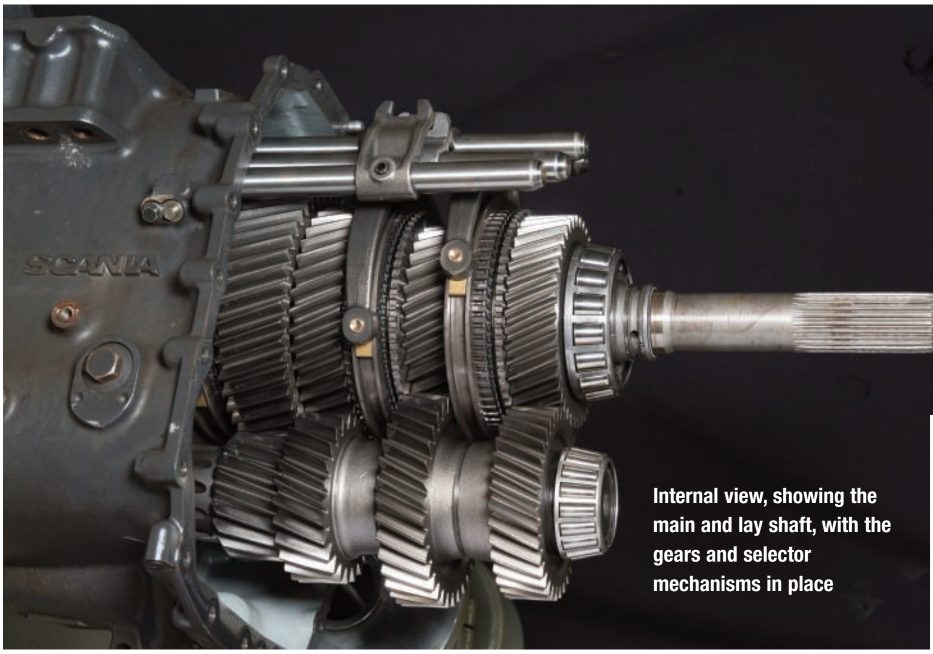
SHIFTING GEAR

In this second of our two-part series on automated manual transmissions, Brian Tinham talks again to Scania technical instructor Keith Gallon about gearbox construction and operation, and modern fuel-saving shift strategies



Internal view, showing the main and lay shaft, with the gears and selector mechanisms in place

Last month, we covered troubleshooting on modern AMTs (automated manual transmissions), and how understanding power paths, shift mechanisms, etc, is crucial for matching fault symptoms to diagnosis and delivering the correct, most cost-effective and speedy repairs. Here we move on to gearbox construction, looking at the detail of transmission shafts and gears, their splitter, range and overdrive mechanisms, gear shifting, synchromesh and the automatic clutch assembly. We also provide an update on modern transmission fuel-saving shift strategies, and the role and purpose of advanced gear control modes.

Taking it from the top, hopefully we all know that even 16-speed gearboxes rarely have more than three main drive gears – the numbers being made up with dual ranges (doubling to six) and splits (doubled again to 12, including overdrive), plus potentially crawler (low and high) and then reverse (low and high). If the gearbox does not have a splitter (for example, a standard four-over-four with range change), there may still only be three gears, with fourth (and hence also eighth) achieved by mating the input shaft directly to the main shaft for a 1:1 ratio.

