

2005 Freestyle Chassis

"The all-new Ford Freestyle does everything you demand as a driver. You want smooth, strong acceleration, confident cornering on nearly any type of surface and firm, predictable braking. With its strong, sophisticated chassis and suspension, Freestyle will provide an enjoyable driving experience that perfectly complements its other capabilities."

- Jan Vulcan, *Chief Nameplate Engineer*

Refinement Key to New Chassis, Powertrain

Freestyle's driving dynamics represent one of the cornerstones of its crossover character. Although it offers the interior flexibility of a minivan and the presence and available all-wheel-drive confidence of a sport utility vehicle, it boasts a chassis tuned for car-like response.

Freestyle's stiff overall body structure, with its robust and rigid front and rear subframes, allow it to shrug off road imperfections and provide quick and secure response to the driver's steering inputs. Its lower center of gravity, compared with sport utility vehicles, helps minimize body pitch and lean.

Its all-new, continuously variable transmission operates more often in the heart of the engine's torque range, providing quick, off-the-line acceleration. While final fuel economy numbers won't be available until closer to the launch date, Ford expects the new Freestyle to be among the most efficient in its class.

Engineers drew on best practices throughout Ford Motor Company to craft the confident ride and handling that help define the new Ford Freestyle. These include Volvo-inspired chassis, Ford's proven, updated Duratec 30 V-6 engine and the all-new, continuously variable transmission developed with joint-venture partner ZF-Batavia.

Among Freestyle's features are:

- An all-new, continuously variable transmission, marking the auto industry's highest-volume CVT application. It enhances fuel efficiency while providing smooth, stepless operation.
- An improved Duratec 30 3.0-liter V-6 engine, complete with electronic throttle control and delivering 200 horsepower and 200 foot-pounds of torque with less unwanted noise and vibration. Combined with Freestyle's new wide-ratio transmissions, the Duratec engine delivers acceleration that is among the best in its class.
- Available all-wheel drive and traction control that enhance grip and performance on all road surfaces
- A sophisticated chassis design inspired from Volvo that offers high torsional stiffness for crisp handling and a smooth ride
- Lighter weight dual-piston cast-aluminum front calipers that contribute to confident braking

New-Era Transmission

The new CVT will be standard on Freestyle, helping to make Ford the industry's volume leader in CVTs.

CVTs use variable input and output pulleys, connected by a chain loop, to vary gear ratios to meet specific driving conditions.

"The beauty of a CVT is that no matter what speed you're driving, it will always seek out optimal torque," said Ray Nicosia, manager of vehicle engineering for Ford's North American cars and family vehicles. "That's why it feels so responsive - you're never out of the torque band."

Continuously variable transmissions offer several key advantages over traditional "step" automatics, including improved fuel economy and performance.

Both of these advantages stem from the CVT's wider ratio span - the difference between the transmission's highest and lowest gear ratios. Freestyle's CVT has an overall ratio of more than 6-to-1. That compares with 4-to-1 for a typical automatic.

The lowest gear ratio - the equivalent of first gear on an automatic transmission - multiplies engine torque to launch the vehicle from a standing start. The Freestyle's low ratio ensures stronger off-the-line acceleration that will delight drivers.

The highest gear ratio - equivalent to the top gear on an automatic transmission - is used primarily for cruising at steady speeds, maximizing fuel economy. The CVT is expected to deliver as much as 8 percent better fuel economy than a conventional four-speed automatic.

The CVT continuously and precisely adjusts gear ratio to engine speed, maximizing performance under various loads like the sudden mashing of the accelerator pedal or the ascent of a steep hill. Properly equipped, Freestyle also is rated to tow up to 2,000 pounds.

Electronic Brains Do More - And Faster

Freestyle's powerful new powertrain control electronics ensure faster, smoother response to driver inputs.

The new Black Oak controller uses PowerPC machine language and floating-point calculations to perform more tasks more quickly. It monitors data from all of the vehicle's sensors, transmitted along an information highway called a Controlled Area Network (CAN) bus, and reacts accordingly.

Powertrain engineers took advantage of this capability and designed a special calibration for times that the vehicle drives downhill. The system detects whether the vehicle is on a descending grade and adjusts engine speed and transmission ratio to hold a steady speed. And, like most powertrain functions, this is entirely seamless to the driver.

This type of calibration, as well as design of the accelerator pedal components, provides the familiar feel and response of a traditional mechanical throttle linkage, while offering the precise performance advantages of electronic throttle control.

