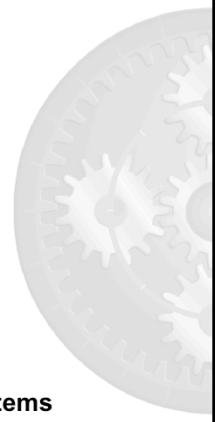
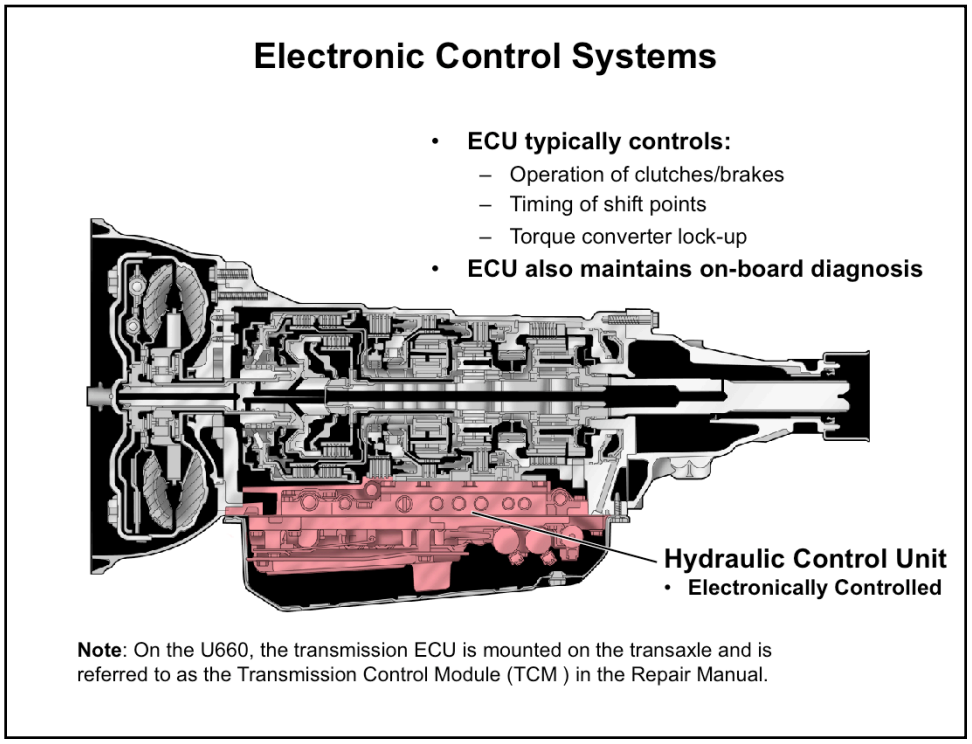
Section 7 Topics

Electronic Control Systems

- Overview
- ON/OFF Solenoids
- Linear Solenoids
- A750 Solenoid Operation
- U660 Solenoid Operation
- Common Solenoids



- Electronic Control Systems Worksheet



Electronically Controlled Transmission (ECT)

The electronically controlled transmission (ECT) uses a computer and electronic components to control transmission operation. The ECT's planetary gear sets and holding devices work in virtually the same manner as earlier hydraulically controlled transmissions. The main differences are ECT valve body components, additional sensors, a computer to control transmission functions, and the electrical wiring required for their operation.

Instead of creating hydraulic control pressures with mechanical devices such as throttle valves, governor valves, and the like, ECTs use electronic technology to control transmission hydraulic pressures and operation. Sensors provide information on operating conditions to the computer, or electronic control unit (ECU). Computer programming inside the ECU decides what needs to be done, and it sends electrical signals to activate solenoids. The movement of these solenoids controls transmission operation.

NOTE

Depending on model and year, Toyota publications may identify the electronic control unit as TCM (transmission control module). ECU is used throughout this training course for consistency.

Electronic Control Transmission (ECT)

- **Planetary gear set and holding devices are similar to non-ECT transmission**
- **Electronic technology controls operation of:**
  - Sensors (input to ECU)
  - Electronic Control Unit (ECU)
  - Solenoids (output from ECU)
- **Sensors typically monitor:**
  - Gear position
  - Vehicle speed (replaces non-ECT governor valve)
  - Throttle position (replaces non-ECT throttle cable/valve)
  - Input and output shaft speeds (verifies gear ratio / holding devices)