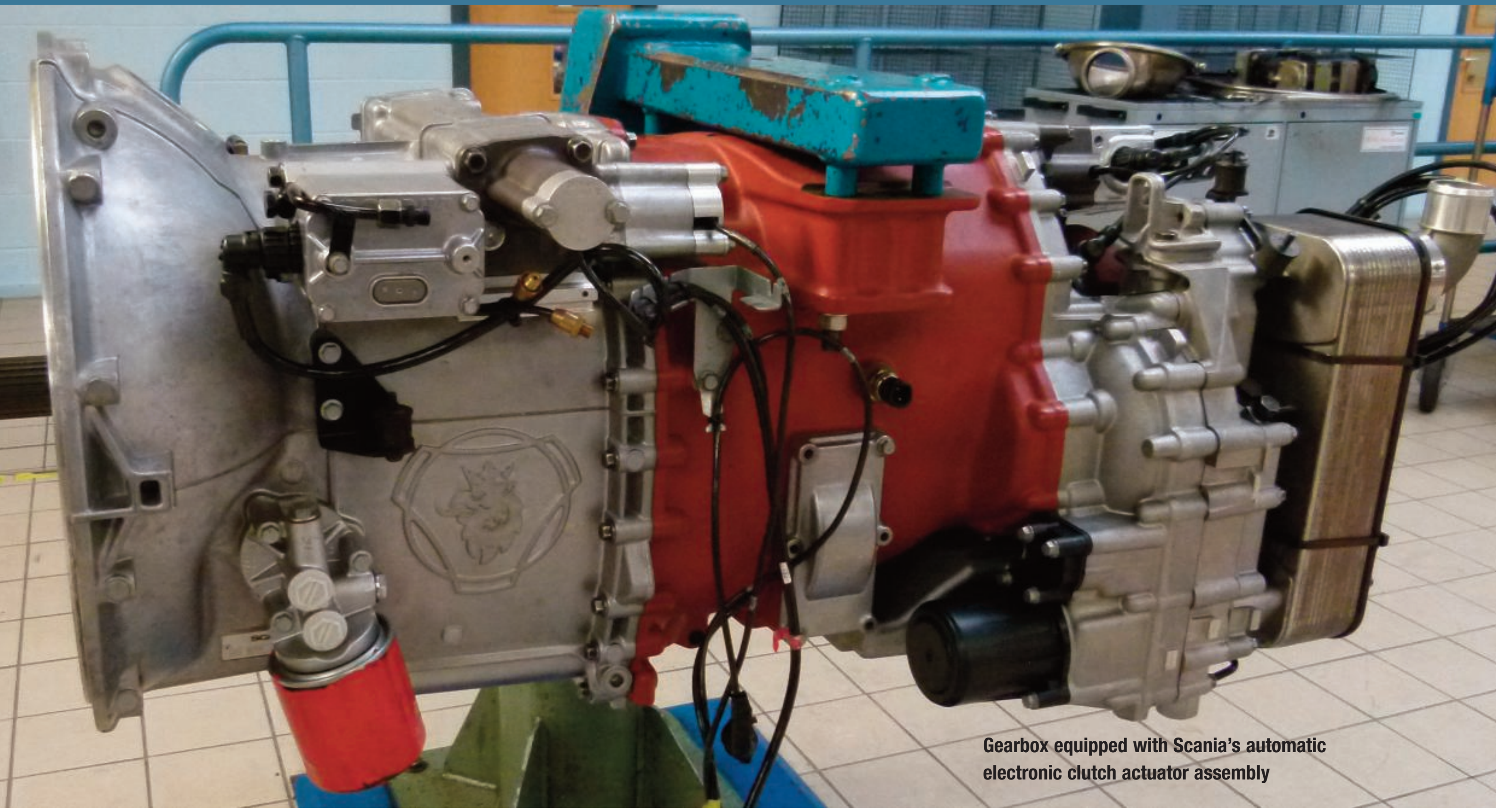
GEAR LAYOUT

Using Scania's GRS 905 as an example, the reverse gear is at the rear of the box, with the largest next gear being crawler. These are followed by first, second and then third at the front, adjacent to the input shaft. The splitter and range shift (planetary gears) are also at the back of the box.

There are three gear selector rods. One selects between crawler, neutral and reverse, running longitudinally, forward and back, on the right of the box. First forward gear is on its own selector in the centre. Then second and third gears are engaged via the left-hand selector, which, again, moves longitudinally: forward for the shift sleeve (splined to the main shaft) to engage second, via its baulk ring and synchro cone; and, similarly, back for third. Note that recent gearboxes generally use triple synchromesh on first, double on second and single synchro on third, where engine and gear speeds are more easily matched, either manually or automatically under GMS (gearbox management system) control.

Finally, there is the large range-changer piston and a smaller rod for the splitter, both of which link to the gear mechanisms at the back of the box. Range change is forward for high (which mates to the high-range synchro cone for one-to-one rotation) and back for low range. For the latter, the shift mechanism locks the rear torque plate on to the back output shaft ring, so engaging the sun gear (splined to the main shaft), with its surrounding planet gears – and generating a 3.75:1 reduction for all the primary gears.

Splitter action is similarly a front (high split) to back (low split), with the former shift operation engaging the gears on the lay shaft so that the power path comes in from the input shaft, along the lay shaft and then onto the main shaft. Note that the lay shaft also provides the power path for overdrive, if present. Note also that the

