

# 更快、更顺畅的变速器

变速箱通常不得不在舒适性和效率之间做出选择，但一种新型的“犬牙啮合式”（dog engagement）变速箱可以同时改善这两种性能

## Faster, smoother transmissions

Transmissions have to compromise on either ride comfort or efficiency, but a new approach to the dog engagement gearbox could improve both

**随**着排放法规的日趋严格，汽车制造商为降低排放所做的努力已不再局限于改善燃烧过程和后期处理。许多公司认为，现代发动机技术已经发展到这样一个阶段：与投入巨额开发成本相比，技术进步带来的收效却很小。

因此为了改善排放，最重要的是要着眼于整车的性能。作为车上第二昂贵的部件，变速箱理所当然地成为第二步改善的目标。

所有变速箱技术中，手动变速箱的效率最高，输出功率可达输入功率的96%。但并不是所有人都能驾驭手动变速箱，也不是所有人都愿意用它。因为用手动变速箱需要踩离合器，这在交通繁忙的时候很不舒服。驾驶员容易疲劳，而由扭矩中断导致的“点头”效应也会使乘客很难受。

由于驾驶员操纵离合器而产生的扭矩中断是手动变速箱的主要缺点。在换挡加速时，每升高一档，驾驶员都必须通过松开油门并

**W**ith tightening emissions regulations, carmakers are not just confining their efforts to improving combustion and after-treatment. Many are finding that modern engines are so advanced that the benefits of some engine technologies are small compared to the huge development costs involved.

It's important to look at the whole vehicle in order to improve emissions. As the second most expensive piece of kit in the car, the transmission is the logical next place to look.

Of all transmission technologies, the manual gearbox is the most efficient; around 96 per cent of the energy that is put in comes out of the other end. But not everyone can drive one or wants to. Because you have to dip the clutch pedal, it's less

踩下离合器来使扭矩暂时中断。完成整个过程大概只需一秒钟，但在这段时间里车辆会暂时停止加速，速度也会降低。

与此截然相反的是传统的自动变速箱。由于采用了变矩器，这种变速箱的换挡质量不错但效率相对较差——即使最近有所改进。因此，最近进行了许多研究，试图发现传统自动变速箱的有效替代方案。

主要的技术仍是无级变速（CVT）、双离合变速（DCT）和手自一体（AMT）变速器。它们在不同的方面优于传统的行星齿轮式自动变速器。

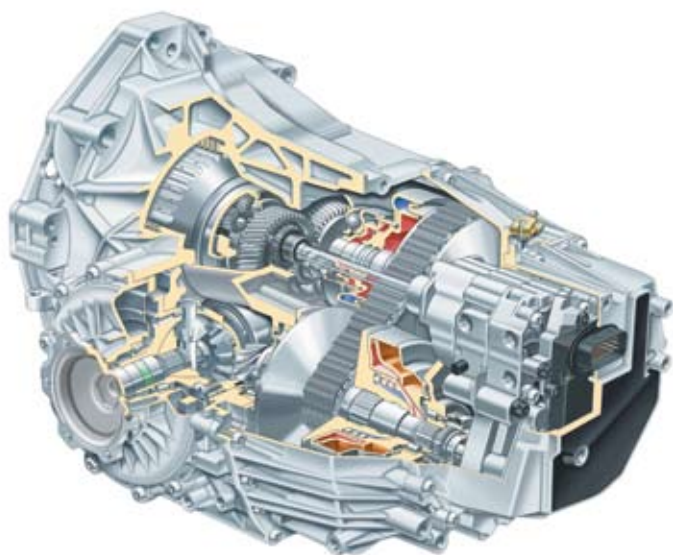
无极变速器采用带链或锥盘滚轮来产生无限多种变速比。与传统自动变速器相比，其效率和成本都有所改善。之所以有这些优点，是因为它结构简单。这种变速器的零部件很少，通常只有一根橡胶或金属传动带、一个液压作用的驱动带轮、一个机械扭矩感应式驱动带轮、一些微处理器和传感器等。

这种变速器的工作原理是改变两个主带轮表面之间的距离。带轮上挂传动带的地方开了V形的槽。一侧的带轮沿轴向固定，另一侧的带轮可在液压的作用下移动。

在驱动后，液压缸可增加或减少带轮两侧之间的距离。这样会使传动带在带轮侧壁上的位置上下变动，变动的方式取决于驾驶情况。这样会使变速比发生变化。锥盘滚轮型变速器的工作原理与此类似但用的是驱动盘和动力滚轮。

CVT变速器“无级”的特点对技术人员最有吸引力。因为没有档位，CVT可以使发动机保持在最佳的功率范围内，这样可以使效率提高并在相同的油耗下增加行驶里程。CVT可将发动机工作曲线上的每一点转换为其本身工作曲线上相应的点。

这种变速器最受日本汽车制造商的青睐，并且日本变速器生产商JATCO是主要的生产者。但在欧美国家，情况有所不同。尽管奥迪和其他一些制造商在一些车型上推出了CVT，但在这方面他们追赶的步伐仍然很缓慢。



CVT可使发动机工作在最佳功率范围内，增加换挡效率并降低燃油消耗  
CVTs can keep the engine in its optimum power range, increasing efficiency and cutting fuel consumption

comfortable to drive in heavy traffic. It makes the driver tired and the torque interruptions' head-nod effect on passengers can be wearing.

