

CROSSOVERS: INTAKE AND EXHAUST

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Lots of bikes and cars have crossover passages or lines (that is bike-speak for tubes) connecting intake throats just as they have crossovers connecting exhaust pipes. These are downstream of the butterfly or slide valve and upstream of the cylinder intake valve. The purpose of these crossovers is essentially to *average* the performance of two parts.

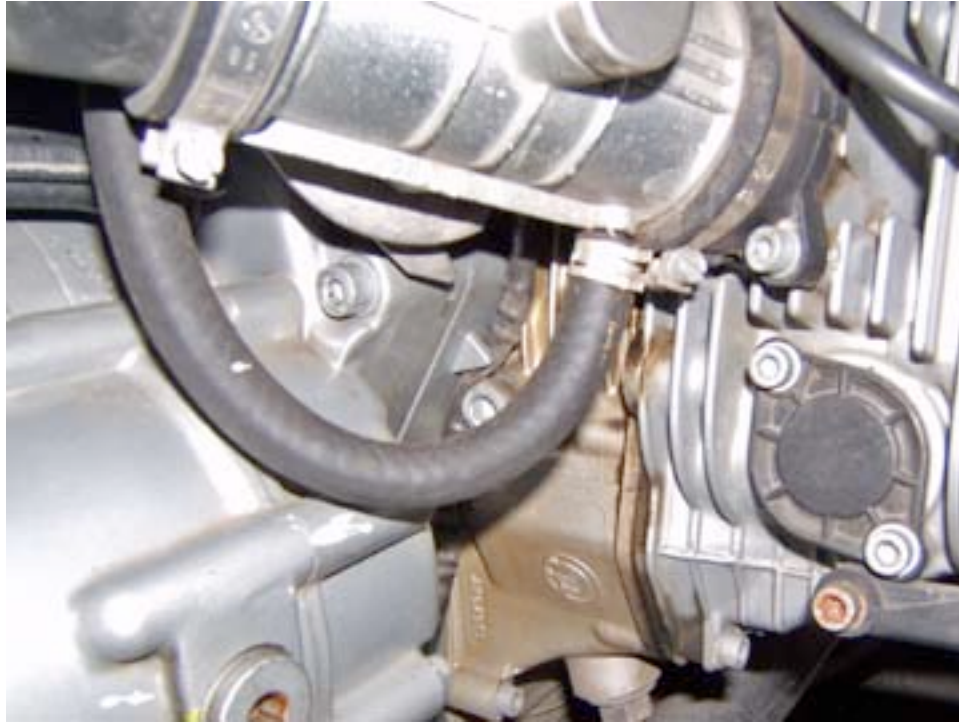
Intake crossovers

Let me explain. I'll start with the intake tracts. Performance cars and pretty much all bikes have one carb or, in the case of fuel injection, one throttle body for each cylinder. The reason is because the closer the carb is to the cylinder, the better the bike's performance. Hence, there's a carb or TB adjacent to each cylinder, rather than one big carb somewhere back upstream, like in older cars.

Bikes have few cylinders, often just two. Bikes are maintained so that the carbs or TBs are compulsively *synchronized* (meaning in bike-speak, matched, paired, or mutually adjusted) so that the pair are as identical as possible. Synching minimizes vibration and shudder. In turn, that improves power, control, and reduces fatigue and harm to hands and feet.

But you can add a passage or tube between two carbs or TBs. If one side has a higher vacuum than the other, fuel mixture will flow in that direction, tending to automatically equalize the two sides. Which is wonderful. In as much as the two sides are never in perfect synchrony, and certainly not at all points in the throttle compass or as time goes on, the crossover will silently adjust.

The carbs and FI are the basic fueling control and it would make for confusion to have all too large a crossover. So modest lines are installed connecting to the vacuum ports. Can a small line help much? If you are thinking in terms of wide-open-throttle, you are thinking wrong. The vast majority of time in street riding is spent with the throttle open a very small amount. At such times, the small crossover line can represent a useful averaging method.



That's what it looks like when you connect balance tube to the vacuum port on the underside on the right throttle body of a BMW R1100S. A bit nutty to use one when the cylinders are as far apart as on this opposed-cylinder twin,

Turns out there's much more to the balancing than I understood. The following was provided by bacn5 on 2009 January 9:

Roger I apologize in advance, but I respectfully disagree¹. One of the first modifications I performed to my used bike was connecting the two vacuum lines together. (The previous owner had already removed the EVAP canister and I had carefully synchronized the throttle plates under load and at idle). With the new connection I immediately noticed an improvement in torque at idle and slightly off idle. I also noticed reduced surging at low throttle plate openings. (I totally eliminated any remaining surging by installing and mapping a PCIII). I tested the set-up several times with and without the connection as it is easy to unplug, cap and reconnect.

I agree that simply connecting the two sides together with a small vacuum line wont help at all. What I did was create a larger vacuum reservoir and connected the two sides to it. As a Master mechanic I understand EFI very well. I am also asked to teach classes on improving emissions to experienced mechanics across

¹ "Roger" is a passive-aggressive bully who is also the moderator of the Pelican Parts website. Cross him and... you are toast (the Word grammar checker suggests that either "you is toast" or "you are toasts"). He has some grasp of technical issues (actually about 50% of what he thinks he has). But sadly, he has alienated any other guru from providing regular help on the list.

the U.S. Of course, these classes always include EFI, A/F ratios, and basically anything else that will effect how clean an engine burns at different rpms.

