AIR TO FUEL RATIOS ON AN R1100S AND COMMENTS ABOUT THE *POWER COMMANDER III AND FRK*

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Bosch are secretive about their bike ECU operation. Even a great book like Adam Wade's *Motorcycle Fuel Injection Handbook,* 2004, doesn't have much information. In addition, air to fuel ratios ("A/F") for max power, vary with the engine and for the same engine vary with the gear, state of tune, valve lash, road grade, etc. Also, my ability to accurately remember observations from road testing is, well, human. But I hope you benefit from reading this – and will post your critical comments.

I provide numeric air to fuel ratios and general characterizations of rich versus lean. But my main "data" is to examine how the Bosch ECU behaves by watching the movement of A/F on a gauge so as to shed some light on what ECU principles seem to govern that behavior. The leading question of behavior relates to how often the ECU leaves map-based fueling and *instead* uses the oxygen sensor ("O2") in a feedback network.

General comments on fueling and observations

The purpose of fueling is to facilitate the filling of the cylinders with a mixture of suitable proportions of air and gasoline, in a timely fashion, and well mixed and swirling to promote good ignition. EFI is naturally better than a carb because you are no longer using venturi vacuum to suck gas into the air stream (the gas injectors spritz gas from a pressure fuel line into the air flow and at the right instant in time). Getting the ratio of air to fuel correct is the focus of this report. But it is only one factor in power delivery.

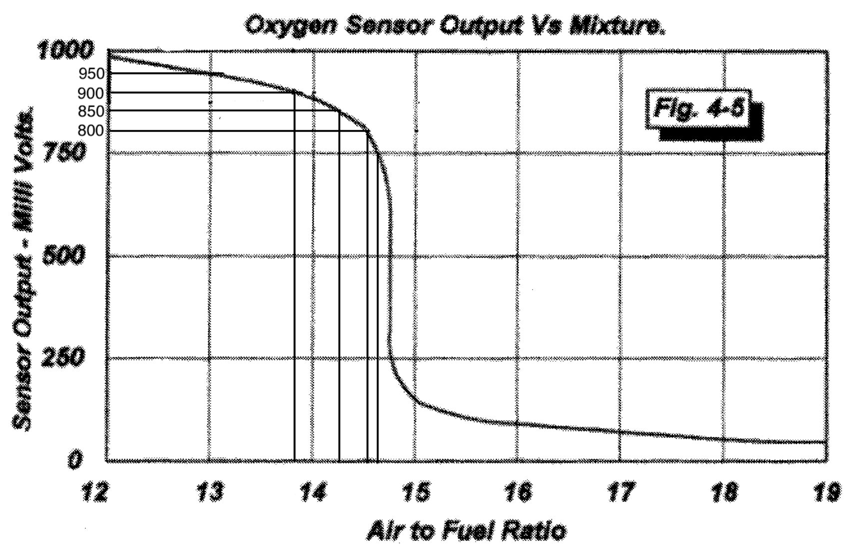
The A/F ratio can be optimized for different criteria but these optima are not the same numeric A/F. There are different optima for minimizing each different chemical component of pollution, for economy, for power, maybe for engine longevity, catalytic converter longevity, etc. Luckily, for max power (the main issue for sport bikes, of course) and for most other performance criteria, the optimum value is really a fairly wide band. You can see that on the second chart below. Sadly, max power tends to be on the rich side and not to overlap too well with pollution criteria.

If you are aiming for high performance, it is lucky the max power is a broad band of A/F values because it would be hard to stay any too precisely on a narrow A/F target. Moreover, when the max power and the various other target A/F values change with practically each turn of the crank, gust of wind, bump in the road, and whim of the drivers on the road it is hard enough to keep anywhere in the max power band, let alone at peak of peak max power.

Here I am talking about air to fuel ratio that is determined by the duration of spray from the injector[1] and that is directly controlled by the ECU. Spray onset relative to crank position is also triggered by the ECU but I don't know if it ever varies with rpm or power demand. But it *should*, eh, just like optimum spark timing should vary with rpm, engine vacuum, etc. There are other fuel delivery factors such as fuel pressure to the injectors, octane, gas volatility, etc. that aren't controlled or whose modification aren't considered by the ECU (but *should* be, eh).

