THE EXPERT
STEWART SANDERSON

Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

A Level 5-trained fuel-injection technician, Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Eight years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, www.remapping.co.uk), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He is the creator and administrator of www.passionford.com, which he started in 2003. It has grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and importantly how they can be improved.

Words: Stewart Sanderson and Will Pedley

PART 2

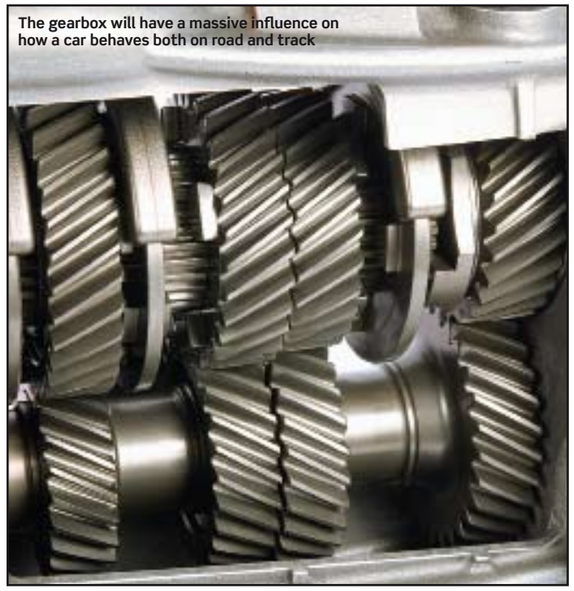
ROAD TO RACE CAR

IF YOU'VE GOT YOUR ENGINE UP TO RACE SPEC, YOU NEED TO GET THAT POWER DOWN. SO THIS MONTH WE'RE LOOKING AT TRANSMISSION.

Last month we looked at what you need to do to transform a run of the mill road car's engine into something that will survive regular track abuse. Now we need to concentrate on modifying the transmission for the same purpose.

Since in most cases you can't actually modify transmission components and have to search out uprated components with fancy features instead, this will serve more as a shopping guide to transmission components.

So, how are you going to transmit your race-spec power to the wheels? Whether your car is fwd, rwd or awd/4wd, read on and look at the options...



The gearbox will have a massive influence on how a car behaves both on road and track

GEARBOX (FWD, RWD, 4WD)

Standard factory gearboxes are designed to cope with the factory engine's torque outputs. The gear ratios are a compromise between acceleration, performance and fuel economy for cruising at constant speeds. Most gearboxes are fitted with a synchromesh that allows for smooth gear changes with no skill or special driving style needed. However, if the car is being driven hard on track, the synchromesh will restrict the speed of the gear change, and when damaged will make it hard to engage gears cleanly or even at all.

There are a number of options to change gear ratios and final drives to adjust your in-gear speeds. For example, a rally car may only want 20mph increments through each gear with a low top speed but in a road car that would mean you were constantly having to change gear and your engine would be screaming up near its redline in top gear on the motorway.

It is sometimes possible to interchange gear ratios and final drives from other gearboxes from within the same manufacturer's range. Alternatively, aftermarket kits are available for many applications.

Once you have decided which gear ratios are most appropriate for your application, you need to establish which style of gear is best suited for your needs. Gears can either be cut helically, semi-helically or straight (also known as spur gears).

ENGAGEMENT

We've got our gear ratio and we know how we want the teeth, so how do we want the gears to engage? There are two options: synchromesh engagement and dog engagement. Now, as we've mentioned the synchromesh provides smooth operation on the road but can become a hindrance on track. Dog engagement allows you to engage a new gear at any engine speed; on shifting it literally grabs the next gear allowing for 'flat shifting'.

Flat shifting is when full release of the throttle and full engagement of the clutch are not required to change gear, only a slight lift on the throttle is needed to release the loading in the gearbox and allow the shift to complete. This makes for very fast gear changes on the track but does require careful engine speed matching by the driver to drive smoothly on the road.

Finally, we need to look at whether the gearbox will be operated sequentially or with a H-pattern gearstick. Factory cars tend to run a H-pattern set-up and this is by far the cheapest set-up for your new gearbox.

