

Lexus CT 200h Hybrid Drive

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CHAPTER 2: LEXUS HYBRID DRIVE POWERTRAIN

- Unique Lexus Energy Management System
- 1.8-liter 98 hp (73kW VVT-i) gas engine and 80 hp (60 kW) electric motor for total system power of 134 hp (100kW)
- Low emissions, remarkably low fuel consumption and almost no NOx or particulate emissions.
- EV, ECO and SPORT ‘on-demand’ drive modes for distinct, Dynamic or Relaxing driving moods
- Additional Energy Saving and Environmental Performance Measures

Marking the introduction of Lexus’ second generation hybrid technology, the new CT 200h reinforces the company’s clear leadership in the development of full hybrid drive systems.

With many manufacturers just starting to produce their first hybrid, Lexus hybrids come from a 10-year heritage of experience in full hybrid powertrains. With the CT 200h joining the GS 450h, HS 250h, LS 600h L and RX 450h, the company has an unrivalled breadth of Lexus full hybrid models available.

The CT 200h’s Lexus Hybrid Drive features a unique energy management system which equips the new full hybrid with remarkably quiet operation, seamless acceleration and the performance customers expect from a luxury vehicle. Conversely, it delivers superior fuel efficiency and excellent NOx and particulate emissions.

Further enhancing the Lexus Hybrid Drive system’s outstanding environmental credentials, the CT 200h design incorporates numerous additional energy saving and environmentally-conscientious measures such as LED lighting, a lightweight, energy-efficient audio system amplifier and bamboo charcoal speakers; and the use of bio-sourced materials.

Lexus Hybrid Drive Unique Energy Management System

Through the application of specific engineering solutions, and a unique energy management system incorporating bespoke software tuning, Lexus engineers have enhanced both the environmental and driving performance of the Lexus Hybrid Drive system, as well as its low NVH levels.

With a total system output of 134 hp (100kW), the CT 200h will deliver performance on par with rivals positioned at the very heart of the premium compact segment. Conversely, offering significant cost of ownership benefits, the new Lexus full hybrid targets class-leading emissions and also generates significantly less NOx and particulate emissions than an equivalent diesel engine vehicle.

Engine control and throttle responses have been tuned to deliver an engaging, dynamic driving experience, while the minimal Noise, Vibration and Harshness levels generated by the CT 200h’s full hybrid powertrain reinforce the remarkable quietness inherent in the DNA of every Lexus model.

Lexus Hybrid Drive System Architecture

The new CT 200h is a full hybrid, offering all the benefits of series/parallel powertrain architecture. Capable of operating in gas and electric modes alone, as well as a combination of both, its Lexus Hybrid Drive system delivers the energy-saving benefits of a series hybrid combined with the performance benefits of a parallel hybrid.

Lexus Hybrid Drive equips the CT 200h with impressive, seamless acceleration and remarkably quiet operation, yet returns high fuel efficiency and excellent emissions.

The CT 200h's hybrid system features a 1.8-liter VVT-i gas engine, a powerful electric motor, a generator, a high performance Ni-MH battery, a power control unit, and a power split device which employs a planetary gear set to combine and re-allocate power from the engine, electric motor and generator according to operational requirements.

The electric motor, generator and power split device are all housed in one lightweight, highly compact transmission casing directly comparable in size to that of a conventional gearbox. Drive to the front wheels is provided by the full hybrid system's seamless, shift-by-wire, Electronically Controlled continuously Variable Transmission (ECVT).

The electric motor works in tandem with the gas engine to boost acceleration and power the driven wheels alone when the CT 200h is operating in EV mode.

During deceleration and under braking, the electric motor acts as high-output generator to effect regenerative braking, optimizing energy management in the Lexus Hybrid Drive system by recovering kinetic energy (normally wasted as heat under braking and deceleration) as electrical energy for storage in the high performance battery.

Moreover, when operating in a switchable EV mode, the new Lexus full hybrid generates zero NOx and particulate emissions, driving for up to one mile at speeds of up to 28 mph.