So I actually drove around with an A/F meter (… and for the moment, seem to be the only person to have done so)[2]

I used a 3 1⁄2-digit DVM, 4 samples/second, purpose-built for A/F reading, connected to my narrow-band stock O2 sensor of middle age and unknown condition on my R1100S, 1999, single sparkplug per cylinder, with enhanced breathing, Italian straight-through exhaust, debaffled front crossover pipe, and no cat converter. The cat code plug was stock and in place. These mods should make the bike run leaner (keep that in mind).



Here is the standard voltage versus A/F chart that applies to all narrow-band O2 sensors, or so I think. While the O2 sensor seems to respond coherently and consistently anywhere north of stoic[3], all the action on my bike is over .700 millivolts.

I installed a switch to instantly connect or disconnect the O2 from the ECU. In as much as my comments on closed-loop operation in this report have been subject to much

[1] But mixture "goodness" is strongly impacted by the quality of the spray pattern as well. You should have the pattern evaluated when you have your injectors cleaned – see my write-up on injector cleaning. Injector upgrade is a neglected mod possibility.
[2] I get pretty livid on the subject of dyno testing. Just not real-world enough for me.
[3] Sorry folks, never saw the bike run leaner than stoich so I don't know if the gauge is coherent and consistent down there.

ignorant criticism, I want the reader to remember that my method of observation was by immediate switched A-B comparison.

Some really ignorant guys keep on insisting the O2 sensor is a two-value device. As you can see from the chart above, it is designed to be sensitive around stoic but it is by no means just a two-valued switch-like sensor. Let's say your meter read ". 850," would you have any trouble knowing that indicates "14.25"?

The BMW Motronic 2.4

You can run your fueling either (1) by taking testimony of various input-variable sensors and using a map or algorithm to calculate spritz length OR (2) sniffing the output gas with an O2 sensor and adjusting the fuel spritz length to achieve a criterion value of richness based on this feedback. The R1100S doesn't run well in feedback mode and so is regularly in map mode until the bike finds itself on very stable flat terrain with no movement of the throttle.

Map mode

The BMW twins use a Bosch "Alpha-n" EFI ("n" represent rpm and "alpha" represents the angle open of the butterfly in the throttle body[4]. So in map mode, injector spritz length is determined by (1) how wide is the butterfly throttle angle (which establishes how much air can be drawn into the cylinders with each inhalation), (2) engine rpm, and (3) sensors for air temperature, engine oil temperature, and barometric pressure (AKA altitude).

Angle and engine rpm are the main factors that the ECU uses to determine the length of injector spritz. The ECU also uses oil temperature, an ambient air temperature sensor, and barometric/altitude pressure to trim the spritz length slightly, as well as crank position sensing to determine the moment to start spritzing.

Do you think you could make an accurate guess at what length of spray is called for from those variables and under the various conditions of biking? Seems loosey-goosey to me. But then it doesn't need to be too precise anyway since a typical engine might have 98% of its power from 13.8 to 11.0 ratios, as the next chart shows.

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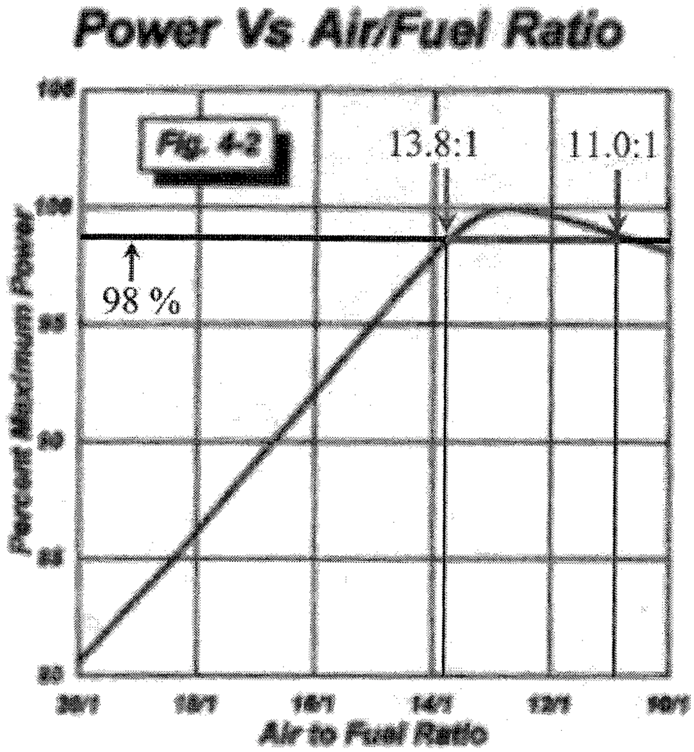
[4] I think that measuring the mass of air with a flapper valve (or, for a few nickels more, a solid-state Motorola MPX2100) would work a whole lot better because it measures the air directly, not infers air mass from the butterfly opening. That's the other kind of ECU, but rarely used on bikes due to backfiring and other problems.



