gear is fixed in the neutral position until the vehicle speed reaches a certain speed that enables the transaxle to be shifted.

*4: Shifting to the 5th and 6th gears is prohibited.