

# Seamless AMT offers efficient alternative to CVT\*

R P G HEATH<sup>1</sup>

Zeroshift technology allows a manual transmission to change gear in zero time. The Zeroshift automated manual transmission (AMT) is easy to manufacture and is an alternative to the CVT. Zeroshift offers potential fuel economy improvements from driveline efficiency and the best possible vehicle acceleration. Compared to an existing AMT, Zeroshift offers an uninterrupted torque path from the engine to vehicle which allows for a seamless gearshift.

Keywords: transmission, synchronizer system, seamless shift, automated manual transmission

## 1. INTRODUCTION

The world is dominated by two forms of transmission, the manual transmission (MT) and the Automatic Transmission (AT). In Japan, there is also a third option as the Continuously Variable Transmission (CVT) is gaining in popularity.

The MT is the most efficient transmission available. This lends itself to providing good fuel economy for the vehicles it is employed in. The efficiency of the MT is dependent on the load applied. Over a representative drive cycle its overall efficiency can approach 97% [1].

The AT and CVT main advantage is their ease of driving. Drivers are willing to pay a premium for this type of transmission even though performance and fuel economy are inferior to the MT. A reduced performance and fuel economy is apparent because of the lower efficiency of the transmission. Over the same representative drive cycle the efficiency is seen to be less than the MT, Table 1.

Transmission type	Efficiency
Manual	97%
Automatic	86%
CVT belt	88%
CVT toroidal	93%

Table 1. Efficiencies of various transmissions over a drive cycle.

If a transmission could have the efficiency of an MT and drive like an AT or CVT, this would introduce a fourth option to segment the market. Traditionally, the AMT has matched or improved on the MT for fuel economy but has suffered from inferior performance (compared to the MT) and bad shift quality. Zeroshift corrects these latter two issues allowing simultaneously good fuel

economy, performance and shift quality. The combination of these has not previously been seen in any other transmission.

## 2. ZEROSHIFT CONCEPT

The Zeroshift concept replaces synchromesh components within a manual transmission with Zeroshift rings, Figure 1. Synchronisation is aided externally with the assistance of torque intervention performed by the engine control unit and an automated single plate dry clutch (standard equipment in an AMT).

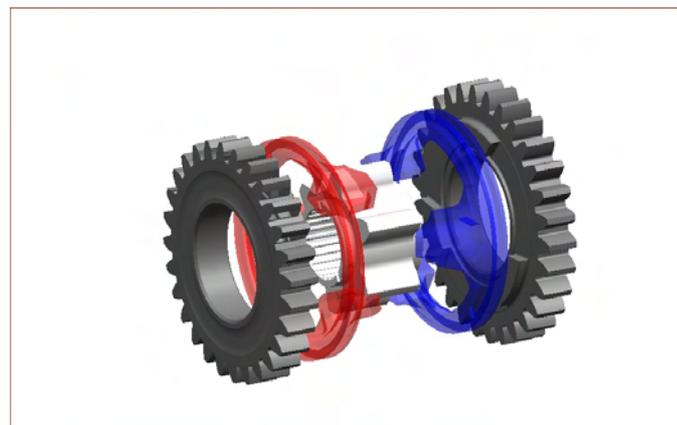


Figure 1. Exploded view showing pair of Zeroshift rings between two gears.

The Zeroshift rings act as a pair with each ring being similar to those found in dog engagement transmissions. The unacceptable backlash found in dog engagement transmissions is eliminated by splitting the dog into two halves. One Zeroshift ring is engaged to take up drive whilst the other Zeroshift ring is brought in afterwards to take up the backlash.

Each ring is double-sided where one side can only drive in one direction and the opposite side in the other direction. When paired back-to-back they present either a direct-drive or a ramp face depending on the vehicle drive direction.

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When initiating a shift from the neutral position, one drive ring is engaged with the dog faces on the gear and the other ring provides drive in the opposite direction to oppose engine overrun and, more importantly, eliminate perceivable backlash. As this unloaded ring will make the next shift, compared to a synchroniser, it requires up to 25 times less shift force.