This is the kind of standard textbook chart relating A/F and power. It's a bit different for each engine in the world, but you get the idea that you are within 98% of max power from a slightly rich 13.8 to a very rich 11.0.

It is clear from the chart that you can be lean enough to burn your valves or rich enough to stink up the whole neighborhood and still get 90% of max power. Even at the much-reviled stoich, you are still chugging at about 96% of max power — a decrement that few could detect with their butt-dynos.

Closed loop or feedback mode

The R1100S uses a self-heated four-wire oxygen sensor, mounted where the two exhaust pipes meet, just ahead of the catalytic converter (if your cat converter hasn't gone missing). Long way away from the engine, eh? But unless you ride the superslab, the ECU is set up to take a minimal guidance from the O2 sensor.

You might say the engine is striving to go closed-loop. In theory, that makes the A/F lean enough to preserve the cat converter, but not really. It is rare to actually get into feedback mode because as soon as the rider moves the throttle (or just hits a bump in the road), the ECU takes its little beady eye off the O2 sensor and goes back to map mode[5].

[5] Don't dispute this paragraph until you've ridden with an A/F gauge.

So when you are scooting down the highway at a steady speed, the ECU runs around 13.5:1[6] and after a few seconds, it *then* starts to move that ratio down towards 14.0 (a good point that is at the lean boundary of the 98% power band) and if things remain steady, it can move nearly to stoich (14.7) but rarely getting to that mark[7].

It seems to struggle to do the same with the O2 disconnected but lags some (as compared to closed-loop) at all points in that direction. Generally, my R1100S tends to settle in at a nice 13.8-14.2 mixture on the highway, a bit leaner when closed-loop.

With the O2 sensor disconnected, there no sensor input at all. But, as far as I can tell, it does not enter a “limp home” mode with the O2 sensor disconnected (or just the black signal wire cut); it just runs as normally from internal map logic and the input sensors but it just doesn’t get as lean as when the O2 sensor is intact.

Old hand at carbs (ahem, ahem) would put white dots on their throttle twist grip to see where they are placing the throttle at different speeds. My throttle twist grip opens about ¼ turn to WOT. I twist my throttle maybe ¾ of that motion open during fierce acceleration on the street. That would be ¾ of 90 degrees, which is maybe a 70-degree twist.

Most riding is below ¼ motion. For example, going 70 or 80 mph in fourth or fifth gear is about 1/5 motion, which is roughly 1/5 of 90 degrees and therefore less than 20 degrees[8].

I remind readers about these tiny opening increments not just to plug my 28-cent throttle counter-force spring idea, but to reinforce the importance of having the TPS set carefully because the TPS offset and general accuracy becomes that much more important at small motions.

In sixth gear, the throttle is open less. As a result of the debaffling of my front crossover pipe (see my write-up), my S is able to pull strongly in sixth gear from below 70 mph, which is about 4000 rpm.

It seems the ECU is borderline indecisive about kicking into closed-loop mode at low throttle openings and/or engine speeds, as is widely suspected. My impression is that it is better for your economy (and HP output) to ride at 70 or 80 mph in fourth gear where the ECU might forego map-mode and head in the stoich direction using O2 feedback.

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[6] “13.5:1” is the ballpark value I saw on my meter, not an armchair or hypothetical engineering idea from people who couldn’t pass an engineering course.