Performance

In combination, the Lexus Hybrid Drive system's petrol engine and electric motor generate a total system power output of 134 hp (100kW). Via an ECVT, the CT 200h will accelerate seamlessly from 0-60 mph in 9.8 seconds, and reach a maximum track speed of 112 mph. Conversely, the CT 200h boasts remarkably low fuel consumption -a combined EPA estimated fuel economy rating of 42 mpg.

1.8-liter Atkinson Cycle Engine

The lightweight, highly compact, four-cylinder, 16-valve, DOHC, 1798 cc Atkinson Cycle gas engine generates 98 hp (73kW) at 5,200 rpm.

Combined with a cooled Exhaust Gas Recirculation (EGR) system, the adoption of the Atkinson Cycle offers significant gains in fuel efficiency and the reduction of emissions.

In conventional four-cycle gas engines, fuel enrichment is sometimes necessary to cool the exhaust gases, preventing degradation or destruction of the catalytic converters. In an Atkinson Cycle engine, compression and expansion are not symmetrical, and the valves close late, delaying compression. This creates a high expansion ratio for less compression, reducing intake and exhaust energy losses and converting combustion energy to engine power more effectively. As a result, the exhaust temperature is lower than that of conventional engines.

Via a stainless steel exhaust manifold, EGR reintroduces precisely metered exhaust gas -cooled from 1,292°F to 266°F into the intake system, further reducing engine operating temperatures, whilst also reducing engine pumping losses through a reduction in intake vacuum pressure.

Together, these technologies minimize situations when fuel enrichment is necessary to protect the catalytic converter from overheating damage, thereby improving fuel economy and lowering emissions.

To improve cold weather fuel economy and cabin comfort, the engine heat management system combines a heat recovery system with an electric water pump. To reduce mechanical losses, an electric system replaces the water pump drive belt. The adoption of an electric water pump not only controls the coolant flow rate with greater precision, but also allows for the use of both air-conditioning and heating without the engine running, all of which contributes to greater fuel efficiency.

In addition, via a valve built into the exhaust assembly, a smaller, lighter, more efficient, exhaust heat recovery system redirects exhaust gases to heat up the engine coolant at start up. As well as allowing for a more rapid delivery of effective cabin heating, this system improves hybrid system efficiency and fuel economy by significantly reducing engine warm up times, allowing it to be shut off earlier for longer electric motor-only operation, particularly in cold weather.

The 1.8-liter engine features numerous further enhancements to both improve performance and minimize fuel consumption and emissions. Variable Valve Timing with intelligence (VVT-i) helps boost response levels across the entire rev range by varying the air-fuel intake and exhaust valve timing to suit the conditions at any given time. As well as improving torque at low and medium engine speeds, the system also reduces emissions and enhances fuel efficiency.

The engine also features roller rocker arm valve-train control, a resin intake manifold with an optimized port configuration, a highly efficient, taper squish combustion chamber design and 12-hole, atomizing, long nozzle injectors. Thin, long reach spark plugs contribute to enhanced anti-knocking performance, and lower tension piston rings, reduced piston friction. A standing oil jet for piston cooling and a stainless steel pipe exhaust manifold further enhance engine efficiency. In combination, these advanced technologies further contribute to improved power output with reductions in both fuel consumption and emissions.

Engine NVH

Ultra-low Noise, Vibration and Harshness (NVH) characteristics are one of the key attributes of Lexus Hybrid Drive, and particular attention has been paid to minimizing engine noise and vibration. The rigidity of engine parts including the cylinder block and crank case has been optimized through in-depth Computer Aided Engineering (CAE) analysis. A highly rigid, ribbed aluminum cylinder head cover combines light weight with reduced noise and vibration.

The engine itself is mounted on a four-point suspension system with mounting rubber characteristics optimized for the suppression of noise and vibration. And a two-step, dynamic damper is integrated within the engine mount to further minimize noise and vibration generated, as well as reducing engine start/stop shock.