And later:

I realize that these bikes don't have MAF sensors and I'm not trying to fool any electrical sensors... What I have accomplished is improvement to the physical science of the needs of the engine. Keep in mind that the intake runners are connected through a central air box. This is good mainly because both sides are working together to draw air into the box, keeping the flow into the box consistent. But at the same time keep in mind that at low rpms when the intake valves on one cylinder are closed the vacuum created on the opposite side of the engine (where the valves are open) is actually trying to draw the air from the opposite intake track. This can cause the flow into that cylinder to stop or reverse direction. By creating a reservoir of vacuum below the throttle plate, I have helped to keep the flow going in the correct direction. Anything you do to damp the pulses and help the air to flow consistently in one direction will help improve and flatten the torque curve at very low rpms or small throttle openings.

I realize that reversion is mainly effected by cam profile and timing, but intake runner design also has a big influence on it. That is why performance intake manifolds for cars are sold and designed for specific rpm ranges.

What is accomplished with a vacuum reservoir is to damp the vacuum signal pulses. These pulses are created by the intake valve as it opens and closes. At low rpms the stream of air (vacuum signal) running into the cylinder can pulsate. You can actually see it if you connect an accurate vacuum gauge to one side of the intake system. These pulses will smooth out at higher rpms as the stream of air running into the cylinder moves at higher velocity. By connecting the two sides together with a reservoir of enough volume, you smooth out the pulses since the cylinders fire opposite of each other and the reservoir has enough volume to maintain the vacuum signal.

I admit that this is not the preferred set-up as the vacuum ports on the TB are very small. I would prefer to have a 1/2" to 3/4" tube running between the two cylinders. The opening to the intake runner should be the same diameter as the tube and the opening should be located below the throttle plate. However, due to packaging constraints this would be very difficult to do on this engine, which may be one reason why BMW has not done it. The other reason is that the engine has sufficient low-end torque for the weight of the bike.

Even though the bike has EFI, the atomized fuel will not flow into the cylinder unless there is a strong consistent flow of air into the cylinder. Vacuum pulses can cause the airflow to stop, or actually flow backward toward the other cylinder.

Once the reservoir was installed the vacuum gauge was very steady at all rpms, and I could release the clutch with much less throttle.

And later:

To be honest with you I didn't believe that the small ports would be large enough to make any difference either... but they did on my bike. I believe that it is due to the large volume of vacuum in the reservoir combined with the high vacuum (almost 22 inches). On my bike this dramatically improved drive-ability. I have tested it several times and would not remove the set up. If I ever get around to enlarging the throttle plates (I am thinking about an elliptical design) I will add a larger diameter port to connect the two sides together. In the mean time the set-up I have is well worth the \$10 I have into it.

And later:

Keep in mind that this is mainly working when the throttle plates are closed or slightly open. We are not talking about much airflow here. This is why the relatively large reservoir combined with 22 inches of vacuum is helping to stabilize the vacuum signal pulses.

Exhaust crossovers

Same averaging logic applies, more or less, to exhaust crossovers. But the issues are different. Consider a bike with two cylinders. Each cylinder has an exhaust system terminating in a silencer of some kind. But these cylinders are firing 360-degrees apart in the crank cycle. Why not join them together since their operation never so much as overlaps a bit?

The further upstream you can join them, then two smaller diameter exhaust pipes will suffice to carry away the exhaust below the point of joining and so on for all the shared components downstream.

The designer can join the pipes together as far upstream as possible. But on a bike, that may not be any too close to the cylinders, given the engine layout and all the constraints in bike design... not the least of which is esthetics. Therefore, the designer has to use pipes joining the two sides and set them as far upstream and as large diameter as possible.

A slightly different take on crossovers and speaking of Harleys, has been written by the excellent journalist, Jon Minton:

<http://www.americanrider.com/output.cfm?id=1021987>

Footnote comment.

In both intake and exhaust systems, designers sometimes implement *tuning*. Just as the word indicates in music, that is a means of using Helmholtz or organ-pipe resonances to

amplify some desirable quality such as scavenging or back pressure. But each time you have a beneficial resonance, you are also creating harmful resonances (or anti-resonances, if you will) at harmonically related rpms. In plain English, if you boost at 6400 rpm, you might inherit a dip at 3200 rpm.

At the urging of the folks in the marketing department, the designers do this so as to boost the power, typically at upper-middle or at the top of the rpm range where power is already max'ed. And that's a really useless location for almost everybody not on a racetrack. But the designers do it even though it hurts power at lower, more useful points. The designers do it for two reasons. First, they know who is *in charge* at the company (the marketing department, of course) and second, they like to see their bikes win races.

Now, crossovers diminish the amplitude and otherwise impair these special location resonances, both the boosts and the inadvertent cuts. So I would always say, "that's great." But the marketing people, looking *only at* the max advertised power, would say, "umm, not so great."

Do you ride on a racetrack or on streets and highways?