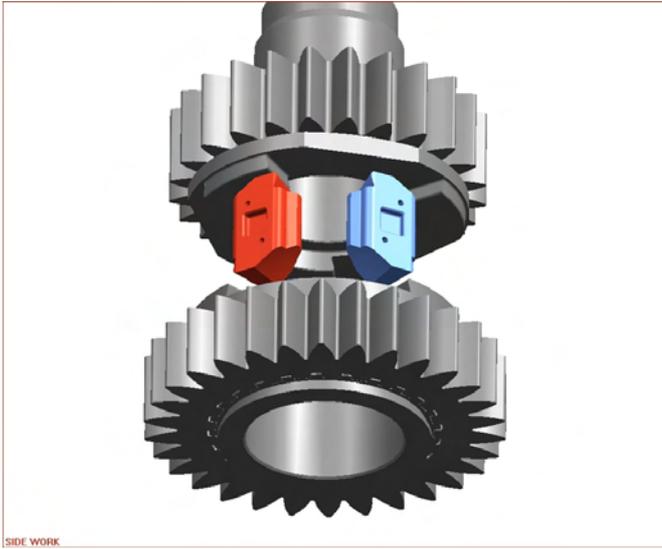


Figure 2. Neutral position.

Each pair of rings has three pairs of “bullets”. It is easier to see the actions of these rings if we look at an exploded view, Figure 2. Here we see just one pair of bullets without the ring for clarity. On one side of the bullet is a retention angle to take up the drive whilst on the opposite side is a ramp face to disengage drive.

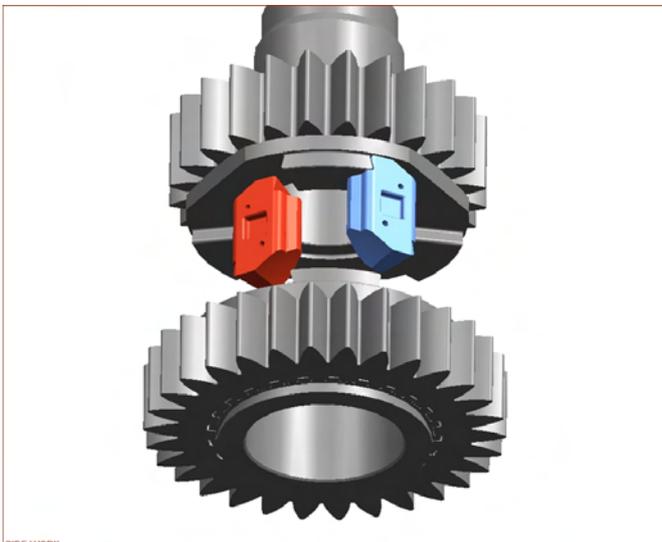


Figure 3. Actuate first ring to take up drive in 1<sup>st</sup> gear.

The unique feature of Zeroshift is that it is able to change gear in zero time, just like a digital switch. We can see in Figure 3 how by shifting the blue ring and its bullets with a shift fork, drive is taken up on the 1<sup>st</sup> gear (top of diagram). Backlash is taken up by shifting the red ring, Figure 4.