Hybrid Transaxle

Housing the electric motor, the electric generator, the power split device and the motor speed reduction device in one lightweight, highly compact transmission casing directly comparable in size to that of a conventional gearbox, the transaxle lies at the heart of the Lexus Hybrid Drive system.

The full hybrid drive system's seamless Electronically-Controlled Continuously Variable Transmission (E-CVT) is controlled by Shift-by-Wire technology, using an electronic shift lever system. The shift lever itself is designed to always return to its 'home' position when released, and the shift position can be checked on the shift position indicator integrated within the driver's instrument panel.

Adjacent to the shift lever, a parking switch with integral indicator light is used to engage or release a parking lock mechanism within the transmission gearing. The parking lock is automatically deactivated when driving off, and automatically re-engages when the car is switched off.

Numerous measures have been adopted to reduce component noise and energy losses, further lowering hybrid system fuel consumption. A highly-advanced, internal gear machining process offers enhanced planetary ring gear precision, minimizing transmission noise. The lubrication system has been designed to reduce oil agitation losses and transaxle component friction has been significantly reduced through the adoption of tapered bearings instead of ball bearings.

80 hp (60 kW) Electric Motor

The high performance, permanent magnet, synchronous 80 hp (60 kW) electric motor works in tandem with the gas engine to boost acceleration and power the driven wheels alone when the CT 200h is operating in EV mode. During regenerative braking, the motor also acts as a high-output generator, recovering kinetic energy as electrical energy to charge the system battery.

Air cooled, the motor generates a maximum 152 lb.-ft. of torque from zero rpm, available torque being boosted through a reduction gear device in the transaxle. Maximum drive voltage amplification is 650V DC. However, under ordinary driving conditions, unless maximum output is required, the motor is driven at an unamplified voltage whenever possible to enhance fuel efficiency.

Generator

As with the electric motor, the generator is also of the AC synchronous type. The generator performs numerous functions within the Lexus Hybrid Drive system.

Because the system has no starter motor, the generator is used to start the petrol gas engine. Under normal driving conditions, engine output is divided according to system requirements to both drive the wheels and power the generator which, via the Power Control Unit (PCU), drives the electric motors and simultaneously charges the high-voltage battery. Moreover, in order to optimize engine speed control for maximum full hybrid system fuel efficiency, engine speed is also controlled by the generator.

When its operation is not required by the hybrid drive system, the generator stops the engine. However, if the CT 200h runs under electric motor power alone for sufficient distance to necessitate battery charging, the generator will start the engine, which itself provides the power for the generator to charge the battery.

High Output Battery

Using proven and reliable nickel-metal hydride technology, the Lexus Hybrid Drive system's 202V, 36 DIN hp (27 kW) battery allows the new CT 200h to operate in EV mode, driving under electric motor power alone. Located beneath the rear loadspace floor, the fan-cooled battery pack size has been minimized to reduced impact on cabin accommodation.

Power Control Unit

Similar in size to a 12 V battery, the Lexus Hybrid Drive system's Power Control Unit (PCU) consists of:

- A voltage boost converter, which boosts electric motor, generator and battery voltage to increase hybrid system power output;
- a highly compact inverter for the motor/generator, which converts the DC power from the battery into 650V AC power for driving the electric motor and, occasionally, the generator;
- and a DC/DC converter, which reduces the high voltage of the 202V system battery pack to 14V, supplying power to the accessory systems and charging the auxiliary battery.

Lexus Hybrid Drive in Operation

Over the course of any journey, the Lexus Hybrid Drive system operates in several different modes to maximize the CT 200h's overall efficiency: At rest, the engine stops automatically to conserve fuel. Under operating conditions of low engine efficiency such as start up and low to mid-range speeds, the vehicle runs on the electric

motor alone, thus eradicating NOx and particulate emissions.

Under normal driving conditions, power allocation is constantly adjusted between engine and electric motor to combine optimum performance with maximum fuel efficiency. Via an Electronically Controlled Braking-Regeneration (ECB-R) system, the electric motor acts as high-output generator during deceleration and under braking to effect regenerative braking, optimizing energy management in the Lexus Hybrid Drive system by recovering kinetic energy (normally wasted as heat under braking and deceleration) as electrical energy for storage in the high performance battery.