[7] Don’t know if it is too late to define “lean” better. Most of the time, “lean” means relative to the lab criterion of perfect combustion or 1:14.7 by weight. So if the bike needs more gas, we say (and the O2 sensor (AKA lambda sensor) says it runs rich. But, in another sense of the term, if a bike needs say, 1:13 to run well, when we are lean *of that,* we say the mixture is too lean.

[8] With these tiny motions of the twist grip in mind, it makes a lot of sense to install a 28-cent throttle counterforce spring to make the throttle feather-light.

Because one critic has ridiculed the previous paragraph, let me explain it in a way he might understand. Yes, more effort to spin the engine at higher speeds as compared to lower speeds. Everybody knows that. But the ECU gives a leaner fueling to power the bike at the sweet-spot band. Maybe it shouldn't be so rich elsewhere or maybe the engine should run better elsewhere? But it seems to run fine and lean at 70 mph in fourth gear and until somebody else rides around with an A/F gauge, that opinion will have to stand.

The ECU seems to be most in its familiar engine milieu from maybe 4800 rpm and up. Below that it struggles to find a good mix and tends to keep rich. I don't know if that is due to sensing the throttle/butterfly/TPS position, the rpm, or some complex time-course logic. If you don't mind riding around with your engine revved up, that is better than shifting to a higher gear. However, I prefer lugging in the course of most ordinary daily riding and have configured my engine towards that preference.

Now and then, the ECU polls the O2 sensor… but not often

There is a widely held misunderstanding of O2 sensor feedback. Some electronic devices would blow up immediately if the negative feedback loop from the output were disconnected even briefly. Almost any integrated circuit device with an amp in it depends on feedback. *The bike ECU acts nothing like that.*

The Bosch Motronic 2.4 enters feedback mode when it feels like it. Like a Prussian schoolmaster[9], the ECU thinks it knows what fueling is best for the engine based only on *input* variables and the built-in map. Only occasionally does the ECU stoop to feedback mode, getting signals from the O2 sensor, the sole *output-like*[10] sensor. Not the way I would do it because I am a big believer in the value of honest feedback. Or the way cars do it.

Some cars have O2 sensors on each exhaust manifold and both before and after their cat converter. Makes sense for a car. But it may be wisest for a sport bike not to seek output-like feedback because waiting around even milli-seconds for feedback and being unduly tethered to its sometimes-idiosyncratic verdict may not be sporty enough. As confirmation of my opinion, the new HP2 super-super-sport bike has two sensors and they are mounted inches from the two sets of exhaust valves.

Except for fairly stable and steady highway driving, the ECU isn't running closed loop. It "looks away" from the O2 sensor when you move the throttle and it doesn't use the O2 sensor at very low speeds (this may be because of the small throttle angle) or in the upper power band either. When the ECU is not closed-loop and you are doing energetic riding, it runs in map-mode at a power-proper 13.8 give or take, which is still in the quite broad 98% max power band. This seems a bit rich to me based on smell and certainly compared

[9] A long footnote I've since removed from here discussed my experiences on a certain bulletin board.
[10] *Power* is the real output variable but oxygen content is a loose reflection of it.

to other refined bikes. But drivability is good and if the A/F were truly lean, the drivability might not be as good.

When it is running closed-loop mode, the ECU pushes the A/F towards stoich but stays on the rich side of stoich… which may still cause a tiny power loss. That sense of loss may be the root of that awful surging feeling as it moves in the stoich direction and just out of the max max power band (see chart above). But even when in the vicinity of stoich, the engine should be developing maybe 95+% of its power. Nice to see that so many riders are sensitive enough to feel the surging. Interesting.

My impression is that fuel consumption is possibly 2 mpg less in feedback mode. Unfortunately, try as hard as I can, I can't keep the bike a steady 70 mph for an adequate length of time for standardized, closed-loop-only mpg testing.

Another thing I wouldn't imitate BMW in doing, the injectors spritz simultaneously even though one is pouring gasoline into the intake manifold during the stroke when the intake valve is closed! If one side it timed optimally apropos the crank cycle, the other spritz has to be awfully timed and hence somewhat wasteful. Seems a thoroughly stupid minor economy (changed in 2006 models, I think). Given the trivial computing effort needed to time the spray for the appropriate moment alternating cylinders, seems pretty crude (the main expense would be an additional power transistor to handle the second injector cylinder separately).

