



Ford has announced that it will introduce this dual-clutch PowerShift transaxle, manufactured in a joint venture with Getrag, to the North American small car market in 2010.

# Automatic for the people

**Automatic-shifting dual-clutch transmissions are poised to grab share from traditional transmissions thanks to their combination of efficiency and convenience.**

by *Dan Carney*

When Volkswagen debuted its DSG (direct shift gearbox) dual-clutch transmission in the 2003 Golf R32, its smooth, quick automatic gear changes, fuel economy, and feeling of more driver involvement than a traditional torque converter planetary automatic transmission made the impression that this technology would quickly carve market share out of both the manual transmission and planetary automatic transmission segments.

That may yet prove to be the case, but as often happens when a new technology challenges an entrenched incumbent technology, the incumbent quickly finds improvements that blunt the challenger's appeal.

Engineers are working to refine and improve the dual-clutch transmission

(DCT) and prepare it for high-volume applications. But while they've been at work, engineers on the planetary transmission side have wrung out efficiency improvements to keep their designs competitive with dual-clutch automatic shifting manual transmissions.

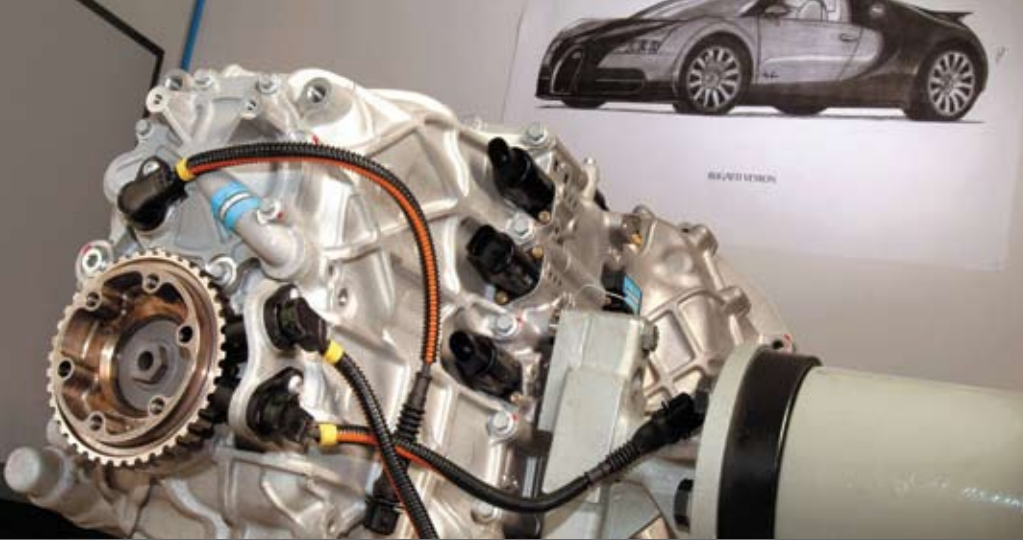
"A lot of simplistic assumptions are turning out to not be as clear," explained Craig Renneker, Ford's Chief Engineer for new programs in transmission and driveline engineering. "The dual clutch has established a benchmark planetary are trying to meet. Now both dual clutch and planetary are both very good and efficient."

#### **Historical roots**

DCT transmissions are essentially two separate manual transmissions enclosed

in a single case, with power to one handling the odd-numbered gears transmitted through an outer clutch, and power to the other going to the even gears through an inner clutch. The computer pre-selects the appropriate gear that is expected to be needed next in the unused half of the gearbox, so when a shift is ordered, it simply declutches the current gear and engages the clutch for the preselected gear, providing seamless power flow.

Manufacturers have worked on dual-clutch technology since the 1980s, recalled Burkhard Pollak, Senior Vice President of R&D at Getrag. The Porsche Doppelkupplungsgetriebe (PDK) even competed in the Porsche 956/962 racecar starting in 1983, but a technology that could be made to work



Despite ample in-house DCT know-how, Volkswagen subsidiary Bugatti turned to high-performance specialist Ricardo for the 1250 N·m (922 lb-ft) Veyron's seven-speed dual-clutch transmission.

The source of different torque specifications among Getrag's similar-looking DCT transaxles is the material selection and gear finishing process specified.



acceptably in prototype or even race form, was not yet ready for production. "The difficulty was finding the proper computer timing and control to operate the dual clutch well enough to ensure the comfort," Pollak remarked.

"My first prototype dual-clutch transmission was 1987," recalled Ulrich Remmlinger, head of product engineering for dual-clutch transmissions at ZF Getriebe GmbH. "At that time the electronics were not as powerful as today," he said. "That is the reason in those days the dual-clutch transmission did not succeed. You have to measure the position of the shift rods and calculate the movement of the rods in real time to accomplish the shift in a fast time. Now we have powerful computers and sensors that can tell us the position of the shift rods accurately and calculate the reaction of the transmission while the shift is ongoing. This was not achievable or affordable 20 years ago."