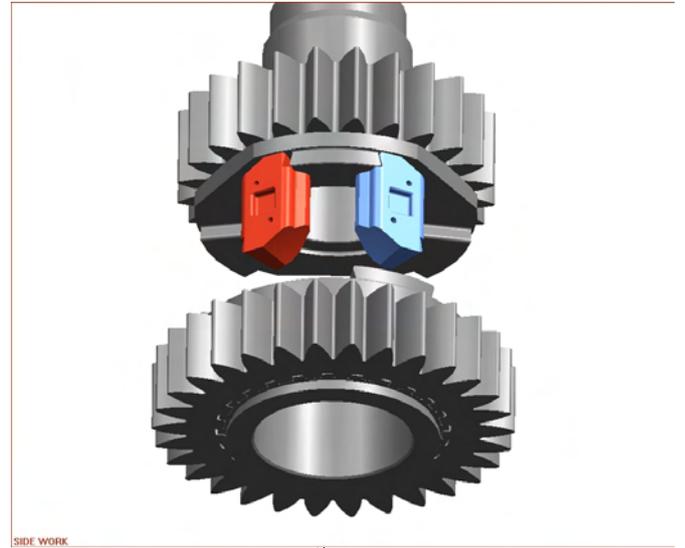


Figure 4. 1<sup>st</sup> gear engaged.

To perform a Zeroshift gearshift, whilst still driving in 1<sup>st</sup> gear on the blue ring, the unloaded red ring may be moved to the 2<sup>nd</sup> gear (bottom of diagram), Figure 5.

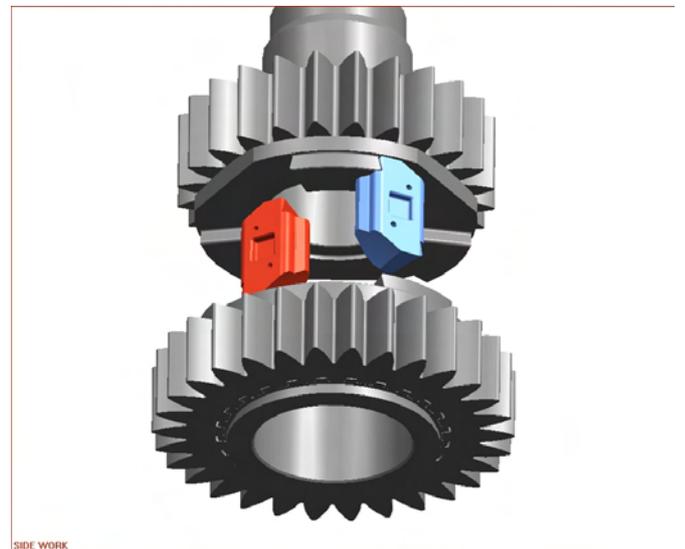


Figure 5. 2<sup>nd</sup> gear overruns 1<sup>st</sup> gear.

As 2<sup>nd</sup> gear is rotating faster, it overruns 1<sup>st</sup> gear and takes up drive on the red ring allowing the engine torque to be handed over. At no time is the engine torque interrupted from being transferred to the vehicle’s wheels.

The gearshift is complete when the original blue ring is no longer loaded on 1<sup>st</sup> gear and is able to be actuated over to 2<sup>nd</sup> gear to take up backlash, Figure 6.

The instantaneous shift is by definition a torque hand-over from one gear to another. This creates a torque or energy impulse in the driveline which is managed through a combination of engine, transmission and clutch control. The result is a continual delivery of torque and unaffected vehicle stability. Such a concept has wide application not only because of improved acceleration performance but also fuel economy and shift quality.

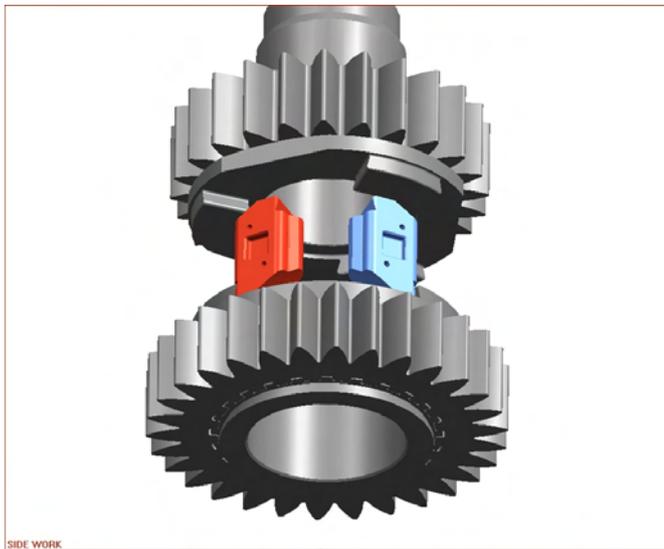


Figure 6. 2<sup>nd</sup> gear engaged.

