

## Semi-auto gearshift

### Solenoid Vs. compressed air & open-loop Vs. closed-loop.

In recent months we've noticed that there are an increasing number of so-called paddle shift systems on the market, all of them claiming to be better than the rest. Many of the suppliers are making claims that are, at best, dubious, and in some cases patently untrue. Almost all of these systems are based on electric solenoids, which are operated by unintelligent 'open-loop' controllers. Their basic argument is that operating the shift lever using an electric solenoid is better than compressed air actuators and that simple systems are better and more reliable. We at Geartronics obviously disagree. We often get asked how our system compares with electric solenoid based systems – well, the fact is that there is no comparison whatsoever. It's like comparing a Château Lafite with a bottle of cheap Tesco's plonk – they are both wines, but that's where the similarity ends!

Of course, don't just take our word for it, do some research on the 'net and ask your fellow competitors what their experiences have been of the various systems that are available. If you've taken the time to read this document, you will at least be in a better position to ask some important questions before handing over your hard-earned cash.

Here are ten FACTS to get you started...

*1. A gearshift takes a variable length of time to complete.* This remains true regardless of vehicle type or the method of actuation, be it manual, solenoid, hydraulic or pneumatic. The shift time is influenced more by engine characteristics and track conditions than by gearbox type or method of actuation. When asked how long the Geartronics system takes to change gear, we simply reply "as long as it takes!"

**Always remember the above, it is crucially important!**

*2. Different gearboxes require differing forces to operate them.* As a general rule, motorcycle gearboxes require less force to operate than car gearboxes. Once manufactured, the force produced by a 12v electric solenoid cannot easily be altered without sophisticated power control techniques. To provide sufficient force to operate a car gearbox, a solenoid needs to be so large that it would weigh several kilograms and draw a massive amount of electrical current.

*3. Pneumatic (compressed air) systems are NOT unreliable.* This is one reason why pneumatic systems are used in industrial applications that operate 24 hours a day, 7 days a week. The duty cycle of a semi-auto shift system is considerably less than an industrial application and reliability is not an issue. Claims of unreliability are regularly made by some of our competitors without them citing any examples, and they expect you to believe them.

4. A 12v air compressor does not sap any measurable power from the engine as some of our competitors incorrectly claim. The Geartronics compressor draws approximately 13 Amps (intermittently) from the vehicle electrical system. This equates to approximately 180 watts, in other words, less than one quarter of one horsepower! This is clearly insignificant and it's wholly misleading to claim otherwise.

5. 12v electric solenoids consist of a large coil of copper wire wound around a moving armature, usually made of iron. To provide sufficient force, the coil of wire needs to be very large and consequently the solenoid becomes bulky and heavy. In electronic terminology, a solenoid is what is referred to as an 'inductive load'. This means that the initial current draw (the inrush current) from the electrical supply is extremely high and places extreme stress on the vehicle electrical system unless the GCU has some form of energy storage. Not only that, but high inductive loads can cause electromagnetic interference (think of ignition coils, only much bigger) and voltage drop-outs that can cause sensitive electronic systems on the vehicle to malfunction.

6. Despite many years of top-level gearshift development in professional motorsport, we know of only one solenoid based shift system used by an entire grid in a global race series. This being the highly respected ZYTEK Motorsport system (as used in A1GP, Formula Nippon & LMP sportscars etc.) The ZYTEK system uses high voltage solenoids and a highly sophisticated gearbox control unit (GCU), and can in no way be compared with the current crop of 'cheap' solenoid based systems. All other 'professional' systems use either pneumatic or hydraulic actuation. Ask yourself why? Just as an aside, one very well known UK vendor of solenoid shifters attempted to sue ZYTEK over a claimed patent infringement – needless to say they didn't get very far, as their system bears no resemblance to the ZYTEK unit other than the fact that it uses a solenoid.

7. At least one manufacturer claims that their system has protection strategies to prevent gearbox damage and engine over-revs. The fact is that it's impossible to have such a protection strategy if the electronic controller does not measure the gear position or the engine speed. With the exception of the aforementioned ZYTEK system, we do not know of any other solenoid system that measures the gearbox barrel position and engine RPM. If you know otherwise, please let us know.

8. There is far more to reliable downshifting than simply blipping the throttle and pushing the shift lever! For example, what happens if a driver requests a part-throttle or full-throttle downshift? Most of the solenoid systems that offer a downshift 'auto-blipper' use a simple diaphragm device that is powered by engine vacuum. On the face of it, this seems like a good idea, but remember that a race engine will usually have separate throttle bodies for each cylinder, and also the available vacuum will be virtually zero because of the need to keep the throttles open to maintain the engine idle. Also, at low engine speed, the engine vacuum will be even less – just when you need more throttle blip! So in actual fact, a diaphragm blipper is a total disaster on a race engine.

9. Paddleshift is faster than manual shift, but not by much. We have read one claim that a particular solenoid shift system resulted in a saving of “over 1/5 of a second per shift”. First of all, any decent driver using a manual stick will be easily capable of performing a shift in *less* than 1/5 of a second (200ms) to start with. In our experience, a typical semi-auto upshift will take between 40 and 100ms to complete (see point 1). Even if this represented a saving of 50ms over a manual shift (which is pretty optimistic), this doesn’t correspond to a reduction in lap time of 50ms. The only reduction in lap time comes from the extra 50ms of acceleration during each shift, so during a typical lap consisting of perhaps 20 upshifts, the vehicle will be accelerating for 1 second longer than the same vehicle with manual shift. Unless you have an extremely high performance car (e.g. F1) there are only marginal ‘straight line’ gains to be made.