The driver's clutch control and corresponding torque interruptions are also the manual's weak point. When accelerating up through the gearbox, each up-shift requires the driver to cut the torque momentarily by lifting the gas pedal and dipping the clutch. It may just take a second to complete the operation, but during this time the vehicle is losing speed and acceleration.

At the opposite end of the spectrum is the traditional automatic. Its shift quality is good thanks to its torque converter, but efficiency is relatively poor despite recent advances. Because of this, a lot of the current research is trying to find an efficient alternative to the conventional automatic.

The main technologies are continuously variable transmissions (CVTs); dual clutch transmissions (DCTs) and automated manual transmissions (AMTs). They all offer different benefits over the conventional planetary automatic.

The CVT uses a belt chain or toroidal shaped dish drive to vary an infinite number of gear ratios. It has improved efficiency and cost when compared to conventional automatics. Its advantage comes from its simplicity. It consists of very few components; usually a rubber or metal-link belt; a hydraulically operated driving pulley, a mechanical torque-sensing driving pulley, microprocessors and some sensors.

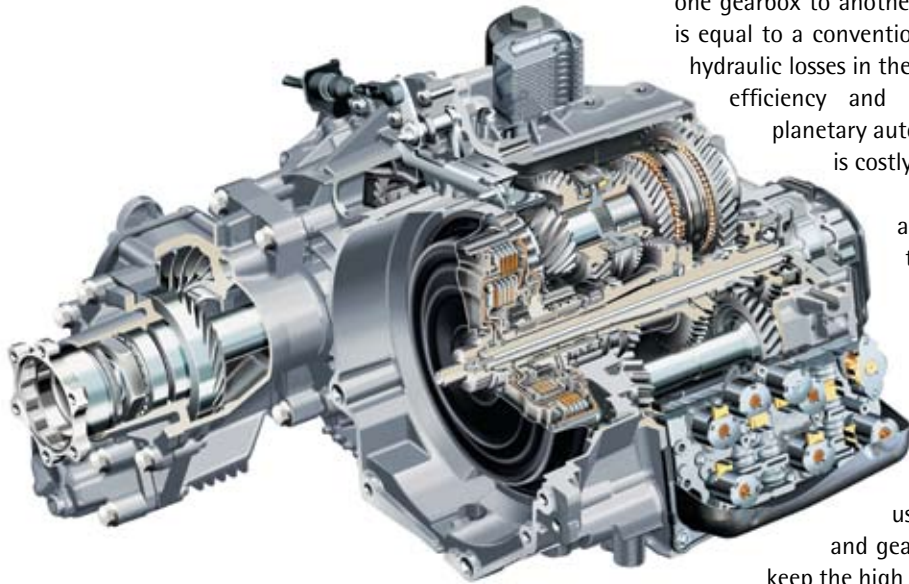
The transmission works by varying the distance between the faces of the two main pulleys. The pulleys have V-shaped grooves in which the connecting belt rides. One side of the pulley is fixed axially; the other side moves, actuated by hydraulics.

When actuated, the cylinder can increase or reduce the amount of space between the two sides of the pulley. This allows the belt to ride lower or higher along the walls of the pulley, depending on driving conditions. This changes the gear ratio. A toroidal-type design works in a similar way but runs on discs and power-rollers.

The "stepless" nature of its design is CVT's biggest draw for automotive engineers. Because of this, a CVT can work to keep the engine in its optimum power range, thereby increasing efficiency and mileage. A CVT can convert every point on the engine's operating curve to a corresponding point on its own operating curve.

The transmission is most popular with Japanese carmakers and Japanese supplier JATCO is a major producer. But in the US and Europe driving styles are different. Uptake has been slow despite Audi and other manufacturers having offered CVT options on their ranges.