ECUs *can* be very smart but that requires more and wiser sensors and more attention to the O2 output sensor or, in the case of new cars, multiple O2 sensors in each manifold and before and after the cat converter. For example, on some K-bikes with a different kind of ECU logic, there is measurement of the actual mass of air being inhaled… rather than a vague guess based on the angle of the butterfly (and air temperature and pressure) without reconnaissance of the actual intake vacuum.

Still to be determined is whether the Motronic 2.4 is a learning ECU, as Brad Black maintains. It is clear that the ECU needs the "two twists" treatment after a power-down (power-down requires pulling the fuse or battery ground strap because the ECU memory stays powered even with the ignition switch off). But it is not clear if the ECU would learn the full-range anchor points of the TPS over time — assuming that day ever came when you twisted the throttle beyond 60%. Brad Black, who I greatly respect, feels there is much more stored away in memory over time.

Topics

General observations

As mentioned, I've been taking air-fuel ratio readings using the stock O2 sensor. My machine has (1) a superior after-market intake system for an R1100S, (2) no Techlusion 1031 enrichment (or the 1031 disconnected which takes 20 seconds), and (3) the O2 sensor disconnectable. Since cleaning my injectors and of course, being persnickety about synch of TBs, I haven't definitely detected surging with the stock set-up or any other way. So I would conclude that surging isn't inevitable even with mods as here.

With the O2 switched out, the engine will scoot around at about 13.2-13.5 but will go leaner during more stable times and seems to go even leaner for very stable-throttle cruising. The earlier chart says 13.2 is roughly max power, with the 98% band running from about 11.0 to 13.8. Do you really need a $500 PCIII (plus cost of dyno time and annual replacement of expensive wide-band O2 sensor) to pinpoint fueling when all you need to do is to land inside that broad range?

Why do I see A/F fluctuations? These may be due to burning city sludge off the O2 sensor or other heat-related sensor issues, possibly the ECU correcting the mix based on long-term stored memories, learning, or perhaps complex algorithms are unfolding as they should.

Broadly speaking, choice of gear has only a small and unpredictable influence on A/F. That is not the way a bike should be run because it fails to take load into account. The sweetest, leanest running seems to be nudging up to 5000 rpm in 4^{th}… which should exceed the speed limit in most jurisdictions.

For max economy, environmental friendliness, and/or for protection of the expensive and beneficial cat converter, you need to be near stoich. If that is where your heart is set, the optimum mixture is somewhere the lean side of stoich. But counteracting pollution from each of various chemicals follows different (and individual) mixture ratio curves. By and large, worrying about pollution on a performance bike will drive you crazy, even if it helps save the earth. Given the difficulty of fueling, the stock chip ECU does a reasonable job balancing all factors. Your call.

Comments about the Techlusion *1031*

The Techlusion 1031 adds as much or as little fuel as you choose. The O2 sensor is disabled when you use the 1031. No sweat changing the settings every morning if the 1031 is mounted conveniently under the seat and you tuck a little screwdriver with a pocket clip into your shirt pocket. It provides two broadly adjustable shelves of enrichment (set by low and high rpm range screws), adding an increment to the already not-too-bad ECU map. You can choose the speed at which you crossover between these two shelves, adding more or less to the lower shelf or higher shelf separately. It also has a control for enrichment during acceleration periods. This is based on principles that cannot be explained to me or other ordinary people.

I have a 1031 and liked it very much before cleaning my injectors (see my report on cleaning). At the moment, the bike is running so well without the Techlusion, not sure where to go from here. For sure, the Techlusion lets you bring out the best and represents an opportunity to fine-tune the ECU. In addition, I don't believe there is an accelerator function in the stock ECU, so that is a strength of the Techlusion.

Techlusion also have a model 259 that does embrace the O2 sensor information. Techlusion (like everybody else) seems unwilling to reveal much about how it works. But the company tends to think customers would be happier with their cheaper 1031.