All-Wheel Drive Provides Confident Traction

The CVT is available with an optional, electronically controlled all-wheel-drive system that delivers optimum performance whether on dry, wet or snow-covered roads or traveling through mud or sand.

Normally, the vehicle functions in front-drive mode. But, like the vehicle's other electronic components, the controller continuously monitors information flow along the CAN bus to determine whether AWD is needed. It can react within 50 milliseconds to distribute virtually all of the available torque to the rear wheels.

The all-wheel-drive system begins at the CVT, where a Volvo-built power transfer unit, similar to one on the Volvo XC70 wagon, siphons off torque being sent to the two front wheels and delivers it to the drive shaft that leads to the rear wheels.

"The Volvo technology was a great enabler for us, because it is much more difficult to package all-wheel drive in a passenger car than in a sport utility vehicle or a truck," said Phil Kurrle, design and release supervisor for Ford's family car powertrain subsystems. "Through Volvo's leadership, we

now have access to lightweight and compact all-wheel-drive components that have proven their reliability beyond question."

This program represents Ford's largest-ever passenger car application of all-wheel drive and places the automaker alongside niche and luxury vehicle manufacturers as industry leaders in this technology.

Haldex Coupler for Silky-Smooth Torque Transfer

The Swedish-built Haldex coupler works through a combination of hydraulic and electro-hydraulic activation of its internal clutch pack.

When the vehicle is in motion, the drive shaft is in motion as well, driven by the CVT-mounted power transfer unit. If the drive shaft turns more quickly than the output shaft at the rear of the Haldex, oil flow is generated, which produces hydraulic pressure in the Haldex coupling.

This increased hydraulic pressure pushes the clutch plates together, transmitting drive shaft torque through the Haldex unit to the rear wheels.

Because a mechanical pump creates a natural pulsing pressure, the Haldex system incorporates three pistons designed to operate out of phase with each other, evening out pressure waves for seamless, smooth actuation. This is another example of the way Freestyle engineers used technology to achieve a refined driving experience.

The Haldex unit also includes an electro-hydraulic pump that offers still another advantage. If the electronic controller senses impending wheel slip, it can use hydraulic pressure from the electro-hydraulic pump to preload the clutch pack, causing it to engage more quickly. This, too, contributes to a more seamless, smoother performance.

The system is designed to quickly apportion torque between front and rear - up to 100 percent in either direction - as needed, to avoid wheel slip.

"It works very quickly," Kurrle said. "Within one-seventh of a turn of the front wheels spinning, the rear is getting power. This is much quicker than a non-electro-hydraulic, viscous-coupler all-wheel-drive system could achieve."

The system also releases just as quickly, avoiding binding or wheel skid once traction improves.

An optional traction control system - standard with all-wheel drive - allows progressive braking to be applied to each wheel within 100-150 milliseconds of the onset of wheel slip. This precise braking adds side-to-side torque transfer capability.

"With the two systems working together, you can send torque to the individual wheels that have traction," Kurrle said.

In addition, the AWD system's relatively light weight and few moving parts should result in negligible impact on Freestyle's fuel economy, compared with front-drive versions.

Traction for All Conditions, All the Time

The CVT adds its own strengths to the all-wheel-drive system. Because it offers such a broad gear ratio range and automatically optimizes engine torque, the all-wheel-drive system always has plenty of torque on hand to plow through deep snow, mud, sand or other challenging conditions.

All-wheel drive offers advantages on dry or wet pavement as well. Because the system can transfer torque quickly and smoothly away from the front wheels, it helps reduce the type of understeer often

associated with front-wheel-drive vehicles.

Traction control adds security to the driving experience by reducing engine power or selectively applying braking to any wheel as needed to enhance steering response. By tapping into sensors at all four wheels, the system even can compensate for use of a space-saver spare tire to maintain all-wheel-drive functionality.

The traction control system seeks to reduce wheel slip by first retarding engine spark, then, if necessary, reducing fuel flow. Finally, it engages selective braking as needed to restore traction. In all-wheel-drive applications, the system uses brake intervention immediately.

"Controllability and stability are important considerations in the way we designed this system," Kurre said.

Newly Refined Duratec 30

Ford's proven, highly efficient, 3.0-liter, 24-valve Duratec 30 V-6 serves as an ideal match for the Freestyle's new CVT powertrain.

The Duratec 30 has seen numerous improvements, including several unique to the Ford Freestyle.

Even the Duratec manufacturing site is all-new - Ford's Cleveland Engine Plant Number One has been converted to employ flexible manufacturing techniques that provide quality improvements and allow rapid response to market demand.

