



Inside story

Conceived as a spec component and re-born as a customer gearbox, Xtrac gives us an exclusive insight into its new Formula 1 transmission

BY CHARLES ARMSTRONG-WILSON

Formula 1 teams typically reveal very little about the transmissions buried in the tails of their cars. Yet these units are innovative, sophisticated and impressive examples of the levels of efficiency throughout an F1 car. Recently, however, *Racecar Engineering* was given a privileged insight into the workings of one of these units.

The company is the leading transmission supplier in F1 and has just unveiled the first off-the-shelf unit in the series for many years.

The origins of the Xtrac transmission date back to an invitation to tender put out by the FIA, not for a gearbox, but for an engine. This was in the autumn of 2008, and the intention was to find a single supplier for all the engines in F1.

⏏ a single transmission for the grid has enormous potential to save money ⏏



A single gearbox casing means that all the teams will have to use similar rear suspension layouts, as pick-up points are fairly limited

However, the same tender also provided the option to include a gearbox. Although Xtrac makes some engine components, it is by no means an engine company, but the possibility of a single transmission made it sit up and take notice. 'We approached Tim Routsis at Cosworth and said, "rather than sitting around for two months, seeing who wins the engine and then put in our gearbox proposal, can we partner with you?"' recalls Xtrac CEO, Peter Digby. That way, even if the Cosworth proposal was rejected, the company could still pitch the successful tender, giving the company a second bite at the cherry.

SAVING MILLIONS

A single transmission for the grid has enormous potential to save money. Digby: 'The gearbox would be frozen for three years, the teams wouldn't need many [gearbox department] employees and all of them are spending, I guess, over a million pounds a year on salaries in

their transmission departments, some a lot more. If, say, there are 10 teams, you can take out 10 times a million Euros, times three years, so you are saving big sums of money. The tooling can then have "divide by 10" underneath it. Suddenly you are producing 100 gearboxes a year rather than 10, all to a lower spec and with nobody allowed to go off and save a bit of weight or change

two ratios can be momentarily selected at the same time

this or that. The savings were enormous, over 50 million Euros across the grid over three years we estimated.' For the tender, Xtrac also partnered with Ricardo, who would have supplied some components and engineering support to assist with the quantity of parts needed.

Yes, it was a lower tech solution but the idea was based

on the fact that nobody in the grandstands was likely to be able to tell whether the cars they were watching had gearboxes made of aluminium, titanium or carbon fibre. Nor were they likely to be able to tell the difference between a 120 millisecond and a 30-millisecond gear change. 'I'm not saying this was the best technical solution, nor the most interesting, or even one that

completely retained F1's DNA, but there is no doubting about the saving,' Digby added.

Unfortunately, this all came at the height of the tensions between the Formula One Teams' Association (FOTA) and the FIA, with both parties manoeuvring to strengthen their position. By February 2009, the single engine idea had become a

casualty of the negotiation process, but Xtrac had by now put a great deal of work into the project and developed a strong product concept. As relations thawed and a clutch of new teams were attracted into the sport it became clear that the Cosworth engine was going to be popular, and so would a cost-effective transmission already engineered to suit that power unit. However, if it were going to compete against other bespoke F1 transmissions, then the spec would need to be a little higher than the original single gearbox proposal. As luck would have it, the specification had already been raised once during the tendering process to counter initial reluctance from the teams. From there it was a relatively short route to a market-ready product that would be competitive in open competition, yet retain much of the unit's original cost-saving ethos.

The result of this process goes by the rather uninspiring title of 1044, which is simply the



next number on Xtrac's list. The company is quick to admit that coming up with inspiring names for their products is not their forte, though Digby recalls once giving his employees a dressing down for christening a new seven-speed transmission the 1006. 'I said, "guys, for the sake of one number..."'