Electronic Control Functions

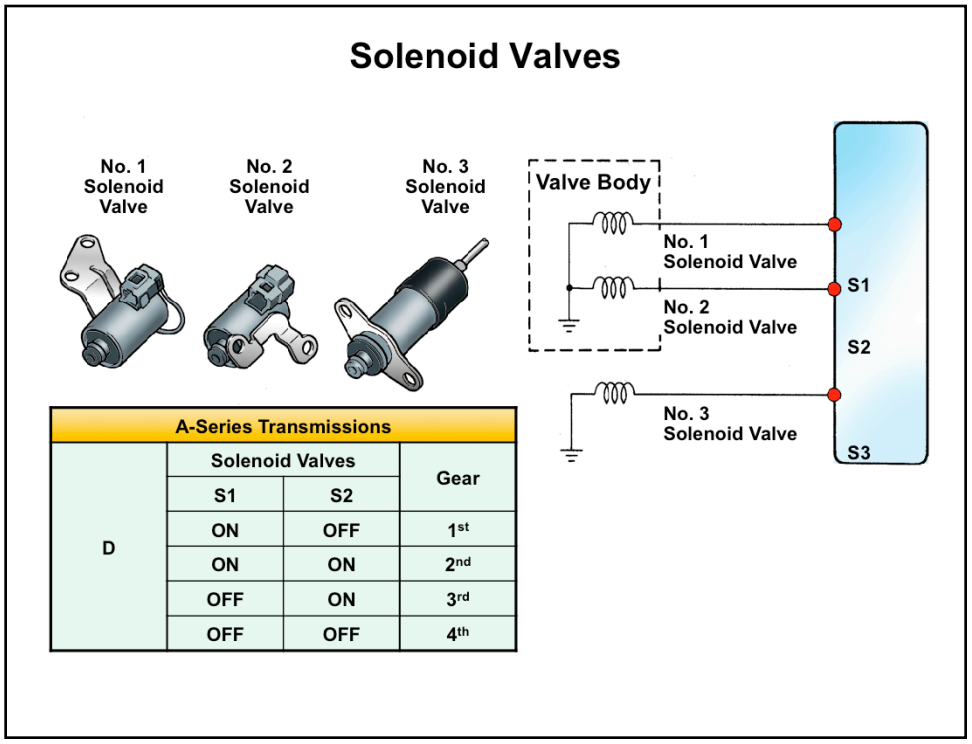
ECT electronic sensors typically monitor:

- Vehicle speed (replacing the governor valve used in non-ECTs)
- Throttle opening (replacing the throttle cable and valve used in non-ECTs)
- Transmission input and output shaft speed (to help precisely control ECT and also to verify that the transmission's hydraulic and mechanical units have responded correctly to electronic commands)
- Selection of gear position (driver movement of gear selector lever)

The main function of the ECU is to control:

- Operation of holding devices (clutches and brakes)
- Timing of shift points
- Torque converter lock-up
- Additional tailoring of ECT operation, such as squat control and overdrive cutoff

The ECU controls these functions by sending electrical signals to solenoid valves. The ECU also maintains on-board diagnosis and fail-safe mode for the ECT.



A-Series Transmissions			
	Solenoid Valves		Gear
	S1	S2	
D	ON	OFF	1st
	ON	ON	2nd
	OFF	ON	3rd
	OFF	OFF	4th

Solenoid Valves

Solenoid valves are electro-mechanical devices that control hydraulic circuits by opening and closing passages for pressurized hydraulic fluid. They can be ON/OFF solenoid valves (choice of two operating conditions) or linear solenoid valves that use a duty cycle to provide a range of operating conditions.

When some change in transmission operation is required (such as an upshift or torque converter lock-up), the ECU sends a voltage signal to the appropriate solenoid. The voltage signal controls the mechanical motion of the solenoid, which then controls a hydraulic circuit by opening or closing a passage. Both types of solenoid can be either normally open or normally closed (determined by internal spring tension). The ECU applies voltage to the solenoid to activate its internal electromagnet, overcome spring tension, and move the solenoid shaft.

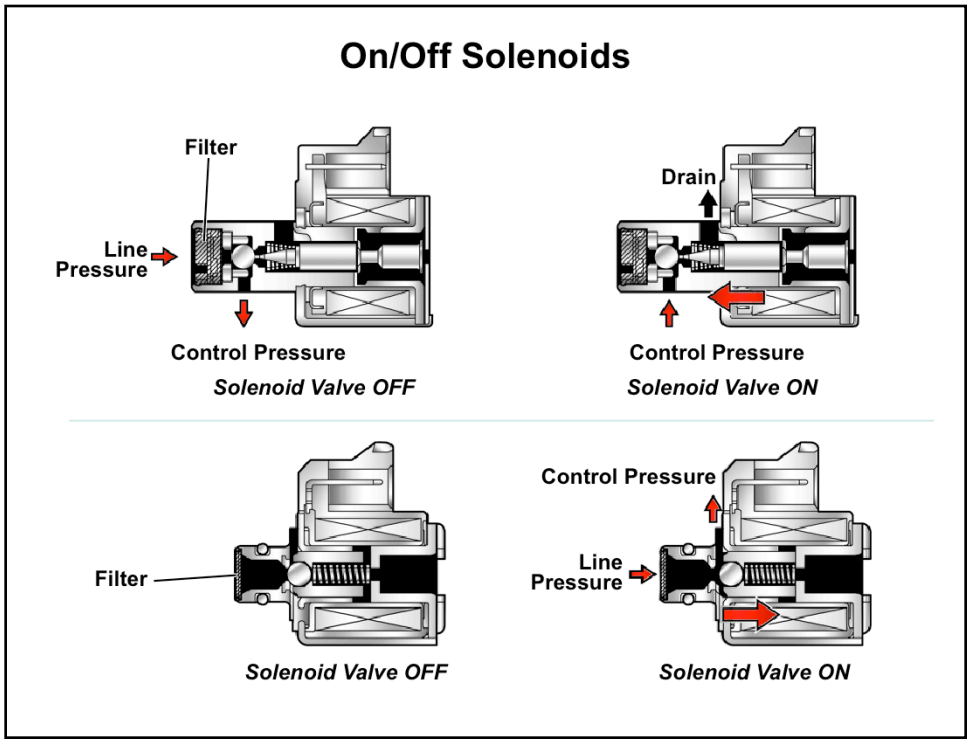
Solenoid operation controls specific functions (depending on transmission model), but all ECTs include these basic controls:

- Gear shift timing
- Torque converter lock-up
- Throttle pressure control
- Accumulator back-pressure control

