V4

What is it about that engine layout that makes it so good? And why aren't we all riding them? Mac McDiarmid investigates

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Clockwise from left: Yamaha's RD500 was one of the most eagerly anticipated bikes in modern motorcycling. Its V-four engine shared little apart from layout with the GP racer and turned out to be slightly less loopy than we'd expected. Exotic and fragile for such an expensive motorbike, it was quickly rendered obsolete by Suzuki's GSX-R750 and Kawasaki's GPZ600R; the 1986 Honda RVF750 racer (seen here at the 1986 Suzuka Eight Hour race) is still considered by many to be the greatest four-stroke motorcycle ever built. The first big four-stroke racer that wasn't big, no other bike represents the V-four advantage so exquisitely. The power of a multi, the traction of a twin – tiny to look at, with a sound that makes grown men cry; the latest VFR road bike is no lightweight and way less nimble than those mid-1980s Honda legends. But it is still unique among road bikes in the way it makes power and sounds on full throttle; Yamaha's V-Max uses its engine layout to allow clever carburation that feeds two carbs' worth of fuel into one cylinder for more power. In 18 years, the V-Max has seen off every challenge to its crown

BEFORE YOU CONSIDER whether to build a V, in-line or any other configuration, first you have to decide if it needs to be a four at all. At the risk of stating the obvious, in supersports land – and even more so in race land – the bottom line is power. And power is all about revs. Just how many do you want? Or, more to the point, how many can your engine bear?

It's an immutable consequence of inertia that you can't just rev the taters off anything. There are limits to the speeds you can hurtle lumps of metal around, stop them dead, burn them, and send them rushing back the other way. If we ask our pistons to average much more than 4000 feet per minute, they're going to fly apart – if the con-rod doesn't let go first. 4000 ft/min might sound like a lot, but it's only around 45mph. Your bike travels a lot faster than its pistons, but then it doesn't have to do half of it in reverse.

You are the chief engine designer for a major bike company. Your bosses are demanding a new sports 750 and insist that it makes a genuine 120bhp. But they're undecided on whether to make it a twin or a four (V or otherwise). So you do a few sums.

However many cylinders it has, to make 120bhp it'll clearly need to rev. Obviously the longer the stroke the further the pistons have to travel and, therefore, the faster they must move at any particular rpm. So, to keep piston speed realistic, the bore will need to be much greater than the stroke – let's say 3:2. For a 750cc twin that gives 89.5mm by 59.5mm, while a four would measure 71 x 47.3mm.

We've already seen that 4000ft/min or so is our maximum piston speed. So that sets our absolute rev ceiling. On our twin, 4000 ft/min works out at 10,300rpm. That's our red line. But the same piston speed on a four equates to 12,800rpm. We can spin it 25 per cent faster. All other things being equal, that means 25 per cent more fuel and air.

Now let me introduce you to bmep – brake mean effective pressure. This is a measure of an engine's efficiency in filling its cylinders, the bottom line for power. Its efficiency is always highest at peak torque rpm, but for the moment we're concerned with top-end power.

