

Shift-by-Wire System for Lexus RWD Vehicles

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ABSTRACT

Shift selection devices are desired to be flexible for design and layout, in order to realize the next generation of cockpits for Lexus vehicles. In addition, refined shift operation feelings are also required to be suitable for Lexus vehicles. To meet these demands, the Lexus LC500 has been equipped with a shift-by-wire system, which replaces the mechanical linkage between the shift selector and transmission with electrical signals and an actuator. This shift-by-wire system will be installed in a wide variety of Lexus powertrain lineup, including conventional gas vehicles and hybrid vehicles. Therefore, the next generation shift-by-wire system for Lexus has been developed with high reliability and applicability. This technology will be essential when autonomous driving and autonomous parking systems are realized in the near future. To enable shifting of the parking mechanism in a simple configuration regardless of the engine operation state, shifting of the parking mechanism is performed by an add-on electric parking actuator, and shifting the driving force direction is performed by a transmission control unit in each powertrain system. The shift selection method basically follows an "h" pattern shift lever and a push-type parking switch, which Toyota has used in hybrid vehicles for many years. Additionally, emotional shift selection devices are even more in tune with the driver's senses. The new flat type high-output parking actuator is developed to enable adoption of this system in rear-wheel drive (RWD) vehicles. This application has a difficult installation environment in terms of space and heat between the transmission and the floor tunnel, and also requires large torque to shift the parking mechanism because of the comparatively high vehicle weight. This paper outlines the new system and its major technologies.

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INTRODUCTION

The functions of shift operation systems include shifting the parking mechanism of the vehicle, and shifting the driving force direction of the vehicle. Historically, this shifting mechanism has mostly been installed inside the transmission, and carries out shifting directly using a mechanical connection with the shift lever. In a shift operation system with this configuration, the shift pattern, operation load/displacement, and shift operation device layout are mostly determined by mechanical requirements. This creates styling and sensory quality limitations which were not compatible with targets set for the next generation of cockpits for Lexus vehicles.

Therefore, a shift-by-wire system was introduced that eliminates the mechanical linkage between the shift lever, judges driver shift inputs using sensors installed on the shift operation devices, and performs shifting using an actuator attached to the transmission. This system enabled dramatic improvements to the layout and styling of shift operation devices, and much greater design flexibility for sensory perception. In addition, because shifting is performed by an actuator, this system is also compatible with future autonomous driving or autonomous parking vehicle systems. It can also respond to human errors such as mistaken operations by the driver.

With this new technology, functions that were once ensured by mechanical linkages in conventional shift operation systems could become a source of new failure modes, such as electrical faults and loss of power. To ensure reliability, the shift-by-wire system must address these new failure modes.

This paper describes the design concept of the shift-by-wire system for Lexus RWD vehicles, and the functional components that realize this system.

SYSTEM OUTLINE

Requirements of System Configuration

Since the shift-by-wire systems are required to shift both the parking mechanism and the driving force direction, the powertrain system has a major effect on the system configuration. The system configuration was designed in consideration of the following points.

- The Lexus powertrain lineup contains both conventional gas vehicles and hybrid vehicles without a source of hydraulic pressure. Assuming use with fuel cell vehicles, gas vehicles, as well as conventional gas vehicles with a start-and-

stop system, a shift system that uses an electric motor has a simpler configuration than a hydraulic system.

- Existing hybrid vehicles perform mechanical shifting for only the parking mechanism. Shifting of the driving force direction is performed electrically by an electronic control unit (ECU) in the powertrain. In contrast, conventional gas vehicles shift both the parking mechanism and the driving force direction mechanically.
- Although this system had to be compatible with the wide powertrain lineup used by Lexus, it was also necessary to minimize the effects on existing powertrain ECUs using conventional shift levers.

After considering these key points, the shift-by-wire ECU (SBW ECU) was introduced to perform judgment of shift inputs and parking mechanism shifting, and the shift function for driving force direction was allocated to the powertrain ECU.

System Configuration

Figure 1 shows the configuration of the shift-by-wire system for Lexus RWD vehicles.