Comments about the Dynojet *Power Commander III*

The PCIII supplants the ECU's judgment pretty much by over-riding the A/F called for by the ECU and trimming it to the set value for the PCIII O2 sensor (13.8 is the PCIII recommendation). The PCIII manufacturer claims the use of a wide-band O2 sensor makes it possible to run closed-loop across a much wider range of throttle openings (to 75%) and speeds (to 6500 rpm) but, I suppose, not at real low rpms either. But narrow-band sensors work just fine across the whole A/F range of interest and can be "fooled" with a "pot" (potentiometer) into richer settings than stoich[11]. The stock ECU appears during my observations to be in closed-loop mode sparingly but the PCIII runs closed-loop all the time, piggy-backing on *whatever* the ECU wants to spritz.

Of course, the stock map is based on a vast amount of testing investment by BMW. The PCIII map is based on your setting for the O2 set-point and outside that area (6500 rpm, 75% throttle), on dyno runs.

The PCIII piggybacks or supplants the ECU much more comprehensively than the Techlusion. It deprives the ECU of O2 information (well, hijacks it and replaces it with its own wide-band sensor that it reads itself) and independently senses throttle position and presumably crank position (hence, rpm) so as to work with your own personal 2D fueling map.

As far as I can tell, only the ECU (and not the PCIII) has access to barometric pressure, air temperature, and oil temperature information. While barometric pressure is of some importance, the temperature sensors provide modest trim factors, perhaps of greatest importance for starting. With a PCIII connected, these still influence the ECU. But that doesn't matter, because the PCIII over-rides the ECU, based on O2 readings. Some say the PCIII starts poorly; I think the reason for that is the sensor is cold.

One point that seems to confuse riders a lot is the relationship of ECU control and PCIII control. Confuses me too. However, in closed-loop operation, only one of the units can be "King" and that would be the PCIII. It is anybody's guess what happens during acceleration when TBs and carbs go funny.

For the stock ECU, you can trick the O2 feedback a bit using a potentiometer, but

[11] Or with active circuitry, lean settings too. Some new gizmos now coming on the market may act this way… as a kind of poor-person's PCIII.

awkwardly. The PCIII lets you program any A/F criterion you want for closed-loop operation and then it tries to adjust the spray length to that criterion at all speeds, throttles, states of acceleration, etc. in its region (under 75% throttle, 6500 rpm).

It takes an enormous corporate effort to do fueling engineering, whether by carb or by EFI. Anyone who has traded carbs on their vehicle knows this. A great variety of possible *normal* operating conditions need to be successfully addressed and all kinds of *rare* conditions that might have dire consequences need to be addressed too. All manufacturers have to spend the time needed to iron out the kinks, otherwise their bikes would seem to run pretty defectively or be subject to rare but costly failures.

The stock ECU is not so bad… maybe it skirts leanness at times in close-loop mode in order to promote fuel economy and to protect the catalytic converter from carbon burning damage. But more often it skirts richness to ensure the engine has all the fuel it needs for odd conditions and to forestall heating and detonation.

The stock ECU rarely goes too close to stoich and generally runs around 13.8 or richer and that is just dandy for max power. Unless you resolutely keep your hand steady on the throttle, it won't readily ramp down to a leaner, closed-loop A/F because it just doesn't pay a lot of attention to the O2 feedback signal.

The familiar whole-bike (AKA chassis) DynoJet inertial dyno simulates a quarter-mile race, very peculiarly done all in 4th gear. The dyno operator gets on the bike, warms it very briefly, kicks it into 4^{th} gear, and then urges on the throttle to the max as fast as he or she can. That's why I say it kind of simulates a funny straight-line road race. Any tardiness would result in overheating of an air-cooled engine and funny run data.

Therefore running a PCIII on a dyno is tuning to an unrepresentative dyno criterion, which has little to do with real street riding. While an inertial dyno is a reasonable way to measure max power, it bears pretty uncertain relationship to any kind of biking outside the shop[12]. BTW, I suppose it would take a fan powered by 100 HP to provide a cooling breeze sufficient for sustained testing for a bike that produces 100 HP!

It should be noted for the benefit of those with Power Commander III units who think very fine tuning of the mixture on a dyno indoors in 4^{th} gear is important, that it isn't important. I suspect you are as likely to screw up the mixture as help it if you get into micro-managing the A/F based on the rather special conditions of 4^{th} gear dyno testing.