TIGHT TIMESCALE

Adrian Moore is Xtrac's technical director and he highlights the incredibly tight timescale they had to work within. Work started in earnest on the project in September [2009], yet they already had the 'box in the metal and being run on the Cosworth dynamometer when we visited in December. A lot of conceptual work was done before that point, admits Moore: 'We always have a standard F1 internals package. We take it to our customers and they choose whether to work with it.' But the changing regulation proposals and the possible cost cap prevented anything being fixed until the

project was finally given the green light. 'Working with one engine supplier helps,' notes Moore, 'it's a Cosworth dedicated package at the moment, so that allowed us to work really closely with Cosworth on all the engine studs and clutch release and everything. It has been a seamless process, which is what

spread the fuel load over the largest plan area possible to keep the c of g low. The regulations prevent them from pushing the driver further forward, so the alternative is to move the engine as far back as possible.

HOW IT WORKS

Drive from the engine enters via

and meshes with the final drive. The differential is an active hydraulic type.

Conventionally, racing transmissions have sequential gear selection operated by selector forks sliding along a revolving barrel. The forks have pegs that follow the path of circumferential grooves on the barrel and kink in sequence, moving the forks in and out of engagement. This works very well but has limitations when it comes to the fastest possible gear change. How fast they follow one another is determined by the profile of the grooves in the barrel and how fast the forks can be accelerated and decelerated again.

Over the years, to drive the barrels, all the teams have turned to high-pressure hydraulics operated by Moog valves. These can be controlled very accurately and, with feedback from position sensors, very fast changes were being achieved. However, within the last decade a new approach to the problem has established

aerospace casting techniques now allow wall thicknesses as low as 3mm

the teams wanted.'

The unit's basic layout is similar to pretty much every gearbox on the F1 grid. 'It's as short as we can make it,' says Moore, 'the new rule preventing refuelling has put pressure back onto the transmission.' With the need to carry a full race distance of fuel, space is at a premium and all the designers want to

the longitudinal layshaft, directly below the mainshaft, to enable the lowest possible crank height. Together these shafts carry the mating pairs of seven forward ratios. Drive is then transferred from the rear of the mainshaft via a pair of bevel gears to a transverse idler shaft. This is needed to lift the drive up to the hub height of the rear wheels



In 2010 all the teams using the new gearbox will also be using the Cosworth CA2010 engine. Originally this would have formed the FIA's low-cost solution

itself in F1 and the Xtrac unit incorporates this system - instead of one selector barrel it has two, with alternate ratios connected to each. As the barrels can be controlled separately, it allows one ratio to chase another much more closely, giving an even faster change.

An exhaustive development process is employed to write gear change maps that bring the proximity of the two ratios almost disastrously close to the point of having two gears selected at once. In fact, two ratios can be momentarily selected at the same time, with the higher ratio speeding up the slower one and taking the load off its dogs' drive faces. The selector fork then swiftly snatches the dogs out of engagement before their other faces are caught up by the rapidly accelerating ratio, avoiding the potentially explosive encounter.

The dogs themselves are a design Xtrac developed

specifically for use in Formula 1 and is still pretty much exclusive to the series. It mainly comes from the need to keep the cluster's overall length as short as possible while, at the same time, retaining sufficient drive face area on the dogs.

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SIX-RACE GEARBOX

All the gear ratios are 12mm wide, simply because this has been written into the rules in an attempt to increase ratio life and reduce costs, as there is constant talk of increasing the current four-race life of gearboxes to six races. Prior to this regulation,

some of the higher ratios were down to as little as 7mm with a resulting short life. 'We've allowed for potentially a six-race gearbox,' says Digby, 'so if they went to six races in 2011, we have produced a final drive and bevel set that should

accommodate six races.'


Xtrac opted for an aluminium casing for a number of reasons. There were doubts about the integrity of magnesium at higher temperatures and, although investment cast titanium and carbon composite have been used successfully in F1, they

would add a great deal of cost and development time to the programme. Xtrac feels that aluminium is still a very efficient material for the role, particularly as aerospace casting techniques now allow wall thicknesses as low as 3mm, half that of a few years ago.

Keeping the gear casing as small as possible is always high on the list of objectives, not only because it keeps the amount of oil required to the minimum, but also because the aerodynamicists highly value space in this region.