### Predicted success

From a basis of zero dual-clutch transmissions in 2002, to about 600,000 in 2008, global production will total five million units by 2014, predicts Bernd Matthes, President of Transmission Joint Ventures at BorgWarner. Most of those sales will be outside North America, with particularly strong sales in Europe and China, he said.

Today, Volkswagen builds 1500 of its older six-speed DCTs per day at its Kassel transmission plant, and has added production of 750 of its new seven-speeds per day, with the capacity to double that as needed.

North American DCT sales will total

814,000, or 5.4% of the market by that time, forecasts David Petrovski, Powertrain Analyst for CSM Worldwide. Established manufacturing capacity and customer preference for planetary automatic transmissions, which already hold about 72% of the North American market will make it tough for dual-clutch transmissions to penetrate the market, he said.

But elsewhere, where most drivers are used to manual transmissions and there isn't as much manufacturing investment in traditional automatics, the technology will be more popular, Petrovski predicted. "You could see it take off in certain markets where consumers accept it" he said. "There will be islands where DCT technology makes a better business case."

With technical practicality achieved, the dual-clutch transmission development work now focuses on the DCT's cost challenges compared to traditional planetary automatic transmissions. Estimates of how much more expensive dual-clutch transmissions are than planetary transmissions vary almost as much as estimates of their efficiency advantage, depending on the source of the estimate and their basis of comparison. Frost & Sullivan Lead Automotive Analyst Larry Rinek pegs the cost premium to OEMs of using a DCT rather than planetary automatic at between 10% and 15%. "It is a super-premium solution," said Rinek. "It is the most costly transmission you can buy." Simpler, lighter-duty dry clutch DCT's like Volkswagen's new seven-speed are less costly, he added.

"When you lay all the parts on the

table, you don't see a drastic difference between a DCT and a planetary automatic," observed Renneker. Rather than parts count or technical complexity, the real source of the DCT's higher cost right now is the small number of suppliers providing components, and the need of those suppliers to recoup their engineering costs, he said. "Since the planetary technology is established throughout the globe there is a lot of competition in the supply base around the world," he said. There is a very good choice of suppliers to work with so there is competition for price.

"In contrast, OEMs seeking a clutch for a DCT have few options. "The dual-clutch device is from BorgWarner," said Renneker. "There is not a long list of suppliers doing that and they've got to recoup a substantial amount of engineering cost. That is where the premium is coming in."

Because these costs are business-related, they should subside, as more suppliers compete for the business, he said. "Over time, we'll see these costs come out to be very close to each other," Renneker predicted.

### DCT benefits

Volkswagen points to myriad advantages of its new DCT thanks to the benefits of the dry clutch design. Even with

one more gear, the new seven-speed weighs an amazing 50 lb (22.7 kg) less than the older six-speed DCT design, at 154 lb (69.9 kg). Porsche says even its new wet clutch DCT is 22 lb (10.0 kg) lighter than the Tiptonic automatic transmission used previously.

Additionally, VW's dry clutch design eliminates the additional fluid, plumbing, and oil pump needed to circulate transmission oil between the gearbox and clutch, slashing the oil volume from 6.5 to 1.7 L.

Correspondingly, this lighter-duty dry clutch is able to accept less torque than the six-speed's wet clutch, with a rating of only 250 N·m (184 lb·ft) rather than the 350 N·m (258 lb·ft). The Bugatti Veyron's Ricardo-supplied wet-clutch DCT tolerates that car's 1250 N·m (922 lb·ft) torque, illustrating the potential of the technology in an extreme instance.

