

Toyota's Integrated Drive Power Control System for Downsized Turbocharged Engine

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ABSTRACT

New engine controls have been developed for the turbocharged Lexus NX200t to improve driving power by reducing engine torque output lag. Drive power management functions have been centralized in an integrated drive power control system. The newly developed controls minimize the potential reduction in drivability associated with the adoption of a turbocharged engine while improving fuel efficiency.

General driveability issues commonly associated with a turbocharged engine include sudden increases in drive power due to the response lag of the turbocharger, and higher shifting frequencies if this response lag triggers a disturbed accelerator operation pattern by the driver. The developed technologies detect and control sudden increases in drive power to create the optimum drive power map, and reduce unnecessary shifts even if the driver's accelerator operation is disturbed.

This paper describes an outline of the integrated drive power control system and its representative technologies, which helped to ensure the product appeal of the Lexus NX200t.

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1. INTRODUCTION

The development of more fuel efficient vehicles with cleaner emissions is a growing priority for automakers as part of efforts to help prevent global warming. From the standpoint of vehicle components, the engine provides the greatest potential to improve fuel efficiency. Various engine-based measures have been proposed to improve vehicle fuel efficiency, including the adoption of downsized turbocharged engines, such as that developed by Toyota Motor Corporation and installed in the Lexus NX200t.

One of the objectives of a downsized turbocharged engine is to improve fuel efficiency by reducing engine displacement. The resulting lower engine torque is offset by the addition of the turbocharger to increase power, creating satisfying power performance. Although a downsized turbocharged engine is capable of simultaneously improving both fuel efficiency and power performance, a driveability trade-off exists due to turbocharger response lag. One effect of turbocharger response lag is two-stage output drive power when a driver depresses the accelerator. As a result, the change in drive power per unit time during the second stage can become large. Another potential effect is busy shifting triggered by the drive power response lag. For this reason, countermeasures to improve driveability are a key part of downsized turbocharged engine development. Example countermeasures include 1) designing an optimum drive power map to reduce the change in drive power per unit time and 2) preventing busy shifting.

This paper describes an outline of a drive power control system and newly developed drive power design technologies that were developed to help improve fuel efficiency and driveability in a downsized turbocharged engine.

2. SYSTEM CONFIGURATION

As background information for developing countermeasures for the NX200t, the following section provides an overview of the associated key systems. The three key systems are the turbocharged engine, transmission, and Integrated Drive Power Control System (IDPCS).

2.1. Turbocharged Engine Performance

Table 1 shows the main specifications of the newly developed 8AR-FTS turbocharged engine installed in the NX200t.

Table 1. Main specifications of 8AR-FTS turbocharged engine.

Displacement	1.998 L
Maximum power	175 kW (238 PS)/4,800 to 5,600 rpm
Maximum torque	350 Nm (35.7 kgf/m)/1,650 to 4,000 rpm

2.2. Transmission Configuration

The NX200t uses the U661 6-speed automatic transmission for front-wheel drive vehicles, which was newly developed for use with turbocharged engines. Table 2 shows the main specifications of this transmission.

Table 2. Gear ratio specifications of U661 transmission.

	Gear Ratio	Gear Step
1st	3.300	
2nd	1.900	1.737
3rd	1.421	1.338
4th	1.000	1.421
5th	0.7134	1.402
6th	0.6807	1.172
Reverse	4.1481	

2.3. Integrated Drive Power Control System (IDPCS) Configuration

Figure 1 outlines the configuration of the IDPCS and related systems. The IDPCS consists of a driver model and a powertrain manager. The related systems include the engine and transmission control systems, which are the actuators of the drive power control system, as well as the vehicle stability control (VSC) and other vehicle control systems. Based on this configuration, the IDPCS performs overall control of the engine and transmission while transmitting information between the systems controlling the vehicle using drive power. Specifically, the driver model determined the target drive power based on the driver's accelerator operation. The powertrain manager then performs mediation (i.e., priority control) with the drive power demanded by the vehicle control systems. It also calculates the optimum target engine torque and target gear position and instructs these values to the engine and transmission control systems.