Moore admits to a degree of caution in the casing design. 'We've been a little bit conservative on the differential in terms of the width of the mounting because F1 crash tests are pretty tough. You want it as narrow as possible for the aerodynamics, but being wider gives you a stable platform for the crash test. It's a compromise.' Despite this, the transmission

A SPECIAL RELATIONSHIP

 A remarkable feature of this project was that it forced a collaboration between the two fiercest competitors in F1 transmissions. Neither Xtrac nor Ricardo had the capacity to supply the entire grid and still maintain their other customers, yet collaboration would inevitably involve the sharing of hard-won technical knowledge. But Iain Wight of Ricardo points out that 'unless we were all completely open right from the start it was never going to work.'

Xtrac agreed. 'We said look, we know what your gear philosophy is, here's our gear data, we don't want to see it cropping up somewhere else,' recalls Digby. Despite the fact that much of this knowledge is not protected by copyright, the risks were not as great as one might suppose. 'We've always had fundamentally different philosophies, like with gear tooth profiles,' says Wight, 'neither is wrong but, unless you understood the philosophy behind it, there's no point in just going off and copying things.'

In the event, the relationship worked and Wight describes the 50-page tender they came up with as, 'one of the best documents I've ever seen as a proposal.' And all this without a single contract or non-disclosure document, just a verbal agreement and a handshake. As Digby says of Ricardo, 'I think we put up a couple of Chinese walls ourselves but firstly, they were nice guys.'

In the end, Xtrac took the initiative on the production gearbox, but Ricardo is still a supplier on the project.



Xtrac CEO Peter Digby and technical director Adrian Moore pose proudly with the new 1044 transmission

still tips the scales at around 40kg, a good figure, even by Formula 1 standards.

Suspension pick-up positions were largely dictated by the first team to sign up for the gearbox on the basis that what worked for them should be a good starting point for later customers. This has worked so far and the majority of the teams are sharing the same casing, but the four-race gearbox rules mean that any changes may require the teams to take a grid penalty.

An area that Xtrac felt it lacked the full skills was in the control hydraulics, including the pressure pump, accumulators and feed to the clutch, gear selector barrels and differential. Normally, the teams would design these, but with this unit it was recognised that there could be significant savings in design, manufacture and especially rig testing if they could be supplied as part of the package. Fortunately, one of the customer teams has agreed to mentor the design process of a system that will be used by all the teams. Developing it is one of the biggest challenges and, with the lack of track testing now available, it involves extensive rig work to bring up to standard.



THE BOTTOM LINE

With the design complete and in production, how successful has Xtrac been in its attempt to

produce a low-cost F1 gearbox? The price of the single unit is under £70,000 (\$114,500), though the true cost has to be considered in the context of the supply for a two-car team throughout a season. Each team will need around six transmissions, plus the odd one that will be lost in action to accident damage. The FIA has limited the teams to a choice of 30 ratios, but even so, creating the inventory of spares is still a big investment.

All this makes the first season disproportionately expensive

great,' says Digby, 'and we have open-book costings to a degree where we just say if there's three to four teams then this is the cost and there won't be any more. If there are more teams, then we can start to reduce the costs.' At the time of our visit, three of Cosworth's five customers - Campos, Lotus and Virgin - were using the Xtrac 'box. The other Cosworth runner, Williams, has its own experienced transmission department and was not about to let that stand idle while it bought in a customer gearbox. US F1 has gone its own way.

 **less than half a million pounds per season on hardware over three years** 

compared with subsequent years. According to Digby, in the context of a three-season supply, 50 to 60 per cent of the expense will be encountered in the first year. However, he believes it would be possible for a team to spend an average of less than half a million pounds per season on hardware over three years. 'The figures the FIA was quoting two to three years ago was of teams allegedly spending over 10 million Euros on their transmissions,' says Digby.

To make the budget work, the company needed a minimum of three teams. 'If there's more, then

Every team will be given full training on running and maintaining the gearbox and during the season there will be Xtrac engineers at every race and official test to provide support. No allowances are being made for the late start, though, as teams needed fully working transmissions ready for the first test of the season. Plus each team will need to have been supplied with five units by the first race. Despite the pressure, at the time of going to press Digby and Moore were confident they would deliver.