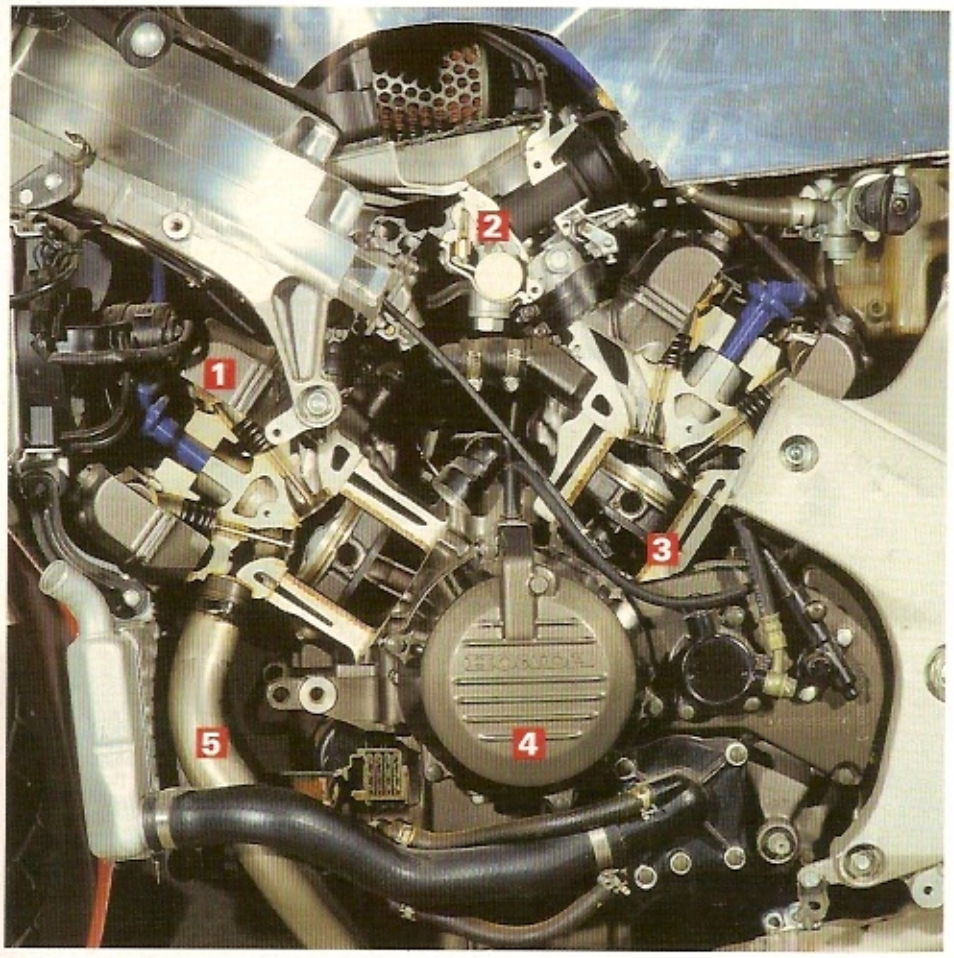
If our 750-four is going to shove out 120bhp, it'll need to develop a peak power bmep of around 163psi – high for a 750cc road bike, but definitely possible. But a twin would need a bmep of 202 to produce the same stomp. 202 is a seriously big ask. In fact, on a road bike you've got fat chance. On its quoted figures, the new Ducati 999 has a bmep of around 158 at peak power rpm. Based on *Bike*'s own dyno tests, the figures for the RSV Mille, GSX-R1000 and GSX-R600 are 146, 155 and 162 respectively.

In other words, if capacity is pre-determined (by choice, race regs or whatever), to get top power you absolutely must have a multi. The main issue now is how our four (or five?) cylinders are arranged.

Incidentally, if you do the same sums with an RC45 and Ducati 996 (which Honda's engine people would certainly have done having estimated what the previous Ducati 888 was pumping out, plus a bit), you come up with this: asking for, say, 140bhp, you get the Honda revving to 13,500rpm, with a bmep of 180. Realistic. The Duke, meanwhile, would rev to 9300rpm with a wildly improbable peak power bmep of 213. Ducati got over this by revving the tits off it. That's why the latest Testastretta engine has a stroke even shorter than 3:2.

GP four-strokes use even more radically over-square motors, nearer 2:1. A 2:1 990cc four revving at 15,000rpm needs a bmep of 193 to produce the current target of around 220bhp. For a full-on race bike, that's realistic. To produce even 200bhp, a twin would need a bmep way off the scale. In fact, it'd need a turbo.

Multis also have an advantage with valve gear. A 16-valve four obviously has twice as many valves as an eight-valve twin. More valves not only offer greater valve area, but each is smaller and lighter. Less valve inertia allows both higher rpm and more radical cam profiles before they can no longer keep



1. A V-four layout allows steep valve angles without making an engine that's too tall for a sharp-handling chassis. It also allows a 360° firing order that mimics a V-twin for extra traction (on the RC30) or 180° for the smoother delivery of an in-line four without the bulk or height (like the roadgoing VFR750s).

2. The biggest problem on such a compact engine is carburation. Keeping the air-fuel mixture cool and therefore dense enough is very difficult in between two roasting-hot banks of cylinders. Fuel injection has made things much easier.

3. The disadvantages of a V-four are mostly down to build costs. Two cylinder heads, two sets of cams, two pairs of cylinders, two cam drives and a more intricate cooling system.

4. As narrow as a twin, as powerful as an in-line four – you can't argue with that. VFR800 has small, side-mounted radiators for more efficient cooling.

5. Exhaust routing is complex to keep pipe lengths the same. Ask a VFR owner about replacing a collector box.

up with the cam lobes and valve float sets in. Ducatis avoid this by using desmodromic valve gear, in which cams not only open but close the valves, too, so float is impossible. But Aprilia, with valves just as big, haven't suffered noticeably by using plain old springs.

As important as outright grunt is the nature of that power. 200-plus bhp and a narrow powerband is too frightening to contemplate. Luckily, at the present state of play in MotoGP, 220bhp is easy enough to obtain from four or more cylinders and so doesn't lead to fiendishly peaky power outputs.

From what we've seen of the Aprilia RS3, triples are a bit more marginal. Honda, with a V-five which seeks all the V-four's advantages, with the added scope of smaller cylinders and hence more revs, has power – and driveability – to burn.