Solenoid Types

Current Toyota ECTs have as many as seven solenoids. The solenoid designation indicates whether it is an ON/OFF or linear design:

- “S” indicates an ON/OFF solenoid
- “SL” indicates a linear-type solenoid



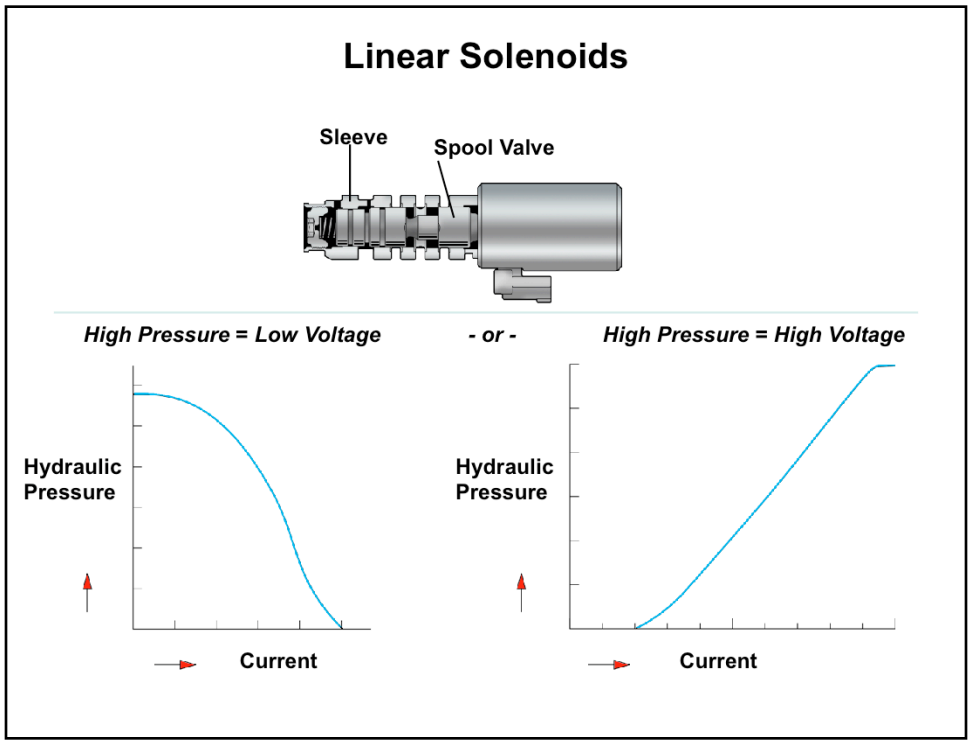
ON/OFF Solenoid

ON/OFF solenoids are identified by an “S” designation. They are typically connected to the electronic control circuit by a single wire (the solenoid body provides the circuit ground). ON/OFF solenoids either receive voltage or no voltage, providing only two possible “duty cycles” — 0% or 100%.

While the solenoid has only two possible operating conditions — ON or OFF — there are two additional variations in solenoid design:

- 2-way solenoids either allow or block a fluid flow
- 3-way solenoids can switch fluid flow from one path to another

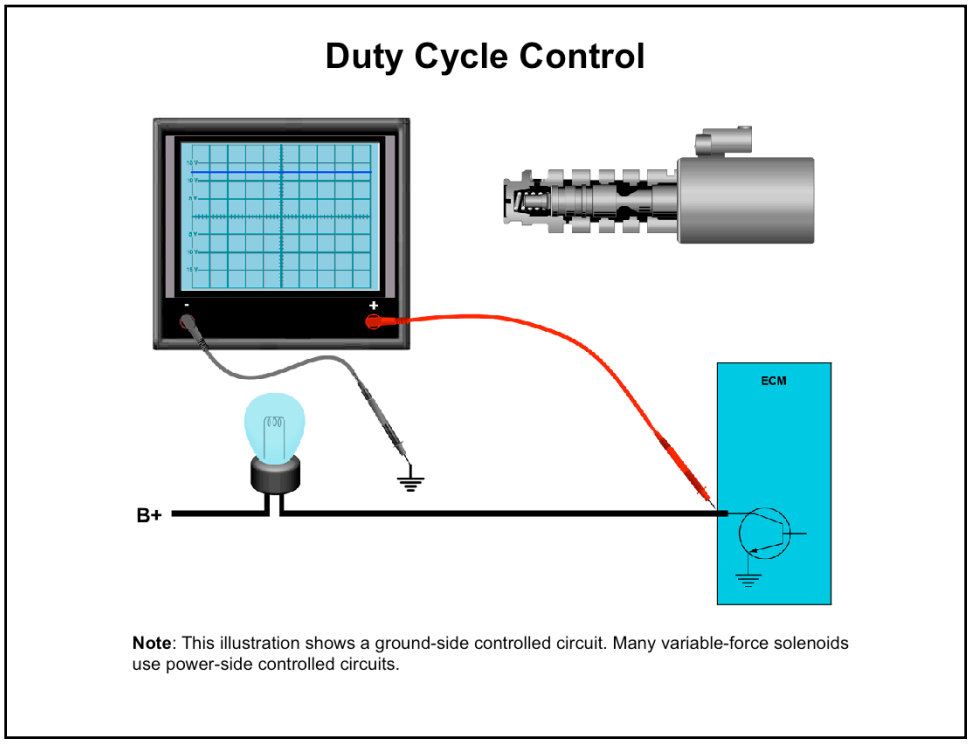
A typical application for an ON/OFF solenoid is to control a shift valve. These are called shift solenoids, the most common type of solenoid in an ECT.