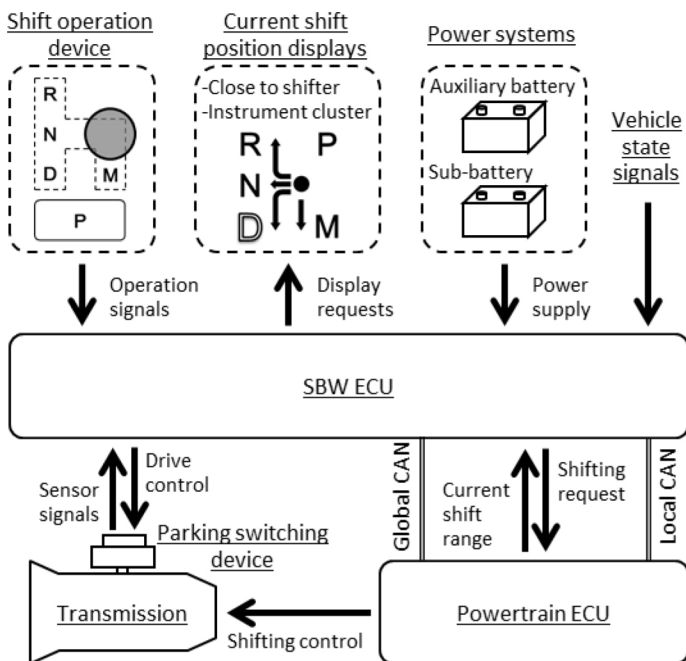


Figure 1. System configuration

- Shift operation device:**
The shift operation device consists of a shift lever that inputs the driving force direction requests from the driver (i.e., the R, N, D, and M positions), and a parking switch that inputs requests to hold the vehicle stationary (i.e., the P position).
- SBW ECU:**
The SBW ECU judges the shift request from the driver and whether to perform a shift based on the vehicle state. Shifting operations to hold the vehicle stationary are controlled by the parking switching device via the SBW ECU, which also transmits the driving force direction commands to the

powertrain ECU. The SBW ECU also transmits the current shift position to the shift position displays.

- Powertrain ECU:**
The powertrain ECU shifts the driving force direction based on commands from the SBW ECU.
- Shift position displays:**
The shift operation method and current shift position are displayed close to the shifter and in the instrument cluster.
- Parking switching device:**
The parking switching device shifts the parking mechanism. The switching device actuator consists of a switched reluctance (SR) motor, reduction gears, and rotation angle sensor. This device also includes an absolute angle sensor to identify the state of the parking mechanism and a manual parking release mechanism.
- Power supply systems:**
Electric power is supplied to the shift-by-wire system by two sources; the auxiliary battery and sub-battery.

As described above, the shift-by-wire system consists of a large number of elements that must coordinate with each other.

The next sections describe details of the shift operation device, parking switching device, and system failsafe design. These were key items in the development of the shift-by-wire system for Lexus RWD vehicles.

SHIFT OPERATION DEVICE

Operation System Requirements

One of the goals for the next generation of cockpits for Lexus vehicles was to realize a functional space that allows the driver to concentrate on driving. To achieve this goal, the operational systems directly related to driving were laid out around the driver based on the position of the steering wheel, to minimize changes in driver posture and gaze (Figure 2). In addition to functional requirements, cockpit sensory perception was also emphasized by, for example, creating an attractive comfortable layout that allows the driver to perform a coherent series of operations, and ensuring a refined operation feel.

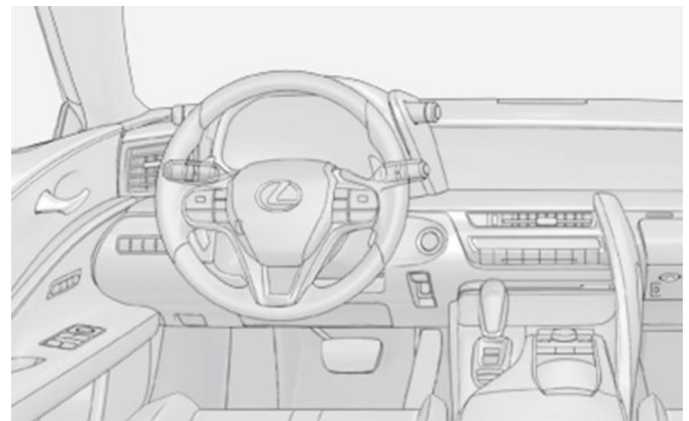


Figure 2. Lexus LC500 cockpit design