A sequential set-up means you have a gearstick that only moves forward and back; you pull back to go up the gearbox and push forwards to go down. The shifter movement rotates a drum by a set number of degrees, which in turn selects the desired gear, this makes for lightning quick changes and means there is no risk of 'stirring the box' and selecting first instead of third when changing down from fourth. With a sequential shifter you have to go through the gears in order.

Synchromesh engagement offers smooth gear changes, but restricts the shifting speed

Sequential 'boxes use a rotating drum with a keyway to select the appropriate gear

TOOTH DESIGN

Helical: Generally found in standard gearboxes. The teeth run diagonally across the gear. They are strong and very quiet in operation. In fact a helical cut gear is stronger than a straight cut gear of the same width and tooth profile because there is more contact area available to spread the load. Also, as helical gears rotate there will usually be two or three teeth in mesh with their opposing pairs, whereas with straight cut gears there is only one tooth in mesh with its pair at any one time.

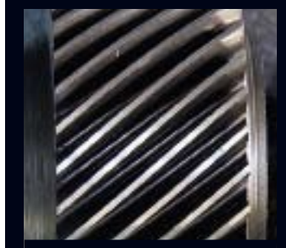
The major downside of helical cut gears is that because of the diagonal engagement, they create a side load that is transmitted into the bearings at the end of the shafts inside the gearbox. This can and does accelerate wear, especially in high power applications.

Semi-helical: Some replacement gear sets are still helical cut, but the angle of the teeth is less than that of the standard gears. These are often referred to as 'semi-helical' gears.

These are slightly noisier, often slightly stronger because the tooth pattern allows for a stronger tooth profile, and reduce the side load mentioned before.

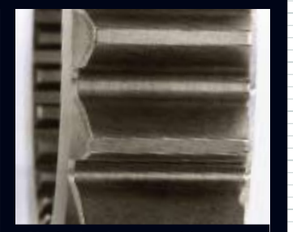
Straight cut: Straight cut gears are often considered the strongest of all gear types, but as we have discussed earlier this is not necessarily true. Most straight cut gear sets use a very chunky tooth profile which helps increase its strength, but the main advantage is they create much less side load on the bearings and dramatically reduce transmission losses.

However, these gearboxes do create a loud whining noise that increases with engine speed, which is the main reason they aren't often used in road cars.



Helical: used in most standard production gearboxes

Semi-helical: usually have larger tooth profile and less aggressive angle than helical gears



Straight cut: reserved for race cars as they're noisy and offer least transmission losses

FRONT AND REAR DIFF (FWD, RWD, AWD)

The front and rear differentials on virtually all factory vehicles are there to transmit the engine power to the wheels and allow the wheels to rotate at different speeds while cornering. The differential can also be used to change the final rotational speeds out of the gearbox to the driven wheels. This can mean that a change of crown wheel and pinion can alter the acceleration and/or top speed properties of your vehicle.

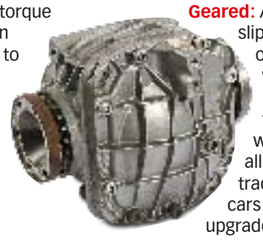
There are a number of differential options available. The most commonly found on standard cars is an open differential. An open differential applies the same amount of torque to each wheel and allows independent wheel speeds when cornering.

The next step is to look at a limited-slip differential (LSD). These come in two main forms: plated and geared. LSDs normally operate through torque sensing and when one wheel starts to lose traction, the difference in torque causes gear or plate engagement within the differential.

Geared diffs like the ATB use worm gears to transfer torque

Plated diffs use a series of plates to create friction to keep both wheels turning at the same speed

Viscous diffs use a thick fluid to resist the amount of wheel slip



Geared: A geared limited-slip diff uses helical or 'worm' gears which rotate and 'bite' to direct torque as and where required. This allows for maximum traction from 2wd cars and makes a good upgrade for awd car centre differentials.