Linear Solenoid

Linear solenoids are identified by an “SL” designation. They are typically connected to the electronic control circuit by two wires, because their ground is controlled through the ECU.

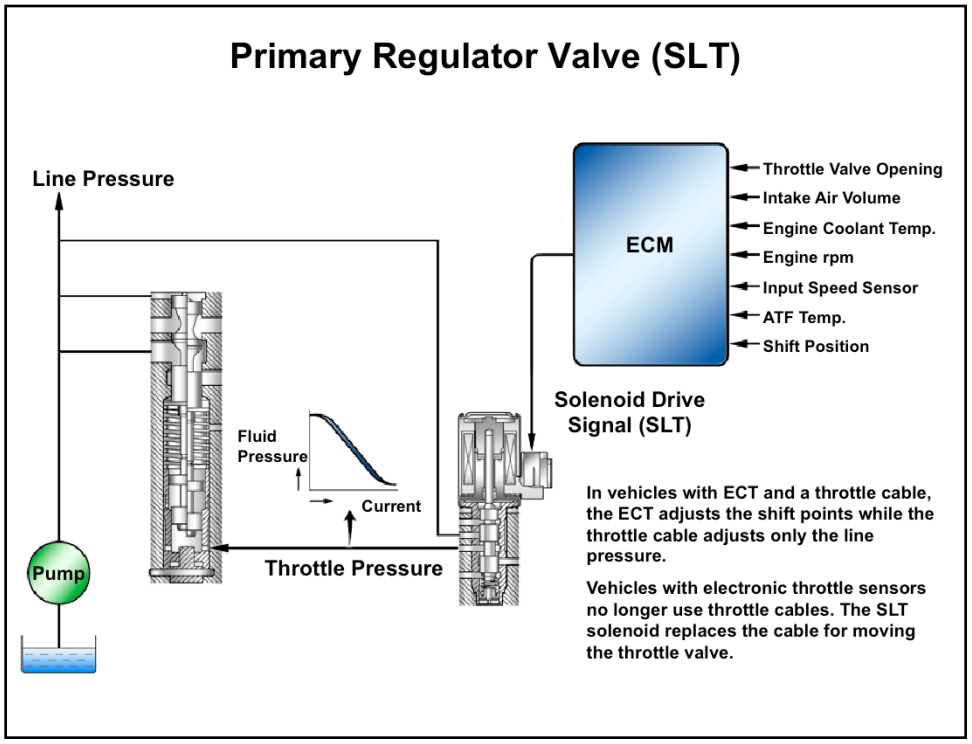
The solenoid regulates hydraulic pressure based on current flow from the ECU (duty cycle). The relationship between current flow and hydraulic pressure is proportional, and can be either low current = high pressure or low current = low pressure.



Duty Cycle Control

The linear solenoid voltage is rapidly switched ON/OFF by the ECU. This creates a varying range of duty cycles between 0% and 100% based on the ratio of ON time to OFF time. This allows the solenoid to move to varying points between fully open and fully closed. The linear solenoid's spool valve has an infinite number of positions within its operating range.

A typical application for a linear solenoid is the line pressure control solenoid (usually designated SLT).



Primary Regulator Valve

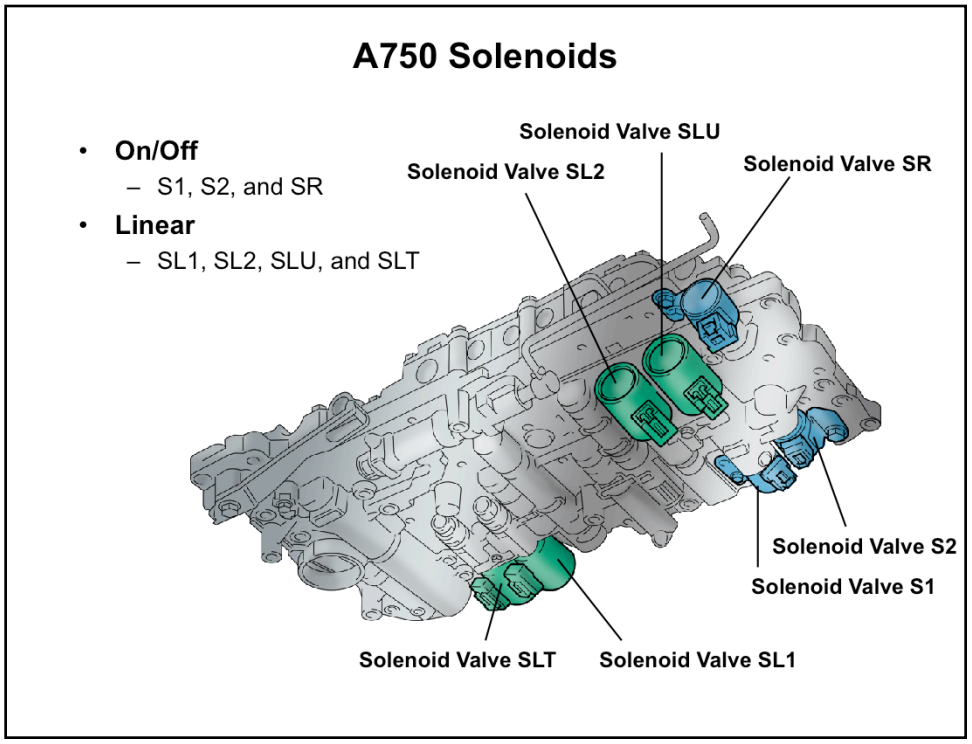
As in non-ECTs, the primary regulator valve in an ECT adjusts pressure from the oil pump to all other circuits in the transmission. Its output is called line pressure, which is the highest pressure in the transmission.