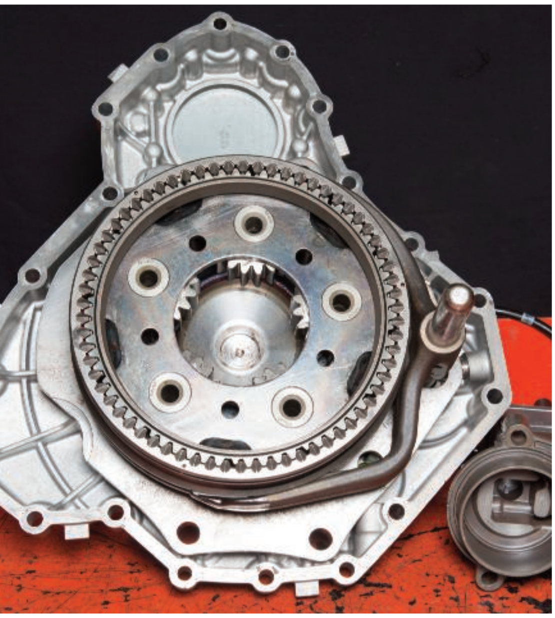


Gearbox equipped with Scania's automatic electronic clutch actuator assembly

lay shaft dips into the transmission fluid pool and throws oil between the gears for extra lubrication. Low drag gearboxes extend that action to reduce gearbox fluid by two or three litres, and hence reduce frictional losses without compromising lubrication.

SELECTOR SEQUENCES

Returning to the selectors, on an AMT they effectively mimic the movements of the familiar 'H' pattern, as used on standard manual gearboxes with their conventional linkages. For an AMT, however, those linkages are replaced by the electronic automation assembly, which on Scania's Opticruise (and most others) is fitted to the top of the gearbox. This provides the motive force and control to mirror the same selector strokes, using solenoid-actuated pneumatic pistons to move the required selectors laterally or longitudinally (under damper control to ease speed matching of the input shaft and lay shaft to the gear selected, via its synchro cone).



You will see the solenoid blocks with their air and wiring connectors, and the side-mounted electrical coil sensors that confirm lateral and longitudinal motion. There are also similar sensors to confirm low and high split, and low and high range. The solenoids are managed by GMS, which causes the pneumatic actuators to stroke and select or deselect gears – and, if the latter, return the box to neutral before triggering the next appropriate gear selection.

Given that first gear is low range, low split and first gear in the gearbox, GMS needs no lateral movement from the selectors but longitudinal motion in the centre, backwards, plus low range and low split – so forward on the rod and piston for both low split and low range. To get second (low range, high split and first gear), the first gear selector remains back but with the splitter rod now pushed back for high split. For third, it needs second gear, low shift and still low range – so lateral left and backwards on the second/third gear selector, plus forward on the low split by firing up the solenoid. And so on.

AUTOMATIC CLUTCH

As for automatic (two-pedal) clutch operation, on most trucks this is electro-pneumatic, but in Scania's case it is electro-hydraulic. That choice gives this assembly an edge in terms of speed and precision of operation. And that, in turn, translates into additional driving flexibility – particularly for low-speed manoeuvres and high-speed gear shifting.

In a little detail, Scania's electronic clutch actuator (ECA) comprises a master cylinder housing an electric servomotor, which spins up a screw under GMS control (using a direct CAN sub-network) at up to 3,500 rpm. This displaces clutch fluid in the slave cylinder and opens the clutch in a controlled manner, via its pushrod and fork assembly, within 0.2 seconds if required.

You will see that the ECA assembly is equipped with two plugs – the main PSU electrical feed and earth, plus the CAN communications port to GMS. The device also has: a hydraulic fluid reservoir level sensor; a Hall effect sensor on the slave cylinder to indicate clutch pushrod movement; and a position (angle) sensor on the master cylinder, giving precise motor position feedback for GMS.

So in operation, the accelerator effectively acts as an indirect 'virtual' clutch, with its position and rate of movement providing a truck acceleration demand signal to Opticruise. When a gear change is triggered, ECA first signals its actual clutch motor and slave pushrod positions, as well as reservoir fluid level (looking for error messages). A control signal from GMS then fires up the 24V dc motor, providing drive currents between 19–20 and 55–60 amps to spin the motor and deliver the required clutch action. That, in turn, increases pressure in the slave cylinder at the requested rate and pops the clutch.


Above: Keith Gallon with the electronic clutch actuator (ECA)
Inset: focus on the ECA itself

As mentioned, the precision afforded by this clutch control mechanism comes into its own when manoeuvring or requiring quick yet comfortable gear shifts, particularly half splits or range changes – for example, from 10th to 12th.

For the former, the electro-hydraulic clutch enables a feathering of power otherwise only achievable through fluid coupling, but while remaining in gear. Meanwhile, for the latter, it enables EMS (the engine management system) to quickly reduce engine torque, enabling gear separation simultaneously with the clutch opening minimally (such that it just skims the cone) as the box drops into neutral. The clutch closes, engine speed syncs to the box and the gear immediately engages – all in a fraction of a second – for resumption of power.