With this configuration, the drive power design functions are consolidated and centrally managed by the IDPCS, and the engine and transmission control systems can be dedicated to injector and clutch operation. As a result, the complexity of drive power design can be greatly simplified, facilitating adoption on various vehicles in a short period of time.

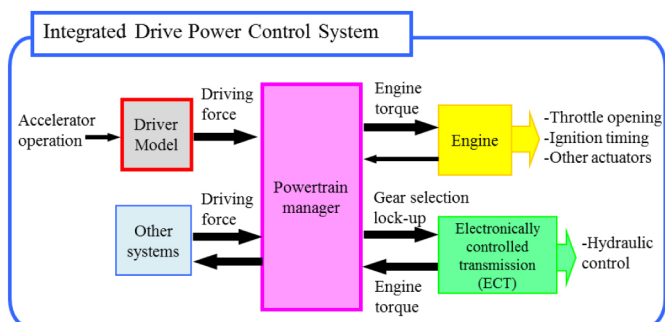


Figure 1. Outline of integrated drive power control system configuration.

3. DEVELOPMENT TARGETS

To determine the desired trade-off for driveability in the Lexus NX200t, two targets are discussed in this section. The targets are: improvement of acceleration feel, and shifting frequency.

3.1. Improvement of Acceleration Feel

Turbocharger response lag and Jerk are set as targets that represent improvement of acceleration feel for a turbocharged vehicle. Figure 2 shows the definition of these two parameters. Jerk is the ratio of drive force change in a unit of time ($\Delta F = \Delta \text{Drive Power} / \Delta \text{Time}$) in the turbocharged torque region. Turbocharger response lag is the duration of the drive power transition from the initial naturally aspirated (NA) region to the initial turbocharged torque region. These are two main points that differ from naturally aspirated (NA) engine drive force characteristics. Using NA characteristics as the benchmark, adequate drive force feel can be achieved when these two objectives meet their specified targets.

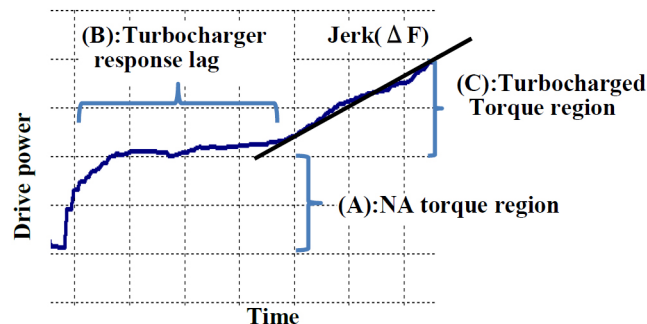


Figure 2. Vehicle drive power when accelerating from standing start with a turbocharged engine.

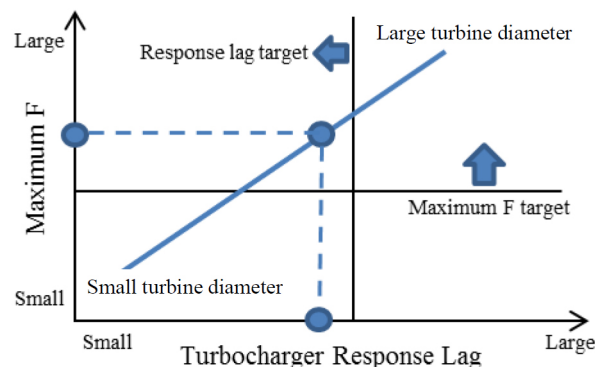


Figure 3. Relationship between turbocharger response lag and maximum drive force (Maximum F).

Turbocharger response lag is one of the two targets. Maximum drive force (Maximum F) is a development target which affects the turbocharger response lag. Maximum F can be defined as the maximum drive force achieved when the accelerator pedal is fully depressed and the turbo is fully charged. A large diameter turbine can generate high maximum drive force because it can generate high turbocharged air pressure. However, a larger diameter turbine may have an adverse effect on turbocharger response lag due to increased inertia of the turbine and thus more time to generate enough turbocharged torque. Figure 3 shows the dependence of Maximum F and turbocharger