Of special note, it takes a self-heated (4-wire) narrow-band O2 sensor about a mile from a cold start to reach operating temperature. When cold, the sensor indicates profound

[12] The other kind of DynoJet dyno can impose variable loads on the bike and hold the bike on those loads indefinitely (or as long as the fan does its job). Contrary to my skepticism about tuning a PCIII on an inertia dyno, the variable load dyno can be used more appropriately. It can also sniff A/F better. But these dynos are uncommon.

leanness, only getting up to correct readings slowly[13]. Idling does not provide full warming to the sensor although the sensor does not seem to cool when idling after being warmed up fully.

A main way we sense power on the butt-dyno is by twisting the happy knob (AKA throttle). I believe the stock ECU has no provision for acceleration enrichment and in fact, based on my observations, goes lean at first like a carb would; on the other hand, whenever you twist the throttle, the stock ECU ceases to listen to the O2 sensor and therefore goes back to it usual rich A/F (well, proper max power A/F) which should have the effect of boosting power but not until the later parts of your acceleration. CV carbs are smarter in this respect.

Some models of the PCIII have provision for acceleration pumping and so does the Techlusion. I don't know how this coordinates with the PCIII being close-loop all the time. And even more smartly conceived, the 1950's SU carb with seasonally managed oil dashpot from my 1961 Jag MkII has really clever acceleration enrichment. How far have we come with fueling?

In summary, I join Adam Wade in being puzzled over the benefits of installing a PCIII since early reports appear to indicate that it keeps the A/F ratio right about where the ECU would keep it if you disconnected the stock O2 sensor.

What a PCIII can do is control the A/F mixture better than the ECU when closed-loop, ensuring the mix remains in the broad max power mix band while not going overboard making it too rich or too lean. Wade says it is a good if expensive way to economize on gas. Compared to a Techlusion (which would produce the same or better performance by ensuring the bike is never leaner than the ECU dictates), at present gas prices, a PCIII possibly could pay for itself in 50,000 miles… not counting the number of expensive wide-band O2 sensors you'd have to replace in that period of time.

Comments about the *FRK*

Somebody in Europe developed the FRK, dunno who. But it is being flogged in North America as the no-adjustment, plug-and-play fix-all. Wouldn't that just be a great mod!

You tell 'em your model and for a few hundred dollars, an FRK comes in a totally epoxy-sealed box (which hides the innards from inquiring eyes). You unplug the ambient air temperature sensor, plug in the FRK, and then plug the sensor back into the circuit. Simple.

About half the riders who install one are deliriously happy. The other half phone the supplier, relate their sad tale to him, he explains there have been some mix-ups in the

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[13] Ever wonder why there are really weird super-lean A/F shown on dyno charts at the low-rpm start of the run. Now you know.

mail (at least that is what some Pelican posters said he said), and sends you the "right" one… and then it always works just deliriously great.

Now here is what is going on. I am going to explain this just once because some readers will wonder why *any* explanation is needed for such a self-evident device while the others never seem to get it (and they continue to believe the FRK has elf's dust or something magic blown into it).

The ambient air temperature sensor tells the ECU what temperature is the air the engine is inhaling. When the air is cold (hence, dense), the ECU has to add extra fuel to make the A/F right. When the air is normal riding temperature, it adds nothing extra. When the sensor is cold is reads, say 7,000 ohms. When it is kind of regular riding temperature it reads say 1,500 ohms, a difference of 5,500 ohms. As I read Brad Black's table of trim factors, which would enrich the A/F by roughly 8-10%. While there's no advantage to pin-pointing A/F on a bulls-eye at the mystical "14.7," most riders kind of like a bit of extra richness and rarely mind a bit of over-richness, as I've argued elsewhere.

An FRK, is a fancy box, well-sealed to prevent snooping. It contains a 5,500 ohm, 30-cent resistor. But if you complain to the supplier about idling or dogged-running, you'll be sent one that contains a 3,500 ohm resistor. These are just my ballpark figures – you can look up the exact ones that suit your latitude on the Bosch air temperature spec sheet.

But remember, you are wiring in-series a 5,500 ohm resistor while your ambient air temp sensor ordinarily will be around 1,500 ohms while riding on a nice day. In other words, the sensor is no longer "talking" to the ECU, only the far larger FRK resistor is. So you've lost almost all functionality from the sensor unless you go riding when it almost arctic temperatures, in which case, the sensor kicks in again.