Plated: These use a series of thin plates connected to a carrier. Depending on the way they engage, they are referred to as 1, 1.5 and 2-way. A 1-way differential will only engage on acceleration, behaving like an open differential under deceleration. A 2-way differential will engage on both acceleration and deceleration making it prone to oversteer on lift off, making it a favourite amongst drifters. A 1.5-way differential engages on acceleration and semi-engages on deceleration.

TRANSFER BOX (AWD)

This is found in awd cars to link the back wheels to the front wheels and transfer torque if one set of wheels is found to be spinning. The most common type of differential for this is the viscous coupling diff, which has two sets of plates rotating in thick fluid within a sealed unit. This allows plate speeds to vary depending on traction and will constantly try to match their speed by transferring additional torque to the set of plates rotating the slowest. Because of the nature of its operation, the viscous coupling tends to cause quite high transmission losses. Alternatively, a geared differential is the other type commonly found or used as an upgrade.

VISCOUS

Found in a number of vehicles as standard and give open differential style behaviour until one driven wheel experiences more traction. Viscous differentials work through hydrodynamic friction using dilatant fluid, which thickens when subjected to a shear force. Operating through a series of perforated plates inside a cylinder, half of the plates are connected to a driveshaft, the other to the differential carrier.

When the two sets of plates are rotating in unison, the fluid stays cool and remains liquid. When the plates start rotating at different speeds, the shear effect of the tabs or perforations on the fluid will cause it to heat, thickening the fluid to engage the differential.

This shear effect is normally generated when a speed difference occurs between the two driven wheels either through cornering of different traction levels depending on the road surface. Viscous differentials can be modified professionally by changing the fluid and the operating pressure to adjust the engagement behaviour.

"TO REDUCE WEIGHT AND MANUFACTURING COSTS A NUMBER OF MANUFACTURERS PRODUCE HOLLOW DRIVESHAFTS."

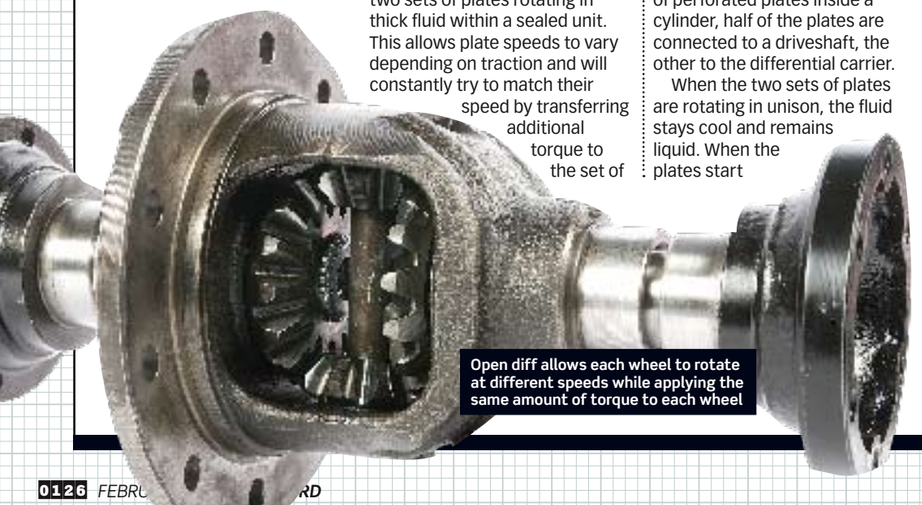
One other differential that is worth mentioning is a spool diff. This is found primarily in rallying, but sometimes in drifting. It allows no difference in speed and is the equivalent of having a solid axle! It is certainly not recommended for road use but is an excellent option for drag racers.

ACTIVE DIFFERENTIALS

Certain vehicles have ECU-controlled differentials that use a system of fluid pumps and solenoids to control fluid flow. The fluid is pressurised and used to load the differential to change its behaviour. With no pressure the differential acts as an open diff, with full pressure applied, the differential acts as a spool diff. This creates variable pre-load, which means that when under pressure additional torque is required to change the torque transfer through the centre diff.

With an active centre differential an ECU is used to control this loading using inputs from wheel speed sensors, throttle position, brake pedal position, lateral and longitudinal G force sensors. Aftermarket active centre differential controllers are available to custom profiles created to suit your own driving style.