### 3. ZEROSHIFT BENEFITS

The main benefits of Zeroshift are:

- fuel economy
- performance
- shift quality

#### 3.1. FUEL ECONOMY

To date, the MT has provided better fuel economy than the AT and CVT [2]. A technology that has demonstrated on occasions, even better fuel economy than the MT is the AMT. This fuel economy is not due to the in gear efficiency of the transmission as it is no more efficient than the MT but due to the gear shift schedule. On a drive cycle an AMT is able to shift to a taller gear earlier whilst the MT is constrained to follow a mandatory gear schedule. In real driving with the AMT in automated mode, an improvement in fuel economy over the MT can be achieved for the same reason. It is unlikely that the driver will always be in the best gear for all situations. At highway cruise the standard AMT will be no better than the MT. It may be slightly worse if parasitic losses are present to operate the power pack for clutch and gearshift actuation.

Zeroshift is an AMT which has no significant parasitic losses when in gear. Only a small amount of power is required during the gear shifting and clutch operation compared to an AMT. There is no hydraulic actuation so there are no parasitic losses to operate a hydraulic pump. Both the gear actuation and clutch control can be electrically operated from the standard 12V vehicle electrical system.

#### 3.2. PERFORMANCE

Compared to an MT the Zeroshift concept allows gear shifts to take place in zero time. This has an immediate

performance benefit as the vehicle is never coasting in neutral. Each gearshift which would normally take a test driver approximately 0.5 seconds to complete is performed in 0 seconds with Zeroshift technology, Figure 7. For most (non-test) drivers, the gearshift would be greater than 1 second.

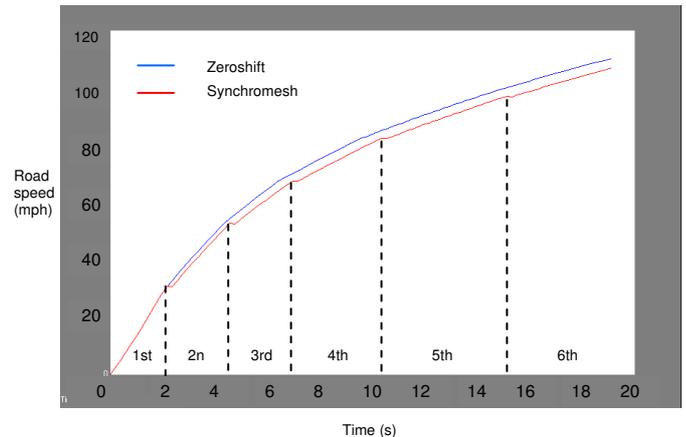


Figure 7. Zeroshift compared to manual gear shift.

For the average automobile equipped with a MT it is necessary to perform one gear shift during a 0 – 100 kph acceleration starting in 1<sup>st</sup> gear and ending in 2<sup>nd</sup> gear. The Zeroshift technology enables the acceleration to be completed approximately 0.5 seconds quicker than a MT driven by a test driver.

Compared to the MT the fuel economy and acceleration performance (0 – 100 kph) of various transmissions are shown in Figure 8. The traditional 4 to 5 speed AT has been superseded with the 6 to 7 speed AT. This transmission is now able to compete directly with the CVT in terms of fuel economy, performance and manufacturing costs [2, 3].