The primary regulator valve's position in its bore is determined by:

- Spring tension
- Line pressure
- Throttle pressure (from SLT)

The pressure from SLT is the equivalent of throttle pressure from a non-ECT throttle valve. When applied to one end of the primary regulator valve, it pushes the valve against spring pressure. The throttle pressure signal increases as the SLT solenoid duty cycle increases.

In vehicles with ECT and a throttle cable, the ECT adjusts the shift points while the throttle cable adjusts only the line pressure. Vehicles with electronic throttle sensors no longer use throttle cables. The SLT solenoid replaces the cable for moving the throttle valve.



A750 Solenoids

Seven solenoids in the A750 RWD transmission electronic control circuit perform the following functions:

- Shifting
- Clutch application pressure
- System line pressure
- Converter lock-up
- Clutch to clutch pressure control

ON/OFF Solenoids

A750 has three ON/OFF solenoids:

- S1 and SR are 3-way valves that switch hydraulic pressure from one passage to another.
- S1 switches the 2-3 shift valve.
- SR switches the clutch apply control valve.
- S2 is a 2-way valve that opens and closes a passage to switch the 1-2 and 3-4 shift valves.

Linear Solenoids

A750 has four linear solenoids that control:

- Line pressure (SLT)
- Holding device apply pressure (SL1 and SL2)
- Accumulator back-pressure (SL1, SLU, and SLT)
- Lock-up clutch pressure (SLU)

A750 Holding Device Application Chart

Shift Lever Position	Gear	Solenoid Valve						Clutch			Brake				One-way Clutch		
		S1	S2	SR	SL1	SL2	SLU	C1	C2	C3	B1	B2	B3	B4	F1	F2	F3
P	Park	ON				ON											
R	Reverse	ON				ON				O	O			O	O		
N	Neutral	ON				ON											
D	1st	ON				ON		O									O
	2nd	ON	ON			ON		O					O		O	O	
	3rd		ON			ON		O		O			●		O		
	4th					ON		O	O	●			●				
	5th			ON	ON		ON		O	O	O		●				
4	1st	ON				ON		O									O
	2nd	ON	ON			ON		O					O		O		
	3rd		ON			ON		O		O			●		O		
	4th					ON	ON	O	O	●			●				
3	1st	ON				ON		O									O
	2nd	ON	ON			ON		O					O		O	O	
	3rd		ON					O		O	O		●		O		
2	1st	ON				ON		O									O
	2nd	ON	ON	ON				O				O	O		O	O	
L	1st	ON						O						O			O

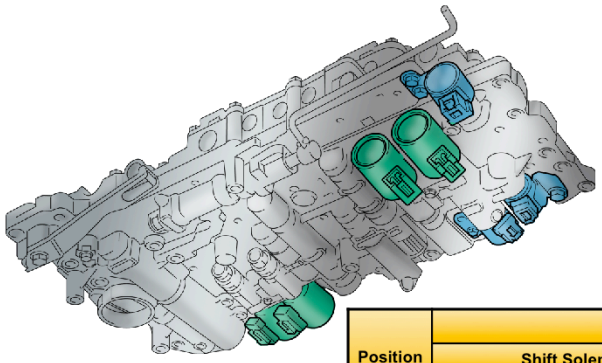
O: Operation
●: Operates but is not related to power transmission

A750 Holding Device Application Chart

The holding device application chart shows the solenoids and the holding devices that operate in each gear.

Note that some holding devices operate in specific gear positions but do not affect power flow in that gear. This means the failure of that component will have no effect on the operation of that gear.