Clean-Burning, Silent Operation

In addition to delivering excellent fuel economy, the newly refined Duratec 30 V-6 provides the Ford Freestyle with outstanding emissions performance.

"Our emissions level will meet the federal Tier II, Bin 5 definition, which is equivalent to the California LEV II standard," said Kim Jackson, powertrain supervisor. "In particular, the vehicle will have very low evaporative emissions. They are just 25 percent of the current allowable federal standards."

Tier II, Bin 5 represents a very low level of emissions - an "8" on the Environmental Protection Agency's guide to green vehicles. That's close to the "9" or "10" ratings achieved by gasoline-electric hybrid vehicles currently on the market. The standard allows only 5.3 pounds of smog-forming tailpipe emissions over 15,000 miles of driving. In comparison, the Ultra-Low Emission Vehicle (ULEV) standard allows 11.7 pounds of smog-forming pollutants.

This is achieved using less-permeable materials in the fuel system, new charcoal canister technology to capture evaporative emissions and upgraded fuel system and vapor line connectors, which reduce the amount of escaping gas. An onboard vapor recovery system captures gasoline fumes during fill-up, routes them to a storage canister and releases them to the engine to be burned.

The electronic, returnless fuel-line system also helps improve fuel economy and prevent vapor lock that can be caused by hot fuel lines.

Noise, vibration and harshness have been reduced in the Duratec 30 as well.

Computer technology helped engineers design a new dual-mass, dual-mode frequency damper that mounts to the crankshaft at the engine's front end. It reduces both torsional and bending vibrations that could produce noise.

Computer optimization also was used to create the complex shape of the front engine cover, featuring "constrained layer damping." This sandwich of materials absorbs frequencies that might

otherwise generate unwanted noise at the front of the engine.

Further engine NVH actions are:

- Application of the industry's first direct-drive water pump
- Use of optimized mounts, including two hydro-mounts for the engine and two roll-restrictor mounts for the transmission, for improved system stiffness
- Use of quieter magnesium cam covers
- Designed-in main bearing clearances that are 6-8 microns tighter for reduced vibration
- Application of an integrated air-fuel module with extensive ribbing for added stiffness
- Incorporation of a resonator in the mass-flow induction system to reduce intake sound at key frequencies

In addition, the engine and transmission are joined by bolts on the engine and by the structural cast aluminum oil pan, contributing to overall powertrain stiffness. By tightly controlling powertrain movement, engineers could tune the engine hydro-mounts to absorb most remaining vibration frequencies, limiting the amount of noise reaching the passenger compartment.

Easy on Maintenance

In addition to smooth, quiet performance, the powertrain was developed to be low-maintenance. For durability and ease of maintenance, platinum-tipped spark plugs, coil-on-plug ignition and plug wires are rated for 100,000 miles of normal use, and the CVT is rated for 60,000 miles before its first routine maintenance.

Suspension Design Key to Ride, Handling

Several factors contribute to exceptional ride and handling. The chassis must be stiff to resist bending and twisting forces, and the suspension must allow long travel to absorb a wide range of road irregularities. Damper, spring and bushing rates must be properly matched to balance ride quality with precise steering. And tires must provide good grip and quiet operation under all driving conditions.

The stiff suspension design for the all-new Ford Freestyle was adapted from a Volvo platform and optimized in key areas using computer-aided engineering.

"Stiffness is a big player in ride and handling," said Nicosia.

Freestyle also offers generous total suspension travel - 3.5 inches of jounce and 4 inches of rebound travel.

"That amount of suspension travel lets you tune the shocks a little bit more," Nicosia said. "You can create a more absorptive suspension for a more comfortable ride."

Rear Suspension Strong Performer

The multi-link independent rear suspension assembly is built on a stout, U-shaped welded-steel subframe that offers the same stiffness and performance as the cast-aluminum Volvo subframe. Its resistance to shaking, bending and other movement under road impact allows shock absorbers, springs and bushings to better do their jobs.

The rear suspension arrives fully assembled (less wheels and tires) from the supplier by way of a plant located at Chicago's "supplier park," near Freestyle's final assembly facility. This helps assure efficient production and manufacturing consistency.

The rear suspension plays a critical role in steering feel and overall chassis response. During heavy

braking, it is designed to "dial in" a bit of toe-in, which helps enhance steering stability. Toe-in measures how much the front part of two opposite wheels point toward the center of the car. It generally is associated with front suspension geometry. Applying this precise, but forgiving, design to the rear reinforces the driver's feeling of control, whatever the circumstance.