10. Electric solenoid actuators are not inherently kind to the gearbox and do not provide natural compliance as is often claimed. On the contrary, electric solenoid shifters have often been described as “vicious” or “brutal”. At the end of the stroke, the heavy armature will be travelling at such speed that its momentum will impose a high shock loading on the selector mechanism as it slams against the stops in the gearbox. If the armature is stopped short of the full travel of the shift lever, there is a risk that the momentum of the selector barrel will cause the gearbox to skip a gear. This is because at the very end of the selector travel, there is usually an internal blocking mechanism that prevents the barrel from over-travelling. By contrast, a pneumatic actuator DOES offer compliance because the compressed air acts as a shock absorber.

So, back to point 1. *This is the big one!* Regardless of the method of actuation, every gearshift (up and down) takes a varying length of time to execute. We can show you high-resolution data logging to demonstrate this if you remain unconvinced. Lets first look at upshifts, mainly because they are easier to understand than downshifts.

When we initiate the shift, we operate the actuator and cut the engine power to remove the torque from the gearbox to allow the dogs to disengage. At first, nothing happens, and the barrel and selector fork don’t move beyond their ‘free play’. This is because of a phenomenon known as ‘transmission wind-up’, and is caused by the minute twisting of the shafts in the transmission and the flexing of the tyre sidewalls. This wind-up effectively stores energy in the transmission and prevents the dogs from disengaging until the energy has dissipated. It’s not too difficult to understand that the degree of wind-up changes with varying conditions. Factors such as engine torque, gear ratios, track grip, wheel-slip etc. all factor into the equation, and it becomes impossible to predict the time it will take for the energy to dissipate and hence the shift to execute. What you might not appreciate is the variation between the fastest & slowest shifts. On the same car, in the same gear, we have seen variations in shift times of more than 200ms!

So what happens if we use a fixed duration engine cut, as is the case with the majority of the ‘cheap’ solenoid shift systems? Sure, you can cut the engine for long enough so that the shift is always successful, but then what if the shift completes in only half the cut time? We are then into the situation where the

car is mechanically in the next gear but the engine is still turned off. Remember that the throttle is wide open at this point and under these circumstances the engine simply becomes a compressor and works as a very effective brake. The momentum of the car is then driving the engine, and the gearbox is transmitting *negative* torque, which suddenly slows the car.

This can lead to loss of grip and vehicle instability, contrary to the claims that are made on some of our competitor's websites. When the engine power is eventually resumed, there is a sudden shunting of the transmission as the torque reverses, and the shift is often very aggressive as a result. So instead of saving time, the total shift event has actually *lost* track time and potentially led to a loss of control.

You might think that the way to overcome this problem is to reduce the engine cut time. This is definitely not the correct thing to do, and you risk serious gearbox damage if you go too far. If the cut time is reduced too much, the currently selected gear will never disengage because the transmission has not been given sufficient time to un-wind. When the driver calls for a gear, he/she will feel the engine cut, but there will be no gearshift. Frustrating, but not usually damaging. However, there is a much more serious scenario – imagine the situation where the engine cut is just long enough to disengage the current gear but not sufficiently long enough to allow the next gear to engage. Remember that the throttle is wide open at this point, and as the engine is turned back on there is no drive to the wheels, so the engine RPM rapidly increases to the rev-limiter (if there is one). Depending upon its design, the gearbox may either try to drop back to the previous gear or carry on to the intended gear. The extreme speed mismatch between the slowing dog ring and the accelerating gear causes a failed shift and also severe gearbox damage as the dogs rapidly skip across each other and fail to engage.

So what *is* the solution? The *only* way to ensure that a gear shift is successful, but without cutting the engine for too long, is to monitor the position of the gearbox selector barrel and cut the engine for exactly the right duration for every shift. This constant monitoring of the barrel position is referred to as “closed-loop” operation. By resuming engine power exactly as the next gear engages, we get the fastest and smoothest shifts possible. Closed-loop operation eliminates any chance of dog damage because the engine is never turned back on prematurely.

Downshifts are even more complex than upshifts and the potential for gearbox damage is even greater. We can't divulge specific details of our downshift strategy because it would give the game away. Suffice to say, it's far more complicated than simply pushing the lever and blipping the throttle.

The importance of closed-loop operation cannot be overstressed. To determine if a paddleshift system uses open-loop or closed-loop operation, simply ask the vendor if their system connects to the barrel position sensor or a linear position sensor on the gear lever. If it doesn't, then it's not closed-loop and you run the risk of seriously damaging your gearbox!

One final thing to bear in mind when making the choice between the various systems on offer is the means by which the system is set up and adjusted. Ask the vendor if setup software is supplied with the system. You might be

surprised to learn that most systems don't even have any setup software! One solenoid-based system we are aware of is imprecisely adjusted by a set of screws on the side of the box, another one by a set of 3 switches. This in itself should give you a clue as to the sophistication of the system on offer. If you read claims that a system will "work perfectly straight out of the box", then be very sceptical. The Geartronics setup software has more than 60 user-defined parameters, and they're not there just to keep our software engineers busy!

As we mentioned at the beginning of this document, do some research before handing over any cash. There is a wealth of information already in existence on numerous web forums. Do a Google search on the system you are thinking of buying and use words such as "problem", "fault", "reliability" & "unreliable" in your search criteria – you might be surprised at what you find! When you've finished researching our competitors, search the forums for Geartronics and see what the motorsport world has to say about us...