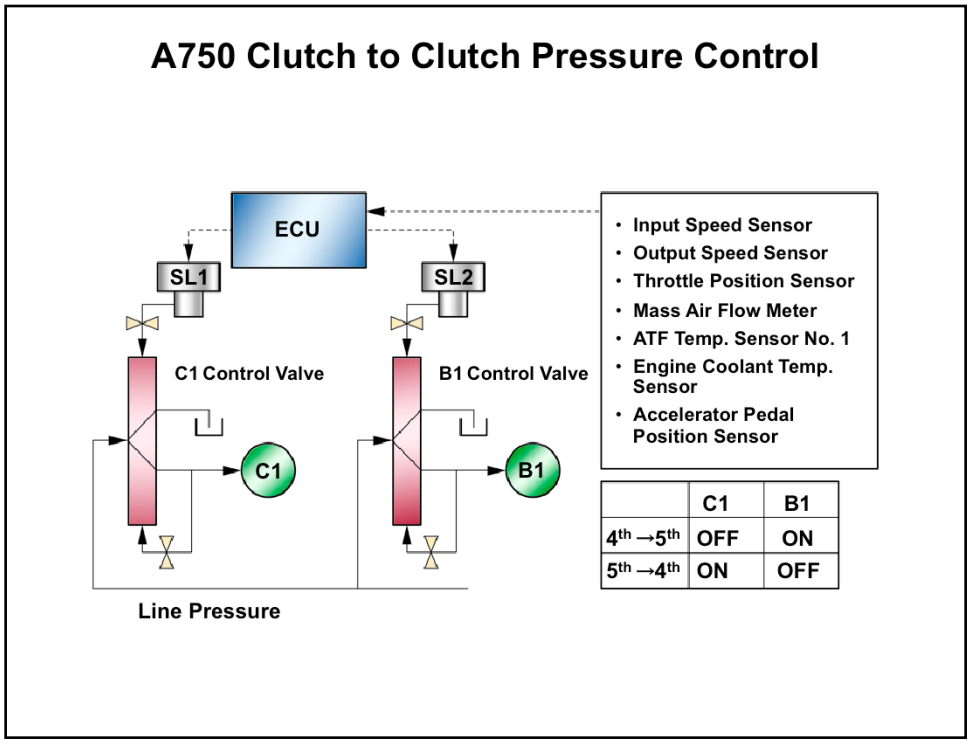
A750 Shift Control



Position	NORMAL					
	Shift Solenoid Valve					Gear
	S1	S2	SR	SL1	SL2	
D	ON	OFF	OFF	OFF	ON	1st
	ON	ON	OFF	OFF	ON	2nd
	OFF	ON	OFF	OFF	ON	3rd
	OFF	OFF	OFF	OFF	ON	4th
	OFF	OFF	ON	ON	OFF	5th

A750 Shift Control

In the A750, ON/OFF solenoids control the position of the shift valves. The ECU turns these solenoids on or off to create gear shifts. At the same time, the ECU is controlling the current to linear solenoids to modulate holding device application and apply pressures to match vehicle operating conditions.



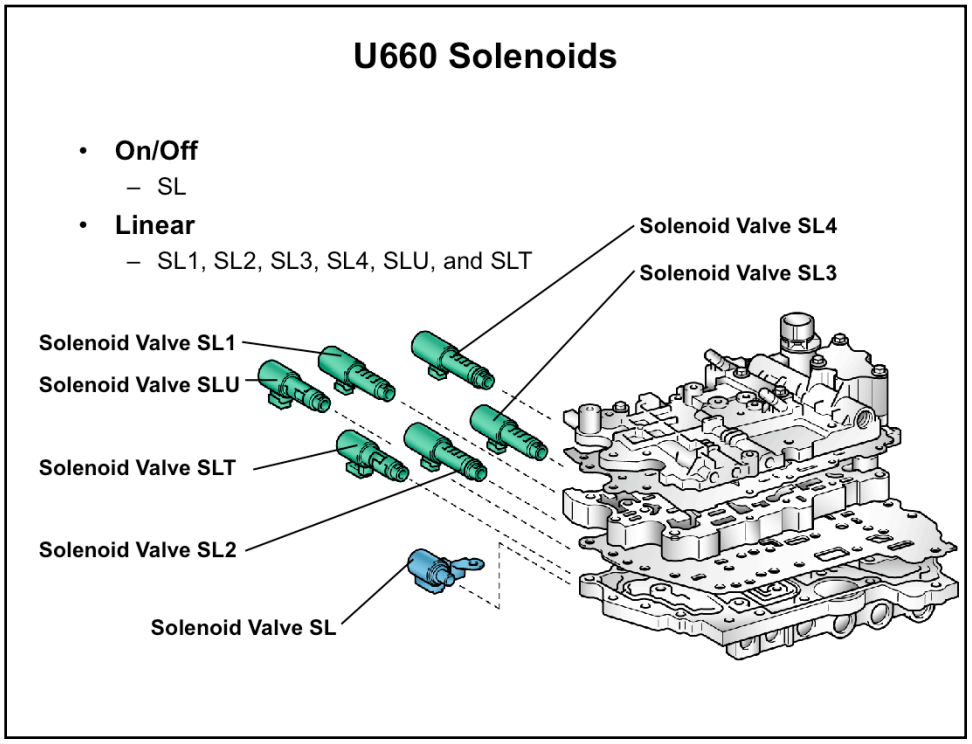
A750 Clutch to Clutch Pressure Control

The A750's ECU uses the SL1 and SL2 linear solenoids to modify line pressure while releasing clutch C1 and applying brake B1 (during an upshift) and vice versa (during a downshift). This results in smoother 4-5 upshifts and 5-4 downshifts.

A750 Fail-safe Operation

Position	Shift Solenoid Valve S1 Malfunction					
	Shift Solenoid Valve					Gear
	S1	S2	SR	SL1	SL2	
D	X	OFF → ON	OFF	OFF	ON	4th → 3rd
	X	ON	OFF	OFF	ON	3rd
	X	ON	OFF	OFF	ON	3rd
	X	OFF	OFF	OFF	ON	4th
	X	OFF	ON	ON	OFF	5th

A750 Fail-safe Operation If any of the A750 solenoids fail, the ECU manages the remaining solenoids to provide limited ECT functionality. Certain gear(s) will not be available, depending on which solenoid is faulty. The MIL should come on and the ECU should store a trouble code. The customer may complain of poor performance.



U660 Solenoids

Seven solenoids in the U660 FWD transmission electronic control circuit perform the following functions:

- Shifting
- Clutch application pressure
- System line pressure
- Converter lock-up
- Clutch to clutch control

ON/OFF Solenoids

U660 has one ON/OFF solenoid:

- SL switches the lock-up relay valve, the B2 apply control valve, and the reverse sequence valve.

Linear Solenoids

U660 has six linear solenoids.