For additional chassis stiffness in the all-wheel-drive platform, which carries the extra load of a rear differential, the engineering team added a small lateral brace that joins the two sides of the subframe.

Lower control arms on all-wheel-drive models are made of hydro-formed steel and are extra stiff to resist both lateral and longitudinal forces. Lateral stiffness in the lower control arms is one of the most important factors affecting handling response. Hydro-forming ensures these critical parts provide exceptional strength for their weight.

Weight is less of a concern in front-wheel-drive versions of the vehicle, so stamped steel lower control arms are used. The suspension knuckle is made from cast aluminum.

Tuned Bushings Ensure Smooth Ride

The stiff control arms are mounted using tuned suspension bushings, which absorb fore-aft forces generated by road seams and sharp bumps. A soft bushing at the front end of the trailing link also soaks up longitudinal shocks.

The attention to ride and handling is evident in the rear suspension, which uses 30 different bushings - each designed for its specific task - and one ball joint located at the point where the upper control arm meets the aluminum suspension knuckle.

"With suspension geometry optimized, one area where you can really improve ride and handling - and customer satisfaction - is through bushings," Nicosia said. "Computer analysis helped us determine the characteristics we wanted from each bushing, and new manufacturing techniques let us achieve these characteristics."

One critical rear-subframe bushing is the front mount of the upper control arm. It incorporates a steel central tube surrounded by a rubber ring that has voids cast into it toward the front and rear of the vehicle. This asymmetric design offers less resistance to longitudinal forces - up to 6 millimeters of total recession - while providing firm control in other directions. It is mounted into a recess in the steel subframe.

In the case of all-wheel-drive models, the rear subframe is joined to the chassis by four isolated mounts to prevent vibrations from reaching occupants. Structurally strong shear-style brackets provide crash strength and stiffness.

Front-wheel-drive versions of the rear subframe are hard-mounted to the body.

Front Suspension - Road Tamer

The front suspension uses MacPherson struts, with a rearward-facing L-arm.

"This design is important for a couple of reasons," Nicosia said. "It gives you the maximum amount of room in front of the suspension to manage crash energy. It also gives you the ability to tune the front suspension for responsive steering and a smooth, comfortable ride."

As with the rear suspension, individually tuned bushings play a critical role. Final bushing rates were determined through a combination of CAE modeling and real-world ride testing.

One key bushing is located at the rear of the lower control arm. This "hydro-bushing" uses oil-filled internal chambers to damp road forces before they can reach the passenger compartment. "It acts like

a small shock absorber," Nicosia said.

A large bushing at the top of the MacPherson strut mount is tuned to resist vertical or axial movements that occur as a result of uneven surfaces, but also to resist side deflection to maintain a crisp steering feel and fight front-to-rear movement in support of firm braking.

Tires, Vehicle - The Perfect Match

Tires are an important component in tuning ride and handling. Seventeen-inch wheels with P215/60R17 Continental tires are standard on the Freestyle, with 18-inch wheels and P225/55R18 Pirelli tires standard on the Limited series.

The 17-inch tires are designed to offer a blend of ride comfort, quiet operation, plush rolling feel and precise steering response. The 18-inch Pirellis provide a bit more steering feel and a sportier ride without excessive noise or harshness.

Both brands also offer solid performance in rain and snow.

Confidence-Inspiring Steering

The rack-and-pinion steering system is tuned for relatively light effort and reasonably quick response, with a steering ratio near 16-to-1.

"You don't have to turn the wheel very far to go around a tight corner in the city," Nicosia said.

"About 180 degrees of movement is all you normally will ever need, even for tight turns. This helps reduce driver fatigue because you're not constantly cranking the steering wheel."

Steering effort also is important.

"People like a steering effort that builds up in a linear fashion as you turn the wheel," Nicosia said. "That helps you judge where you're at, when the wheels come back to center. You always want the steering wheel to generate some response - for example, in on-center steering you should get steering response before you move the steering wheel 5 degrees. But it's not so touchy that it's hard to drive in a straight line."

Variable power assist wasn't required to make parking easier, as can be the case with heavier trucks and SUVs.

The torsionally stiff steering column improves steering response and the feel of the steering wheel in the driver's hands by reducing vibration. It also rapidly and directly transmits the driver's input from steering wheel to steering gear. There's little "wind-up" in the system.

In fact, part of Ford's dynamic engineering philosophy is to reinforce the driver's feeling of confidence through a reassuring motoring experience.

"When people feel like the vehicle is reacting intuitively to what they want it to do, it takes some of the stress and fatigue out of driving," Nicosia said.