The DCT is, in effect, two manual gearboxes coupled together. Gear shifts are made by switching from one clutch on



DCT的换挡质量和自动变速器相等，但开发成本太高  
DCTs' shift quality equal an automatic, but development costs are high

DCT实际上是将两台手动变速箱合在一起。换挡过程是通过在两台变速箱的离合器之间相互切换实现的。这种变速器的换挡质量和传统自动变速箱相同，但由于系统会发生滑动、流体阻力和液压损失，其效率和加速性能只比传统行星齿轮自动变速器稍有提高。开发控制系统的成本也很高。

“最近在传统自动变速器技术上取得的进展，使开发和生产CVT或DCT的呼声有所降低。”变速器生产企业Zeroshift公司的执行总裁Bill Martin说。“由于成本过高，有些汽车厂已经取消了DCT项目。”

AMT是成本最低的自动变速器技术。AMT用执行器来代替传统的离合器踏板和换挡杆。这种变速器保留了手动变速器的高效率和加速性能，但某些型号的变速器的换挡质量不高。扭矩中断和“点头”效应仍是主要的缺点。

那么什么是最好的替代方案？变速器方面的新技术是曾出不穷的，但Zeroshift公司声称其变速器的效率优于手动变速器，能提高市区驾驶的燃油经济性。同时，其换挡效率可以和改进后的自动变速器相媲美。

Zeroshift公司采用的是一种改进版的AMT技术。这种技术用先进的犬牙啮合（dog engagement）系统代替同步器。

犬牙啮合技术许多年前就已在赛车运动中采用，目的是为了加快换挡速度。传统的犬牙式变速箱并不适合用在公路上，因为驱动环或犬牙之间的空间很大，会产生后坐—由扭矩突然变向而产生的一种不舒适的窜动。

Zeroshift公司通过增加第二套驱动犬牙来解决这一问题。这种技术还使每组犬牙只能传递两种相反方向扭矩中的一种。“通过对两套犬牙的啮合和分离，可在上一个档位没有分离的情况下换入新的档位。”Martin说。“换挡质量超过采用现代化的6档变速器的豪华轿车。”

one gearbox to another clutch on the other. The shift quality is equal to a conventional automatic, but slip, fluid drag and hydraulic losses in the system result in only slightly improved efficiency and acceleration over the conventional planetary automatic. Developing the control strategy is costly too.

“Recent advances in conventional automatic technology have weakened the argument to develop and set up production for CVT or DCT,” says Bill Martin, managing director of transmission firm Zeroshift. “Some carmakers have cancelled DCT projects because of the cost.”

The cheapest way to build an automatic is with an AMT. AMTs use actuators to replace the clutch pedal and gear stick of a conventional manual. They keep the high efficiency and acceleration of a manual gearbox, but the shift quality on some models is lacking. Torque interruptions and the head-nod effect are the most common complaint.

So what is the alternative? There are always new ideas in transmissions, but Zeroshift says that its technology has efficiency benefits over a manual, delivering fuel economy improvements to city driving. Shift quality can also be equal to that of a refined automatic.

Zeroshift's approach is an upgrade to the AMT. The synchromesh is replaced with an advanced dog engagement system.

Dog engagement has been used for many years in motor sport to allow fast shifts. Conventional dog boxes are unsuitable for road use as the large spaces between the drive lugs or “dogs” create backlash, an uncomfortable shunt caused by the sudden change in torque direction.

Zeroshift's technology solves this problem by adding a second set of drive dogs. It has also made each of the two sets of dogs only capable of transmitting torque in one or other opposing directions. “By controlling the engagement and disengagement of the two sets you can shift into the new gear before disengaging the previous gear,” says Martin. “The shift quality is smoother than a typical modern six-speed automatic luxury car.”

The shift is instant and the torque is not interrupted. This philosophy is used for both up and down shifts.

“In conventional AMT there is an emissions spike during a shift due to the need to back off and reintroduce throttle, this is eliminated by going seamless,” says Martin. “This also reduces fuel consumption.”

It is a relative newcomer to the transmission sector, but the firm says that it is already attracting the attention of major

换挡可在瞬间完成，而扭矩不会发生中断。而且这种方法既可用于升档也可用于降档。

“在使用传统的AMT变速器时，由于需要关闭并重新打开油门，换挡过程中排放会达到高峰，而通过这种无过渡的换挡方式则可以消除这种现象。”Martin说，“这样还能降低燃油消耗。”

尽管该技术在变速器领域还比较新，但该公司称已经引起了欧美各大汽车制造商的注意。最大的吸引力在于其成本比DCT低，Martin说。

由于可以保留大部分手动变速器的结构，这种变速器的成本和复杂性都不会高于传统的AMT变速器。控制系统的开发成本也会大大降低。这对试图减少排放和削减成本的工程师来说是个好消息。

“大部分汽车制造商都来参观过。”Martin说。“有些公司马上就和我们签合同，另一些未作决定，拒绝的则一个都没有。”这再清楚不过地表明了汽车制造商现在正在将动力系统开发的重点转移到变速箱上。