U660 Holding Device Application Chart

Shift Lever Position	Gear	Solenoid Valve						Clutch		Brake			One-way Clutch
		SL	SL1	SL2	SL3	SL4	SLU	C1	C2	B1	B2	B3	F1
P	Park		O										
R	Reverse	n				O					O	O	
N	Neutral		O										
D, S6	1st		O				-	O					O
	2nd	O	O		O		-	O		O			
	3rd	O	O			O	-	O				O	
	4th	O	O	O			-	O	O				
	5th	O		O		O	-		O			O	
	6th	O		O	O		-		O	O			
S5	1st		O					O					O
	2nd	O	O		O		-	O		O			
	3rd	O	O			O	-	O				O	
	4th	O	O	O			-	O	O				
	5th	O		O		O	-		O			O	
S4	1st		O					O					O
	2nd	O	O		O		-	O		O			
	3rd	O	O			O	-	O				O	
	4th	O	O	O			-	O	O				
S3	1st		O					O					O
	2nd		O		O			O		O			
	3rd		O			O		O				O	
S2	1st		O					O					O
	2nd		O		O			O		O			
S1	1st		O				O	O			O		O

O: Operation -: In accordance with flex lock-up n: ON while engaging, OFF after engaging

U660 Holding Device Application Chart

The holding device application chart shows the solenoids and the holding devices that operate in each gear.

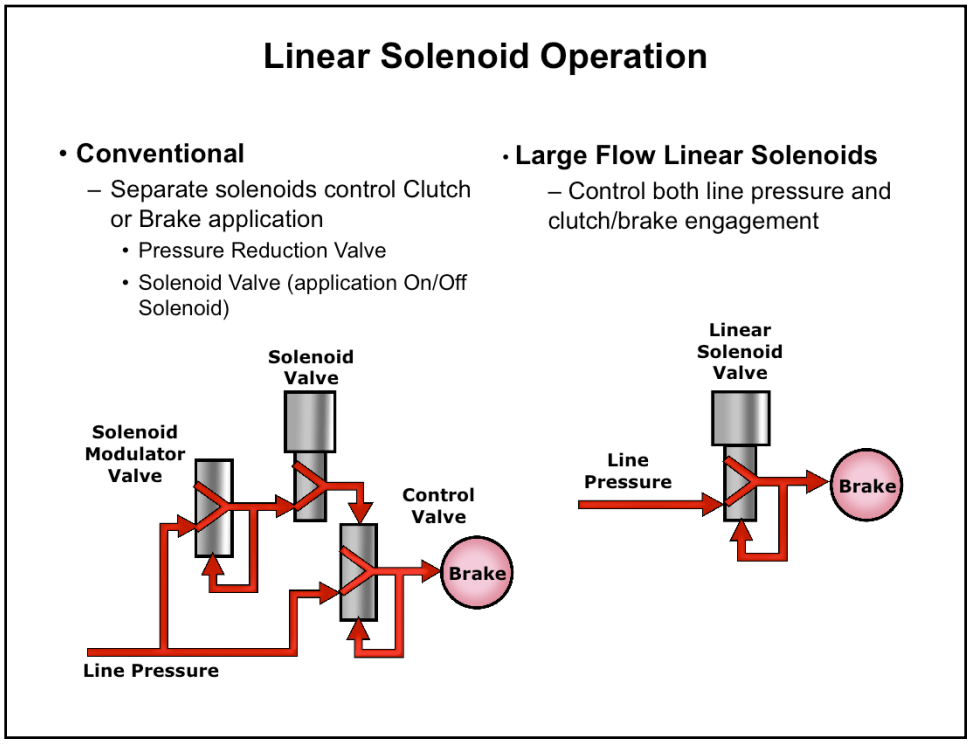
Note that the operation of SLU in each gear varies depending on operating conditions in accordance with flex lock-up.

U660 Shift Control

Gear Position		1st	2nd	3rd	4th	5th	6th
Solenoid Valve	SL1 (C1)	O	O	O	O		
	SL2 (C2)				O	O	O
	SL3 (B1)		O				O
	SL4 (B3)			O		O	

Note: With U660 transmissions, replacement units require a Compensation Code to be input into the TCM for specific ECT operation. Neglecting to input the code for a replacement unit may result in poor ECT operation and damage.

U660 Shift Control U660 design incorporates the function of separate shift valves and accumulators directly into the linear solenoids. Each linear solenoid controls a single holding device. The solenoid both controls whether the holding device is applied, and varies the hydraulic apply pressure according to operating conditions.



Linear Solenoid Advantages

Prior to Linear Control Solenoids, hydraulic pressure regulation and clutch/brake application were controlled separately. Two solenoids were necessary to accomplish these tasks, whereas with the advent of Large Flow Linear Solenoids both are now possible with one device.

An advantage of Large Flow Linear Solenoid Valves is that they can supply more pressure than conventional solenoids. They also control engagement elements by directly regulating the line pressure without using the pressure regulation valve (control valve) or the pressure reduction valve (solenoid modulator valve). Thus, the number of valves and the length of the valve body fluid passage are reduced, the shifting response is increased and the shift shock is minimized.

Due to the variety of solenoid types and their operation, identifying solenoids correctly is important to be sure you use the proper test procedures.