ADVANCED SHIFT STRATEGIES

See *TE*, November 2014, page 10, for an explanation of fully-automatic gear change sequences. When it comes to the logic of gear selection, Opticruise (like all manufacturers' AMTs) watches wheel speed – BMS (brake management system) input – along with tacho and engine speed and vehicle weight, using suspension data. However, Scania's most recent two-pedal version (Opticruise 5) now looks not only at how much the driver demands (accelerator or brake position, as with earlier systems) but also the rate of that demand – how rapidly he or she changes the pedal position. That is defined as the 'target' and it means the driver's boot significantly influences the gearbox strategy and driving style – although the preference is always for fuel saving via low revs and high gears.

So, if we're talking about a tractor unit (with no trailer attached), in 'Drive', starting off in third and making good progress and with conservative driver pressure on the accelerator, the 'Normal Mode' fuel-saving shift strategy means that fourth gear and indeed low range generally are unlikely to be the optimal next selection. Instead, GMS (working in

concert with EMS) may select seventh. That's high range, first gear, low split – centre and back on the selector, and back on the rod for low split.

In operation, GMS signals EMS to ramp off engine torque and ECA to open the clutch, before engaging the electro-pneumatic selector controls to drop the gearbox into neutral. Then, with the clutch re-closed, but engine speed high and the gearbox slow, Opticruise signals EMS to slow the engine using appropriate means (such as exhaust brake), according to operational conditions, to match the speeds. It rechecks the gear selection and then engages and confirms the required gear set.

Looking at fuel-saving shift strategies in more detail, as stated, it's all about moving the vehicle up into higher optimal gears as rapidly as possible, taking into account vehicle speed, inclination, engine revs and weight. That applies regardless of terrain and target, but with subtle, yet important variations managed automatically by GMS, EMS and the driver.

DRIVER INFLUENCE

Again using Opticruise 5 as the example, options such as 'Hill Mode' and 'Kickdown' – which simply instruct GMS to raise the engine rev shift-up trigger from say 1,200 to 1,500 rpm to provide more power (in lieu of torque) – have gone. They are replaced by 'Power Mode', which does a similar job, but with greater sophistication. Effectively, the system now optimises gear selection and engine revs in real time to match target demand in line with the force balance of the truck – but allowing professional drivers to take control where additional power is required.

Scania describes it as the system selecting the highest gear capable of providing the power to accelerate to target. On hill climbing, for instance, GMS senses the weight of the vehicle and the inclinometer angle, so the software knows the force balance. If, on approaching the incline, the driver does nothing other than increase throttle demand, GMS looks at engine speed and, if lower than a threshold, drops down to the highest possible temporary gear calculated as being capable of delivering against target without further frequent downshifts. If, however, the system determines that the engine speed is within limits, it leaves the gear unchanged.

So, if the vehicle is in 12th, encounters a hill and GMS sees the driver gently increasing accelerator range, if the engine speed be too low, it has a choice. It would probably request either 11th gear (high split to low split) or 10th (into second, high split, high range), the former only being selected if the system knows it can maintain that gear for long enough before being forced to change down again (and lose further momentum). Higher engine speed is allowed if that is the only way to deliver the power demanded. However, if the inclination sensor shows the hill is not getting steeper and a force balance has been reached, it automatically shifts back up again to maximise fuel savings.

Meanwhile, had the driver flicked on 'Power Mode', the system would have favoured lower gears faster – to deliver the increased power he or she requests more quickly. Again, however, if the system sees the hill levelling out, it would revert to 'Normal Mode' and change up accordingly. Then, if another steeper hill is reached, it automatically resumes 'Power Mode' and drops down as aggressively as the driver demands.

It's a similar story with 'Adaptive Starting Gear Selection', with the choice of ratio being calculated according to vehicle mass (from SMS – the suspension management system), road inclination (gearbox sensor) and vehicle configuration, all under automatic clutch control. If the system sees a 20% hill, for example, GMS selects the appropriate gear and controls the clutch position and torque (again, with the accelerator pedal acting as a virtual clutch), as well as the engine revs (via EMS), to ensure a successful launch without rolling back or stalling. 'Hill Hold' also provides up to four seconds of service brakes to ease the manoeuvre.

If it's 20% downhill, foot on the footbrake, handbrake off and in drive, the system may select fourth gear. If the driver then doesn't touch the brake or accelerator, it may shift up from fourth to seventh and so on. If he or she depresses the brake lightly, then it might shift up to fifth and provide engine braking. If, however, the footbrake is floored, fourth would not be appropriate, so the system might select second and exhaust brake – keeping the engine revs high under Scania's 'Motor Brake Program' control settings. If the gearbox has a retarder, and the driver pulls on Stage Two or Three, the system also looks at retarder temperature and engine speed, and ensures that the water pump rotates fast enough to deliver coolant to maintain the retarder fluid in the required range.

The point: throughout, GMS works in concert with EMS, BMS and other truck management systems to maximise fuel savings consistent with delivering as responsively as possible against target, without compromising the mechanical integrity of the drivetrain.