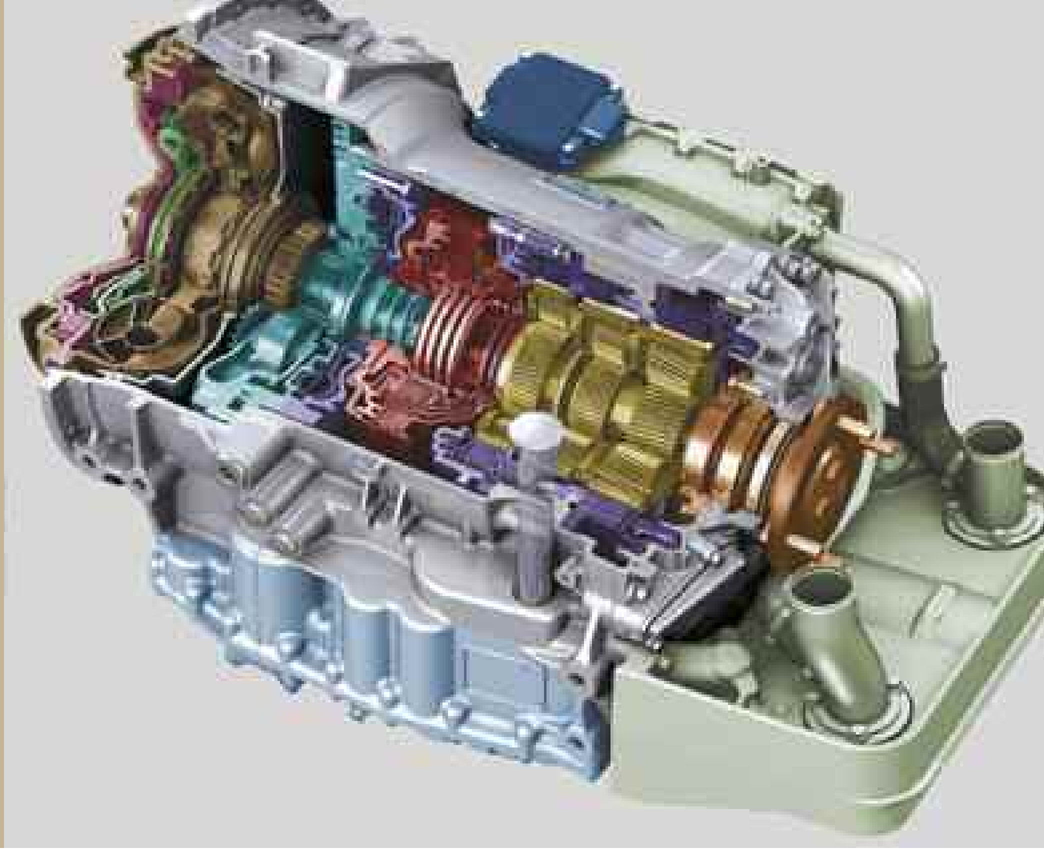
Fuel Economy and the Modern Bus Transmission

Photos courtesy of ZF



As the price of diesel fuel increases, more and more effort has gone into fuel economy. ZF is a leader in improving fuel economy in both transit buses and over-the-road coaches. Shown here is a cutaway view of the ZF EcoLife transmission.

Fuel Economy and the Modern Bus Transmission

In the not so distant past, fuel economy was seldom discussed in the North American bus market. Fifteen years ago diesel prices were around $1 per gallon, and operators were not ready to think, or care, about optimizing bus systems for fuel economy. Powertrain suppliers optimized their systems for power, because that is what the customer wanted.

Fast forward to today, where fuel is hovering around $4 a gallon in the U.S. ($5 a gallon in Canada), and it is a completely different story. Customers and manufacturers are more concerned with fuel economy and efficiency than ever before. This article will focus on what the major transmission manufacturers are doing today to improve the efficiency of their products and the vehicle as a whole. With these improvements, along with systems like electric cooling fans, conventional diesel powertrains are coming close to matching the same fuel economy numbers as much more expensive hybrid systems. This type of performance was once considered impossible.

Before we begin to discuss the technology behind improving the modern transmission, we should point out a few things regarding fuel economy in general. When one starts to compare one vehicle to another, or one vehicle system to another in the area of fuel economy, it is crucial to limit the amount of variables between the two. For instance, EPA emissions level, tire pressure, tire condition, wheel alignment, weather conditions, axle ratio, topography, driving style, A/C operation, amongst a host of other variables will all affect the fuel economy results of any given test. Idle times, maintenance practices and driver habits can affect the fuel economy of a vehicle or fleet just as much as any individual system on the vehicle. For instance, it has been found that each MPH over 55 mph can increase fuel consumption by approximately 0.1 mpg. In an over the road coach, this means just by dropping your speed from 72 to 65 mph could win you 1 mpg, or as much as a 15 percent gain in fuel economy.