Good idea? It enrichens the mixture and, within limits, should make a lot of riders a bit happier, if not quite delirious.

Any problem that it over-rides the good judgment of the BMW engineers? No big problem, that's the owner's privilege. True, it can screw up and/or confuse the ECU a bit at idle, cold start, etc. But that may be very minor. Also, it is clear that many riders — especially some that have done bolt-on mods — are all together exaggerating the risk of being too lean and in danger of pooping in their pants from fear, needlessly.

According to a knowledgeable fellow at RhineWest BMW, the ambient air temp sensor does not influence spark timing. So that makes it a kind low-class if expensive mod, at least compared to re-chipping or a RapidBike 3. But sometimes you've got to pay Big Bucks for plug-and-play convenience.

Costing hundreds of dollars and vastly overpriced compared to the R&D (which might be little at all) and the parts (the connectors being the only parts costing more than a dollar), is it worth it? Not to anybody who has ever connected two wires together and it sure would be no trouble to solder a 30-cent resistor in place yourself… like owners of older

VWs who have been adding these ambient air temperature sensor resistors for years.

Ben's recommendation

My impression is that an R1100S will run really nicely without or without the O2 sensor. But *without* the O2 sensor, you'd have somewhat more drivability (broader gear ranges, low end grunt, engine plushness…) and less chance of surging and a mite more power. *With* the O2 sensor, you'd have more economy if you ride the superslab much.

But if you've made modifications to significantly improve breathing (after reading my report on air flow in different filter media, of course) here's the smartest thing to do: make a "fooler" that will make your ECU think it is running leaner during those uncommon closed-loop periods than it is and therefore… you get the idea[14]. Simple as that:

http://better-mileage.com/memberadx.html

Well, simpler would be to install a Techlusion!

Or do this: pull back the loose cable sheathe on the O2 cable a few inches at the ECU connector end and snip the black wire. Goodbye O2 signal.

Or try interrupting the black wire and insert a SPST switch mounted conveniently. If you don't know what a "SPST switch" is, you are not ready for this mod. None of these wires are shielded or otherwise esp. sensitive; but having said that, I'd slip on a split ferrite bead suppressor anyway because the ECU cable does have shielding on the signal wire. With a switch, you could run *without* the O2 sensor for sporty (if somewhat polluted) riding and *with* the O2 sensor for economy on trips… not that you could really tell the difference in power. Prolly unsound to switch while the main key power switch is on although the ECU has its own unswitched power access always on anyway to maintain some stored parameters (let me know if you tried to switch while riding and if that annoyed the ECU). Simple as that.

You read it here first.

Practical note about why pure theory (as held by other people, of course) breaks down

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[14] There is an interesting circuit – a very creative use of the familiar LM3914 dot-bar generator for evenly stepped voltage control purposes – that you can make to dial-in any A/F from leanish to richish, as a kind of adjustable fooler. Sadly, the R1100S polls the O2 sensor rarely so the benefit is limited to occasional closed-loop operation.

In the comments below, I can speak only about what I see in the Motronic 2.4 and not sure how the R12S ECU might differ.

In thinking about fueling, there are number of critical issues that he or Roger for that matter, may not have a satisfactory handle on.

1. Of greatest importance, nobody has a sense of how often people jog their throttle. Each time you jog it, you return to map (static) mode that is not lean, unlike feedback (closed-loop). Hint: a couple of times a minute, unless you've fallen asleep.

2. Nobody has a sense how big of a jog is needed to return to map mode or how little a jog will keep you closed-loop.

3. Nobody has a good sense at what point at low throttle settings, you are committed to map mode. Related to that, and to Deans BMW observations, nobody has a good sense at what road speeds and gears you are in that range since you can't just eyeball the degree of throttle advance. Likewise, nobody is sure where the ECU thinks WOT begins (80%???) or when riding, actually knows when you hand gets there.

4. Nobody has a good sense how long it takes for the ECU to decide you are no longer moving your throttle and/or accelerating (PCIII is very fast, but stock ECU is not).

5. Nobody has a sense of how fast the ECU segues into close-loop mode once it decides you are no longer accelerating.

By now - finally - there's no serious dispute about the general outlines of the alpha-n 2.4 software architecture. But without a good sense of these issues, a lot of discussions are poorly anchored in the real-world.