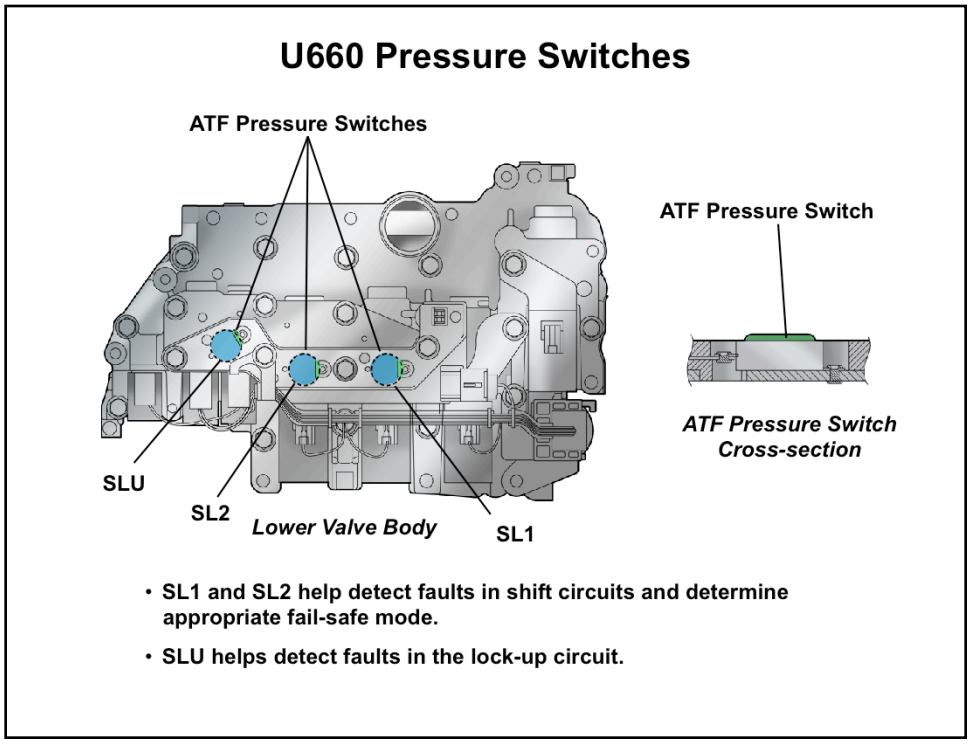
U660 Fail-safe Operation

Gear selected during normal operation	1st	2nd	3rd	4th	5th	6th
Without Fail-Safe Control						
Gear selected during SL2 OFF malfunction	1st	2nd	3rd	1st	N	N
Gear selected during SL2 ON malfunction	4th	4th	4th	4th	5th	6th
With Fail-Safe Control						
Gear selected during SL2 OFF malfunction	1st	2nd	3rd	3rd	3rd	3rd
Gear selected during SL2 OFF malfunction (and ATF pressure switch 1 or 2 malfunctions)	Fixed in 2nd or 3rd					

U660 Fail-safe Operation

Without fail-safe control, a malfunctioning solenoid would cause the transmission to shift abnormally, possibly making it undriveable. With fail-safe control, when a solenoid malfunction is identified and a code is set, the ECM manages the remaining solenoids to provide limited functionality. The ECM has various programs stored to manage transmission shifting depending on which solenoid is malfunctioning.

Charts for other solenoid malfunctions similar to the one above are provided in the Repair Manual.



U660 Pressure Switches

U660's ECU/TCM monitors three pressure switches to determine if the ECT is operating correctly. These are simple ON/OFF switches located in outlet passages from:

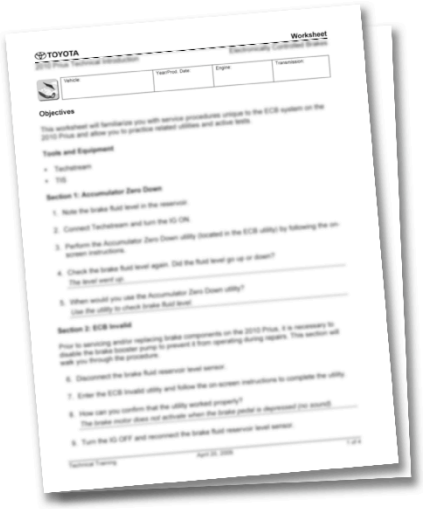
- **SL1 and SL2:** helps detect faults in shift circuits and determine appropriate fail-safe mode
- **SLU:** helps detect faults in lock-up circuit.

Common Solenoids

CIRCUIT	OPERATION	TYPE	POSSIBLE ECT
SLT	Line pressure control	Duty cycle	All without cables
SLN	Accumulator back pressure	Duty cycle	A540
S1	No. 1 shift solenoid	On/off	A-series, U340
S2	No. 2 shift solenoid	On/off	A-series, U340
SL (S3 or SLU)	Lock-up solenoid	On/off	A-series, U340, U660
SLU	Flex lock-up solenoid	Duty cycle	U660
SR	Relay valve solenoid	On/off	A750, U150
SL1	1-2 shift solenoid (turns 4th off - A750)	Duty cycle	U140, U240, U660, A750
SL2	2-3 shift solenoid (turns 5th off - A750)	Duty cycle	U140, U240, U660, A750
SL3	3-4 shift solenoid	Duty cycle	U150, U151, U660
SL4	4-5 shift solenoid	Duty cycle	U660
S4	OD shift solenoid	On/off	U140, U240
DSL	B2 (M Low) & Lock-Up	Duty cycle	U140, U240
ST	Modify 3-4 shift	Duty cycle	U340

Common Solenoids The chart above summarizes common solenoids found on Toyota electronically controlled transmissions (ECTs).

Worksheet



Electronic Control Systems

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