Let us now focus on just one vehicle system, and discuss what transmission manufacturers have been doing to try and pull every ounce of efficiency out of the modern bus. In the North American bus and coach market today, the most popular transmission type is the torque converter equipped automatic behind a conventional "clean diesel" engine. Unfortunately in regards to fuel economy, it is this torque converter which is responsible for the highest efficiency loss in the transmission system.

Power flow from the engine to the wheels is conveyed via fluid shearing against a finned turbine wheel, which is attached to the transmission input shaft. The transmission input shaft never truly turns 1:1 with engine speed based on this fluid coupling alone, which can account for as much as a 30 percent loss in mechanical efficiency. Transmission manufacturers have focused on dealing with this issue in two main ways – adding lockup clutches to the converter, and developing some kind of "neutral during stop" feature.

Lockup Torque Converters

One way converter inefficiency is attacked is by placing a set of clutches within the torque converter which, when activated, physically locks the transmission input shaft to the engine crankshaft. The end result is that all the torque produced by the engine is transferred directly to the input shaft. With a converter lockup clutch, transmission manufacturers today strive to "lock" the converter as soon as possible to maximize fuel efficiency.

However, the downside to locking up the converter at low engine speeds and under high loads is that it can cause torsional vibrations from the engine to be transferred directly to the transmission and driveline. If left unchecked, this could at the least cause discomfort to passengers, and at the worst damage to the transmission and other drivetrain components. In order to deal with this phenomenon, transmission manufactures have added torsional dampers to the lockup clutches in their converters. The end result of adding these features, along with modern electronic controls, allows some manufacturers to lockup the converter in first gear. In the competition for achieving the best possible fuel economy, whoever locks up the converter first, wins.

AIS/RELS/ANS

The efficiency loss from the torque converter is at the highest when the engine is forced to idle while the vehicle is stopped and the transmission is in gear. In this situation, the engine must add fuel to maintain idle speed against the stationary turbine and input shaft. However, when the transmission is in neutral, the input shaft and turbine are able to spin freely, thus reducing the load on the engine by as much as 30 percent. To deal with this major inefficiency transmission manufacturers have come up with creative ways to mimic neutral behavior when the vehicle comes to a stop or sits in gear at idle speed. Whether it is called Automatic Idle Shift, Reduced Engine Load at Stop or Automatic Neutral at Stop, each of these features work based on the same general principle. The transmission is automatically and seamlessly placed into a pseudo-neutral position during a stop, allowing the input shaft and converter to turn freely with reduced load.

This is not a new idea. Some manufacturers have been using and developing features like this for 20 years or so. What is new is that some manufacturers take this a step further and actually decouple the input shaft from the rest of the transmission prior to the stop. This reduces the load on the engine for a longer period of time during each stop. Transmission manufacturers claim these features alone, depending on the amount of stops in the duty cycle, can add as much as five percent to fuel economy figures. This is not surprising when you consider that bus idle time in most large cities is around 50 percent of the duty cycle.

One way of increasing fuel economy in transmissions is by using a locking clutch to eliminate the loss of mechanical efficiency caused by the internal fluid coupling. Another way is to simulate being in neutral while standing still in gear. Shown here is a cutaway of the ZF Ecolife torque converter, including lockup clutch with a torsional damper.

Intelligent Pressure Management

Parasitic loss is another enemy when it comes to fuel economy. Unfortunately for powershift transmissions, they rely on fluid pressure to operate, which is provided by an engine driven pump. This pump takes a certain amount of torque to turn. With today's powerful transmission control units, modern transmissions can now vary the pump pressure to reduce this parasitic loss. This is normally done under low load conditions when full pressure is not required to keep the clutches closed.

Topodyn/LBSS/Sensotop/Acceleration Management

When the goal is to achieve the best fuel economy out of a vehicle, one must find a way to operate the engine in its most efficient rpm and load range for the majority of the duty cycle. This is typically a very narrow rpm band, low in the rpm range of the engine. Therefore, a transmission manufacturer aiming for this fuel economy "sweet spot" will target shifting at the lowest and narrowest engine rpm possible. This is partly achieved by designing into the gearbox as many gears as practical (typically six for today's transit buses, but as high as nine for the modern passenger car automatic).

However, just as much thought is now put into the software controlling the transmission shift points as there is into its mechanical design. A narrow, low rpm shift strategy does come at the sacrifice of acceleration performance. So, one must ask themselves, how serious am I about saving fuel and money? What type of sacrifices am I willing to make? What if I have hilly terrain in my region, and I need high power to maintain my route times and compete with cars for merging into traffic? Modern transmissions have come up with a solution for these issues.