But grip is about more than merely creating relatively benign torque graphs. Much is made of the ability of V-twins to find grip, as their firing intervals put two bangs close together, followed by a relatively lengthy pause during which the tyre's contact patch 'recovers'. The same reasoning went into 'big bang' racing two-stroke V-fours.

With an in-line multi you're more or less stuck with even firing intervals – the opposite of big bang. But with V-fours you get the choice. Depending on whether you arrange your crank throws parallel (360° crank, where pairs of pistons rise and fall together) or opposite (180°), you get a power delivery similar to a V-twin's, or something more like a straight four. The main shortcoming of the big-bang set-up is that it tends to make the transmission snatchy at low revs – but on a racer or even a sportsbike you'll care little about that. On the road, 180s tend to be a bit too sanitised and bland.

Honda V-fours, both street and racing, have had both crank layouts. But the flat drone of the RC30 made it unmistakably a 360 big banger. That's principally why that V-four gem was renowned not so much for its sheer power, but for being easy to set up and, above all, for its ability to find grip out of turns.

Before then we'd had the exquisite RVF750. Until Valentino Rossi's V-five proves otherwise in the long term, the RVF of the mid-1980s is arguably the finest four-stroke racer ever built. Honda only sent three to Europe – two for the French World Endurance squad and one for a bloke called Joey from Ballymoney.

Nick Goodison was the only Brit entrusted to poke around inside this factory jewel. "It was gorgeous," he recalls, "so tiny and so fast." The RVF was the first big four-stroke racer that wasn't, well, big. Making the most of the ultra-compact V-four engine, Honda revolutionised the class.

Top engine tuner Tony Scott is equally besotted by V-fours. "They don't spin wheels like in-line fours," he says, "they just seem to drive so well." Much though he's loved fettling RC30s and RC45s, he's just itching for someone to bring out a 1000cc V-four. "Now you could get that ridiculously fast," he chuckles.

Then there are factors other than power. In a sportsbike, wide is bad both dynamically and aerodynamically – but so is tall. Tall engines mean tall frames with unwieldy riding positions, like spine frame Triumphs.

With double overhead cams and the necessity for very narrow included valve angles (these days valve stems are getting close to parallel) heads are very tall. Clock a modern engine and only the first inch or two poking out of the crankcases is actually cylinder – practically everything above that is valve gear. Clearly, splaying your cylinders reduces overall engine height.

Then there's length – a big deal in something as short as a bike. 90° V-twin engines tend to be long, V-fours much less so. One of the biggest shortcomings of WSB Ducatis isn't the sheer length of the thing, because the engine manifestly does fit, but only just. But there's only one place it can go, so you're stuck with whatever

weight distribution you've got. Ideally, you'd want to play around with front/rear weight bias, swing-arm length and geometry to find the best handling compromise. This is precisely why Aprilia chose a 60° V for the RSV – although that made it a tad taller than they'd have liked.

A V-four has few of these disadvantages. It's narrower than a straight four, yet shorter fore and aft and less tall than a V-twin. In fact it's pretty well as compact a box of poke as you can get – giving maximum flexibility to locate it to where you choose. Square layouts have similar advantages, but at the cost of an extra crankshaft.

And it's easier to silence – a boring issue to you, maybe, but a very big deal if you want to sell motorbikes. A 90° V-four has the same perfect primary balance as a V-twin, so won't need heavy, power-sapping balance shafts. And, with its shorter stroke and lighter valves, it'll rev like any other four. Yet it's possible to make it drive and grip like a twin, or run as smooth and refined as a straight four. V-fours: why aren't they all like that?

Don't get me wrong. I love V-twins. In fact, I own two. And on the street it doesn't matter one bit that it takes 1000cc of twin to equal the top end of a 750cc four. When was the last time you found yourself musing about the niceties of piston speed and bore to stroke ratios as you hacked along your favourite road? But when they were in hard-nosed pursuit of power-per-cc, as they are now, even Ducati came up with a V-four.

So why doesn't everyone build them? Typically, they are a little more expensive to make. You've got two separate valve trains, cylinder heads and a more complex exhaust run and cooling system. For years it was rumoured that Honda lost money on every VFR they built (due to expense of engine build, and especially the cam gear drive). They must have been delighted to drop that for the latest VFR ■.

How the V-four has progressed
Far left: the supercharged V4 AJS racer from 1939 was so terrifying to ride that even the man who developed it was pleased to see it retire from the 1939 Ulster GP before someone got hurt.
Centre: Yamaha perfected the racing V4. Starting in 1982, by 1984 they were streets ahead. Eddie Lawson (pictured in 1984) won three of his four world titles on Yamahas.
Left: Ducati describe their 2003 GP-racing V4 as a 'double-twin'.