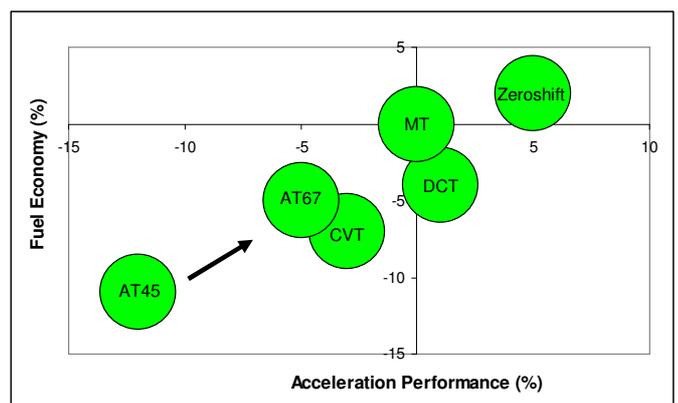


Figure 8. Fuel economy and acceleration performance of various transmissions as compared to MT.

It is necessary for CVT manufacturers to improve their product in order to retain market share. Even the MT is under threat from the Dual Clutch Transmission (DCT). Zeroshift is able to exceed all these current transmission technologies by offering the best fuel economy and acceleration performance.

### 3.3. SHIFT QUALITY

Transmission shift quality is measured in many ways, some objectively and others subjectively. We consider here the longitudinal acceleration of a vehicle which can be measured both objectively and subjectively.

Objectively, a vehicle may be instrumented to measure longitudinal acceleration which will show the deceleration and acceleration experienced during a gear shift. It can be seen from Figure 9 that during a standard upshift in a MT there is a torque interrupt to the wheels. This is shown in the figure by the reduction in longitudinal acceleration during the shift.

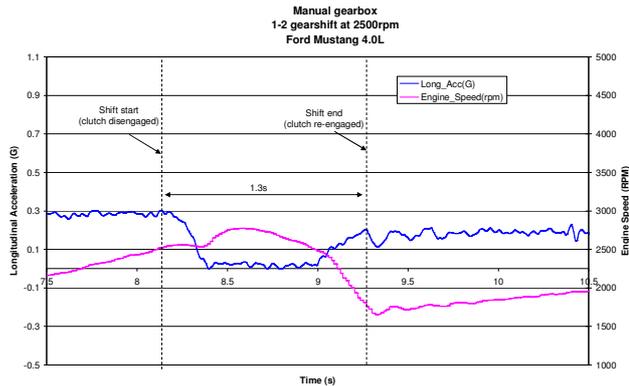


Figure 9. Manual transmission with torque interrupt.

Subjectively, this is experienced by the vehicle's occupants not only by observing the pitching of the front of the vehicle but also by what is known as head nod. In its mildest form this is merely a discomfort to the occupants. In its severest form this can lead to instability of the car, especially during cornering.

It can be seen from Figure 10 that during a standard upshift in a vehicle fitted with Zeroshift there is no torque interrupt to the wheels. This is shown in the figure by the consistently flat longitudinal acceleration during the shift. Subjectively, the shift is unobserved by the vehicle's occupants as there is no pitching of the vehicle and stability is maintained.

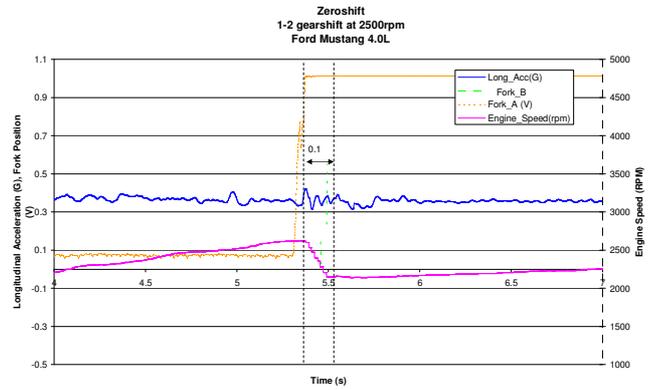


Figure 10. Zeroshift transmission with no torque interrupt.

## 4. CONCLUSIONS

The Zeroshift transmission has been demonstrated and has the following benefits:

- Improved fuel economy compared with torque converter automatic transmission and CVT
- Improved acceleration performance compared with manual transmission
- Improved shift quality compared with manual transmission

## 5. REFERENCES

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