First, the following has all been made possible by the marvel of computer networking. Today, nearly every computer system on board a vehicle can "talk" to every other system in real time. This allows the transmission to monitor and sometimes control engine performance. The result is that the modern transmission has the ability to limit vehicle acceleration by limiting the torque produced by the engine. With this, transmission manufacturers are working with OEMs and fleet customers to "dial in" the lowest acceleration rate the customers will accept.

Sometimes the acceptable rate is APTA White Book recommended levels, but some fleets have elected to go even lower. The point here is, the lower the acceleration rate, the lower the engine rpm's, and the lowest amount of fuel is consumed to achieve the goal of moving people from place to place. Once this lowest acceptable rate is found, it is up to the transmission control unit to calculate and maintain this rate, no matter what topography the vehicle encounters, how the driver tries to drive, or how many people are on board. Each manufacturer has their own name for it (SensoTop, Load Based Shift Scheduling or Topodyn), but all do essentially the same thing. Each tries to measure or calculate the percent grade the vehicle is on and how much the vehicle weighs. It takes this information, and only releases enough power from the engine to maintain the minimum acceleration accepted by the fleet. Each manufacturer has been perfecting their strategy over many years now, and

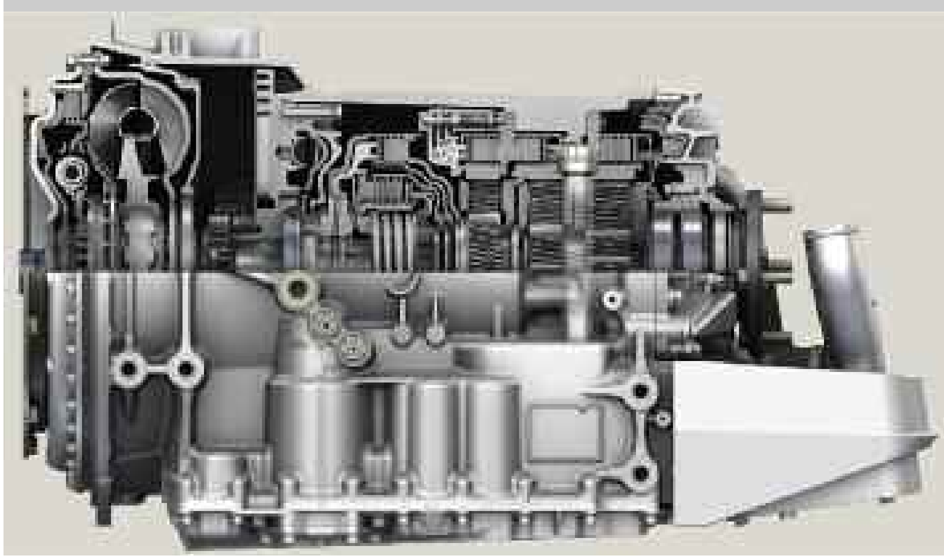
AIS While Driving allows the ZF transmission to go into neutral before a vehicle comes to a stop. With this feature, ZF EcoLife is able to gain approximately seven seconds of additional AIS per stop. This is an approximate fuel savings of one gallon for 850 stops

field results have proven this type of operation has gained 10, 15, even 20 percent better fuel economy over previous transmission shifting strategies.

It should be noted that a customer's preference for an acceleration rate is not always the limiting factor when lowering shift speeds. Even though it is generally true that lowering the rpm of an engine will reduce its fuel consumption, it can also increase the amount of harmful emissions generated. Due to this, transmission manufacturers now have to certify their shifting strategies with some engine OEMs to ensure the transmission shift strategy does not affect the engine's emissions compliance or affect its reliability.

In conclusion, no matter what transmission or vehicle OEM preference you have, if you are interested at all in saving fuel and money make sure your next vehicle includes the discussed fuel saving features. History has shown us that fuel prices will only go up, so the question to you is this: How serious are you about saving money? How low can you go? ❑

As time goes on, the transmission manufacturers are finding that the software controlling the transmissions can be as important as the transmission itself in increasing fuel economy. ZF's Topodyne system computes the actual topography the vehicle is operating on, and adjusts the shift strategy accordingly to maximize fuel economy.



Shown here is a partial cutaway view of the ZF EcoLife transmission. By using state-of-the-art manufacturing technology combined with computer programs, modern diesel buses have overtaken the old hybrid systems in providing fuel economy. With the price of diesel fuel so much higher today than years ago, this can only be good thing for bus operators and our environment.

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