These aftermarket controllers can also utilise user-switchable maps that allow for different behaviour under certain conditions. For example when launching and the handbrake is being used or when the footbrake is being used etc.



Open diff allows each wheel to rotate at different speeds while applying the same amount of torque to each wheel

CLUTCH

So, we've found our additional power from the engine and we've decided what transmission we need. Now we need to join one to the other. Your clutch is the device to do just that and there is a wide range of options available.

First we need to look at what kind of use the vehicle will be subjected to. Drag cars for example subject the clutch to a horrendous amount of abuse when performing a burnout followed by slipping during staging and finally a full bore launch. If the vehicle is only going to be used for circuit racing from a rolling start with clutched gearchanges, then things are a little more forgiving!

The materials for the clutch drive plates come in three main forms: organic, cerametallic and carbon.

Organic plates: These are made from the same material as most factory production vehicles and normally feature a solid ring of material. They provide very smooth, progressive engagement and are pleasant to drive on the road. However, they have quite low torque handling capabilities and do not stand up well to repeated hard launches.

Cerametallic: Made of a compound formed from a combination of ceramic and metal, these are normally formed into four or six blocks referred to as 'paddles' or 'pucks'. They are aggressive in engagement and not suited to refined road use, however, they can handle launches and competition use without excessive wear.

Carbon: The ultimate option to consider as they offer smooth, progressive engagement and outstanding heat handling, which means they can be repeatedly launched without problem.

Multi-plate clutches spread the torque load over more than one clutch plate, making them suitable for high-power applications

Depending on the torque output of the engine, a single friction plate may not be sufficient, at which point we need to go for two friction plates and join them together with a driven plate. The driven plate is normally made from steel and 'floats' up and down between the two plates inside the clutch assembly.

The clutch cover is our next consideration. If there is insufficient cover pressure, the clutch plate is likely to slip at peak torque. As we select clutch covers to handle our engine's torque, we tend to find that the higher the torque handling, the stiffer the cover springs become. The clutch pedal becomes stiffer and heavier to operate, even more so in the case of vehicles running a cable clutch. We can overcome this in some cases by fitting a centre push hydraulic release bearing. This operates the tip of the cover fingers, giving maximum output from pedal input.

Heavy duty organic clutches are ideal for Fast Road, but won't last long with heavy track abuse

Paddle or cermetallic clutches can handle increased torque but aren't suited to constant road use

DRIVESHAFTS

In our final quest to get our new-found power to the wheels, we need to address the link from the gearbox/differential to the wheel itself. This comes in the form of a driveshaft and depending on your intended use, you need to consider upgrades.

To reduce weight and manufacturing costs a number of manufacturers produce hollow driveshafts. As the resistance to torsional force (twisting effect) is mainly performed in the outside diameter of the shaft, there is no need to have 'spare' material in the middle. This is fine for a standard vehicle with standard power, but not for race cars.

To increase the strength we need solid driveshafts, preferably ones that have been subjected to heat treatment processes to further increase their resistance to stress raisers – cracks or surface defects that are liable to lead to failure.

TRANSMISSION LUBRICATION

The lubrication system of your standard components is fine for light competition use but as the severity increases, the lubrication system needs upgrading to suit. As a minimum, the transmission oils need changing more regularly and potentially with a more competition style oil.

There are specific lubricants on the market tailored for different styles of competition use. Their additives and construction offer well-needed protection for less than double the price of the standard fluids.

If the vehicle is going to be used hard for prolonged periods of time then it might be worth fitting transmission coolers. These operate in a very similar way to the engine oil coolers we discussed last month. However, as there is no pressure in either the gearbox or differential, a pump will need to be installed to circulate the oil through the cooler and back.

CONCLUSION

With all of the components we've discussed, please bear in mind that it is worth doing some investigating before you start spending your money.

See if there is a racing series that uses your kind of car, look at what those guys have upgraded and what they have left standard. It is very easy to get out the Visa and start spending all your hard earned money on very exotic, but totally unnecessary transmission parts when in reality the standard item was more than up to the job. Spend wisely, spend once.