Confident Braking

Braking feel and response are crucial to the confident driving experience that engineers sought for the Freestyle. They achieved this by maximizing the size of the four-wheel-disc brake rotors, using dual-piston aluminum calipers on the front brakes, selecting high-friction brake pad materials and fine-tuning the brake system components.

The standard anti-lock braking system improves performance on slippery surfaces, and electronic

brake force distribution continually optimizes balance between the front and rear brakes across the range of road surfaces and vehicle load conditions.

New Brake Pads: More Friction, Less Dust

One of the team's first collaborative projects was to help develop a new Ford standard for brake pad performance.

Pad material directly affects braking feel and performance. Until recently, the quest for shorter stopping distances and superb feedback meant accepting dirty wheels because of high levels of brake dust associated with high-friction pad materials.

The Ford Freestyle takes advantage of new low-metallic pad materials' high-mu levels - "engineer speak" for high friction - to achieve strong, reassuring brake performance, while generating far less dust than other pads with comparable friction.

New Front Calipers for Quicker Response

The front brake calipers are made from cast aluminum and use two pistons on each wheel - a common feature in high performance and sports cars.

The aluminum calipers weigh 10.8 pounds less than cast iron single-piston calipers of comparable size. In addition, they deliver the stopping benefits of the dual 45 mm pistons and the heat-shedding properties of aluminum.

Spreading the braking force over two pistons reduces uneven lining wear and promotes even wear of the rotor, enhancing durability and reducing vibration.

There's a dynamics benefit, too.

"By using two smaller pistons, we achieve more precise control of the piston movement," said Joe Kurcz, braking supervisor for the Ford Freestyle.

"We can keep the brake pads closer to the rotors when they are not in use. That means there's less brake pedal travel before you feel the initial bite of the pads against the rotor. This improves braking feel and driver confidence."

Because only a small protective rubber piston "boot" is required, pistons don't pull away as much from the rotor when the brake is released, allowing the pads to remain closer to the rotor for quicker activation when braking is needed.

To ensure that the brakes retain their feel and performance during repeated hard stopping, the brake pistons use a combination of phenolic coating - which helps prevent heat transfer to the brake fluid - and stainless steel. The majority of heat generated during braking is absorbed by the rotors and dissipated.

The parking brake is integral to the rear caliper, rather than employing a separate parking brake drum. The parking brake cable actuates a ball-and-ramp cam in the rear brake which mechanically applies the brake pads.

Large Wheels Mean Larger Rotors

The 17-inch standard wheels on the Ford Freestyle allowed brake engineers to specify a large rotor size. The front brake discs are 315 mm (12.4 inches) in diameter by 28 mm (1.1 inches) thick. The rear brake discs are slightly larger - 330 mm (13 inches) in diameter by 11 mm (0.43 inch) thick.

The front rotors are larger than those on the Ford Crown Victoria. The front rotors offer 408 centimeters² (63.3 inches²) of swept braking area. The rear rotors have 380 centimeters² (58.8 inches²) of swept area.

Brakes Are Stiffer, Too

Total system stiffness and a reduction in wasted pedal travel are important to achieving a premium, confident braking feel.

"We made a breakthrough on the overall pedal stiffness," Kurcz said. "We benchmarked pedal force versus deflection of the best vehicles on the market. Based on our findings, we made significant increases in stiffness within the brake pedal assembly, which directly relates to improved pedal feel."

One particularly important vehicle design element that also helped brake system engineers achieve the "feel" they wanted, was the very stiff dash panel designed into the Freestyle.

"Since the brake pedal assembly attaches to the dash panel, the reduced flex in this critical area results in reduced pedal travel at any given brake force, a direct improvement to pedal feel and braking confidence," Kurcz said.

Another key to achieving the right braking feel was reducing "lash" or wasted movement in the system. The team tightened up several tolerances, including the actuating rod in the master cylinder and bushings in the brake linkage.

Braking force also often is wasted in the flexible brake lines. But the Freestyle addresses this through the use of a premium material that expands minimally under pressure.

A number of tests helped engineers focus on results they wanted. One repeatedly measured pedal travel and pedal force performance up to 0.7 g of deceleration - the equivalent of a very firm stop in traffic.

"We also do what we call the gorilla stomp test. We hit the brake pedal with 350 pounds of force, and there can be no permanent pedal deflection - no permanent damage to any of the parts," Kurcz said. "People rarely use the full braking power that's available. With the Freestyle, you can really stand on the brakes with confidence, if you have to."