At all speeds, the Lexus Hybrid Drive system monitors itself for optimum performance and fuel efficiency with minimum emissions, either running the electric motors in isolation, the engine in isolation, or a combination of both. Furthermore, battery power level is constantly managed via the engine driven generator to obviate any requirement to recharge the system from an external source.

Full described in the Driving Dynamics chapter, three 'on-demand' drive modes supplement the NORMAL drive mode, increasing the capabilities of the CT 200h's full hybrid powertrain. An EV mode allows for ultra-quiet running on electric motor power alone, resulting in zero fuel consumption and emissions; an ECO mode maximizes hybrid system efficiency and fuel economy; and a SPORT mode boosts system performance.

ENERGY SAVING AND ENVIRONMENTAL PERFORMANCE

Air Conditioning Performance

Allowing for independent control of left and right hand sides of the cabin, the new CT 200h is equipped with a compact, lightweight air conditioning unit incorporating a powerful, electric, variable capacity compressor. The use of a hybrid battery-powered electric compressor reduces the load on the engine, improving fuel economy, whilst the surplus power of the unit allows it run below full capacity, with greater efficiency and with less noise.

The integrated-inverter electric compressor contains a centrifugal oil separator that removes oil from the refrigerant, reducing the amount of oil escaping from the compressor. This allows for a more efficient refrigerant cycle, optimizing the air conditioning's cooling performance.

The use of a lightweight, MF (Multi Flow)-IV sub cool condenser reduces refrigerant volume to further improve system efficiency. And the characteristics of the brushless blower motor have been refined to suppress noise whilst delivering a large volume of cool air.

Exhaust Heat Recirculation System

Because of the need to heat the cabin and de-fog the windscreen, hybrid vehicles can suffer a drop in fuel economy during winter months. To counter this, Lexus engineers have incorporated a third generation exhaust heat recirculation system.

The exhaust heat recirculation system helps the engine coolant reach normal operating temperature more rapidly by circulating it around a section of exhaust pipe. This not only improves fuel efficiency by reducing the time needed for the engine to warm up, allowing the Lexus Hybrid Drive system to shut of the engine sooner, but also enables the 495 watt Positive Temperature Coefficient (PTC) heater to provide warm cabin air more quickly in winter.

LED Lighting

Lexus was the first automotive company to introduce LED headlamps for low beam use, with the LS 600h L in 2007. Consuming 45 percent less power than conventional, halogen units, they offer an improvement in fuel economy, perfectly complimenting the energy saving efficiency of Lexus Hybrid Drive.

With available LED headlamps, up to 46 LEDs are used in front, eight used for the door mirror-mounted turn indicators and 35 in the rear, the CT 200h is equipped with no less than 89 external LEDs –the largest number yet fitted to a Lexus model.

Lexus Audio System Amplifier

An available, energy efficient, Digital Signal Processing-integrated (DSP), eight-channel, full range class D amplifier makes its first appearance in the CT 200h. The new DSP unit consumes 50 percent less power than a conventional, analogue-powered amplifier and, with its weight reduced from 2.9 lbs. to 2.1 lbs., is 26 percent lighter.

Bio-sourced Materials and Bamboo Charcoal Speakers

Improving its environmental performance, several of the CT 200h's larger components including the loadspace deck sides, deck board and deck board trim have been fabricated from a bioplastic material containing 30 percent plant-based polyethylene terephthalate. The new full hybrid also benefits from an easy-to-dismantle construction, and recycle marks have been placed on the front, rear and tailgate trim to facilitate optimum recycling.

A Lexus and industry first, both sound systems are equipped with unique, bamboo charcoal-based resin diaphragm speakers. Constructed using a complex compound combining bamboo charcoal, bamboo fiber and resin, the diaphragms are injection-molded to a thickness of only 0.008-0.01 in., and are some 10-15 percent lighter than a conventional speaker diaphragm.