Zeroshift 对犬牙啮合技术进行了改进，采用了两套犬牙，只沿两个相反的方向传递扭矩  
Zeroshift improves dog engagement with two sets of dogs, which only transmit torque in opposing directions

### Zeroshift变速系统的工作原理

硬件部分包括两套犬牙，安装在两个独立的犬牙环上并受其驱动。两套犬牙有一个共同的轂盖，轂盖和一个带花键的轴相连。

每个犬牙具有特殊的轮廓。在一侧是用于啮合的直角面。这些直角面是沿对角线相对的，这样犬牙在对某一个档位具有驱动功能的同时，对另一个档位具有超越传动（overrun）功能。啮合面有轻微的后向锥度，以保证犬牙能在加载时锁定在啮合的齿面上。

相对角上有一个斜坡，可在新档位接合后将犬牙从前一个档位上推离。

在空档时，两个犬牙环处于变速比的中间位置。选一档时，犬牙会发生移动并与犬牙啮合面发生啮合。犬牙通过与换挡执行器相连的换挡拨叉驱动。

驱动犬牙将一档齿轮与输出轴锁定在一起，将扭矩从齿轮传递到输出轴。一档的超越传动犬牙也会移动并将齿轮以相反的方向和输出轴锁定。这样可在油门关闭且发动机倒拖时将扭矩从齿轮传递到输出轴。这样就消除了犬牙啮合式变速箱常见的后坐现象。

在加大油门换高档时，一档齿轮的超越传动犬牙卸载后和二档齿轮啮合。然后在换入二档时，前一个犬牙环卸载。

如果犬牙之间不能完全啮合，即实现两个犬牙面之间的啮合，由于相对速度差的存在，二档啮合会打开一个啮合缺口。在犬牙抵住犬牙啮合面后，在拨叉和执行器的共同作用下，储存的能量会将犬牙送入缺口内。

此时一档超越传动犬牙成为二档的驱动犬牙。在换入二档后，一档的驱动犬牙随即卸载。这时候，这些犬牙不再受其固定面的固定，可以被执行器或犬牙上的斜面推离档位。

然后一档齿轮的驱动犬牙会移动到和二档齿轮发生啮合的位置。在二档时，犬牙的作用正好相反。

European and US carmakers. The big draw is as a low-cost alternative to DCT, says Martin.

Because the manual gearbox architecture is largely maintained, production costs and complexity are not greater than for a conventional AMT. Development of the controls side is also considerably cheaper. Music to the ears of engineers trying to cut emissions and costs.

“Most of the carmakers have seen the system at least once,” says Martin. “Some signed us up immediately. Some have said not yet. None have said no.” That may be the clearest sign yet that when it comes to powertrain developments, carmakers are starting to focus on the transmission. ■

### HOW ZEROSHIFT WORKS

The hardware consists of two sets of bullets, mounted and actuated on two independent bullet rings. Both sets of bullets run on the common hub, which is attached to the shaft with splines.

Each bullet has a special profile. On one side they have an angled face for engagement. These are diagonally opposed, allowing the bullet to have a drive function for one gear and an overrun function for the other gear. The engagement faces taper backwards slightly to ensure the bullet latches onto the engaged gear under load.

The opposite corners have a ramp, which pushes the bullet out of the previous gear once the new gear has been engaged.

In neutral both bullet rings are positioned midway between the ratios. To select first gear, the bullets are moved into mesh with the engagement dogs. The bullets are actuated via shift forks connected to the shift actuators

The driving bullets lock first gear to the output shaft and transfer torque from the gearwheel onto the output shaft. The first gear overrun bullets are also moved into gear to lock the wheel to the output shaft in the opposite direction. This transfers torque from the gearwheel onto the output shaft when the throttle closes and the engine overruns. This eliminates the backlash you'd expect from a dog engagement gearbox.

To shift up with an open throttle, first gear's overrun bullets are unloaded and move in to engage second gear. This is followed by the previous driving ring which becomes unloaded when second gear is taken up.

If the bullet is stopped from engaging fully – dog-face to dog-face – the second gear wheel opens an engagement window due to the relative speed difference. With the bullet pushed against the engagement dog, compliance between the fork and actuator allows the stored energy to fire the bullet into the window.

The first gear overrun bullets have now become the second gear drive bullets. As second gear takes over, the load is removed from the first gear drive bullets. These bullets are now no longer held by their retention angle and can be either moved out of gear by actuators or pushed out of gear by contact with the ramp face of the bullet.

The first gear drive bullets then move across into engagement with second gear. In second gear, the roles of the bullets are reversed.