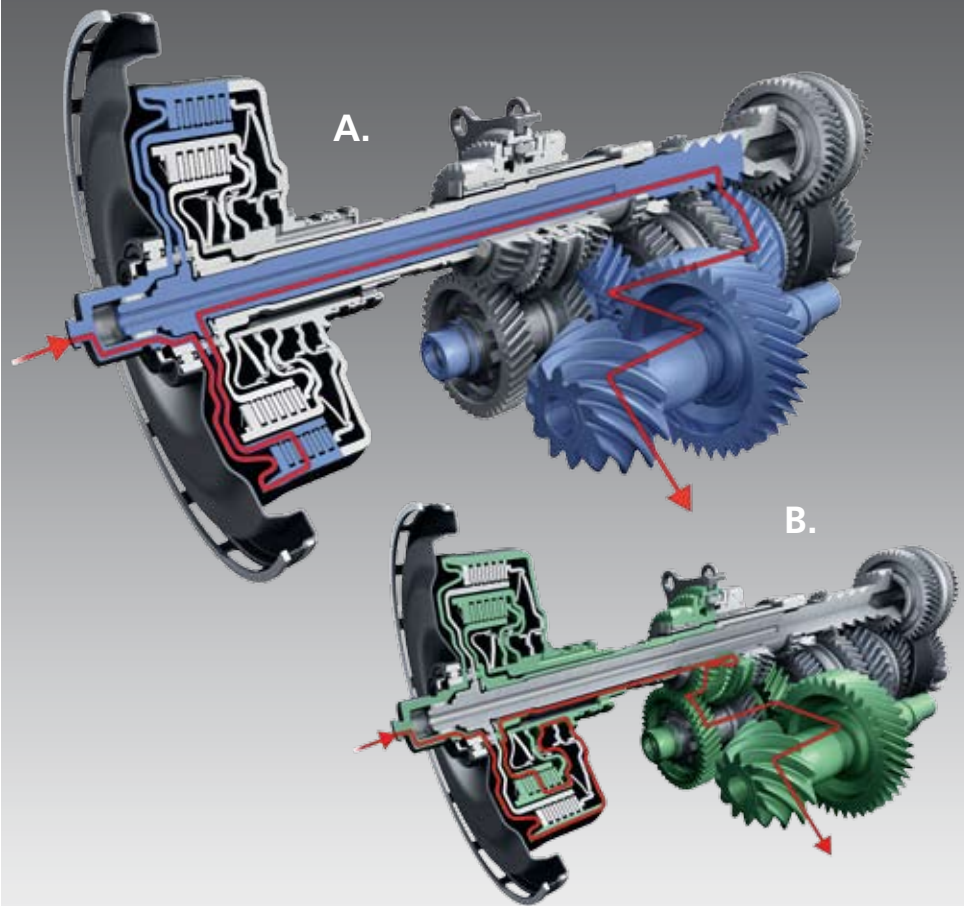
For high torque applications more typical in North America, such as trucks and SUVs, a torque converter planetary automatic transmission remains the preferred solution, both for its ability to withstand torque loads and for the torque multiplication it provides at take-off, said Renneker.

### Fuel frugality

Dual-clutch transmissions are much more efficient than the four-speed automatics that were the industry standard when VW debuted its DSG in 2003. But the world is switching rapidly to six-speed automatics, which close the efficiency gap, and Remmlinger says that ZF's eight-speed planetary transmission is as efficient as the company's six-speed dual-clutch transmission.

VW, meanwhile, touts its new seven-speed dual-clutch transmission as more efficient than even a six-speed manual. A seven-speed DCT-equipped gasoline-fueled Golf burns just 5.9 L/100 km, compared to 6.3 L/100 km for the six-speed manual transmission version of the same car. The company further claims a 20% advantage over a torque converter automatic, but it doesn't specify how many speeds.

Porsche claims that its new dual-clutch-equipped 911 Carrera is 12.5% more fuel efficient than its previous automatic transmission model. Remmlinger says that more than half that improvement is the result of Porsche's switch to direct fuel injection,



When first gear is engaged (A), power in the Porsche 911's PDK transmission flows through the 202 mm (8.0 in) diameter outer clutch pack to the rearmost gearset, then to the output shaft. When fourth gear is engaged (B), power flows through the 153 mm (6.0 in) diameter inner clutch pack to a gearset on the other layshaft, then to the output shaft.

and that the remaining 6% is attributable to the more efficient transmission.

A dry clutch setup enjoys a 1% fuel economy benefit compared to a wet clutch DCT because of the elimination of the oil pump and its attendant losses, according to Pollak.

Two additional advantages of DCTs compared to planetary automatics are complete independence of gear ratios, which are not related to one another the way that all the ratios in a planetary arrangement are related to one another, and the consequent larger spread of ratios that this freedom makes possible in a DCT. This is seen in the Porsche 911, where the seventh gear in the DCT cuts engine rpm at 100 km/h (62 mph) from 2450 rpm, with the old five-speed automatic, to 1750 rpm.

### Future features

With Volkswagen rolling out its second generation of DCTs with an extra gear and a dry clutch, other transmission makers will be releasing improved versions of their products in the near future.

ZF plans to focus on refining the manufacturing of its DCTs, reports Remmlinger, designing for ease of man-

ufacturing and incorporating more robotics into the transmission's assembly. "These are all in our focus," he said. The transmission itself will not be dramatically different, he said. "For the next generation of our dual-clutch transmission three years from now, we will have an improved version of our transmission," he said. "This will incorporate minor changes for better efficiency and a few minor features. Fuel economy is really the focus.

"The current six- and seven-speed designs contain as many gear ratios as is practical or beneficial, so DCTs will probably not follow planetary transmissions to eight or more speeds, he said. "Nobody is thinking about more gears at the moment because every additional gear is an additional gearset, which increases length and frictional losses," Remmlinger said.

Additionally, there is little benefit to be gained from more ratios, according to Pollak. "As you go beyond seven speeds, the difference between eight and nine speeds is not that great," he said. **aei**