Subaru Knock Monitoring FAQ

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Brief Background

Thanks to the power of the AccessPORT and AccessTUNER software, it’s now easier than ever to gain unparalleled insight into the current status of your engine’s tune and running condition at any given time. Monitoring for detonation and knock is likely the most frequent topic we receive inquiries on. Subaru’s factory knock control strategy is somewhat complex, though with some basic knowledge the picture is much clearer. First, a few items to remember:

• Detonation events are inevitable and will occur from time-to-time on any modern vehicle running on pump gas. Properly advanced ignition timing is important for maximizing fuel economy and power output while minimizing tailpipe emissions; in many instances this timing value is at the edge of the knock threshold for pump fuels and occasional detonation is the result as external conditions vary slightly. This is why all factory EFI implementations feature knock detection and control systems.

• No detonation/knock detection system is perfectly accurate. We choose to err to the side of safety when it comes to listening for and responding to noise detected from non-detonation causes (“false knock”).

Relevant Monitors

• Dynamic Advance Multiplier (DAM): This value represents a global adjustment to ignition timing. In general this value is determined by historical detonation/knock as well as the default mapping value. For the 2.5L ECU DAM is stated as a decimal ranging from 0 to 1. For the 2.0L ECU DAM is stated as an integer between 0 and 16. DAM will tend to vary the most immediately following a reflash or ECU Reset procedure.

• Feedback Knock Correction: This value represents a current realtime minor timing correction made by the ECU in response to a perceived noise. Feedback Knock Correction is the default correction used by the ECU. The ECU will “respond” with this monitor by immediately removing timing and then slowly decaying the value back to zero assuming no further noise is detected.
• Fine Knock Learning: This value represents minor learned corrections currently being applied by the ECU as a product of historical noise. These values are reset if the DAM value is changed; once DAM has stabilized, any learned corrections will be intermittently evaluated for sanity when certain thresholds/conditions are met. Fine Knock Learning is learned (and thus applied) for specific ranges defined by load and RPM; once a correction value has been learned into a particular range, it will be applied whenever the engine is operated within that range.

• Knock Sum (where applicable): This is a somewhat arbitrary value that should only be analyzed under the specific conditions you wish to evaluate, such as during wide-open throttle (WOT) operation over a set RPM range. Some later ECUs can report this on a per-cylinder level, some only on a global basis. If a noise is perceived, this value will increment at all times, regardless of if the knock detection system is deemed to be accurate or not, such as idle and very low RPM.

Frequently Asked Questions

Q: What type of logs should I take to monitor for detonation/knock?

A: The default logging list on the AccessPORT will include the relevant monitors, so that is a great place to start. In general, detonation and knock will be most dangerous when cylinder pressures are highest, which will usually occur during full power (WOT) operation. In general, a log over a singular gear through the full RPM range (from 2000 RPM to redline) is sufficient for a street car; for a race car you should consider logging longer sessions that includes gear shifts. Making sure to keep your logs short (IE, start and end the logging session when appropriate) will help prevent from having to filter through large quantities of irrelevant data.

Q: What is detonation or knock? How is it detected by the ECU?

A: "When unburned fuel/air mixture beyond the boundary of the flame front is subjected to a combination of heat and pressure for a certain duration (beyond the delay period of the fuel used), detonation may occur. Detonation is characterized by an instantaneous, explosive ignition of at least one pocket of fuel/air mixture outside of the flame front. A local shockwave is created around each pocket and the cylinder pressure may rise sharply beyond its design limits." From a more succinct technical perspective, "Knock is the explosive spontaneous ignition of fuel/air mixture ahead of the normal propagating flame and the subsequent cylinder pressure oscillations." Audible detonation is often referred to as “pinging” due to the sound created; knock takes its namesake from the audible sound created by the event (much like a fist knocking on a door) and is sometimes also known is pre-ignition. To facilitate detonation detection, a Piezoelectric microphone sensor is hard-mounted to the engine block and relays detected noises to the ECU, where they are further filtered to hone in on the specific frequencies generated by detonation in an attempt to accurately determine their source and relevance. The timing of these events...
relative to the measured crank shaft angle is used to estimate the source cylinder(s) by more advanced recent implementations.

Q: What causes detonation and/or knock?

A: In short, any number of conditions or factors can induce detonation. The sources are highly variable but in general, increased cylinder pressures and/or temperatures or reductions in effective octane level are the common “causes”. The factors that lead into those are again varied, but from a tuning perspective, detonation and knock occur:

- When the engine speed is low and the manifold absolute pressure (MAP) is high
- When combustion duration is long
- When temperatures are high (ambient, coolant, combustion chamber surface)
- When the charge dilution is low
- With high carbon deposits
- When the spark advance (or injection timing) is high

As can be seen, the “big three” of boost, ignition timing and air-fuel can all play an integral part in causing or contributing to detonation/knock.

Q: When is it common to see corrections? Are these of concern?

A: There are some known situations where it is very common to see timing corrections in response to perceived noise. In general, these events are not of concern and should not be particularly alarming unless the corrections are very large. The corrections made during these scenarios are often due to shifting or rapid movements within the drive train and not necessarily to harmful noises generated within the engine:

- On from-stop takeoffs while clutching out
- During gear shifts (this can be exacerbated by “power shifting” or using FFS)
- While attempting acceleration at a low RPM in a high gear
- Under cruising-type conditions at freeway speeds
- After sharply pressing/depressing the accelerator pedal

Q: When should I be concerned about detonation/knock? What are some things to try or items to check?

A: This is probably the most difficult question to answer but in general, we consider corrections of ~2.5 degrees to be “normal” and not of major concern. If DAM is persistently below 1 or 16 and/or corrections
greater than -2.5 degrees are repeatedly observed to the “Feedback Knock Correction” or “Fine Knock Learning” monitors, this is good reason for further inspection.

Not all detonation and knock events are created equal. Depending on the size of the event and the conditions under which it happens, the level of harmfulness for the engine’s internals can range from perfectly harmless to fatally catastrophic. The former is very common for an engine running on pump gas; the latter is extremely rare but the risk is very real. In general, the events of little to no concern are those that happen at low throttle and boost levels – what we commonly refer to as “cruising” conditions. It is much more concerning to observe repeated knock events when cylinder pressures are very high, such as during full boost WOT operation as the chance of engine damage from knock is much higher under those conditions.

If you are running a COBB Tuning OTS map, try switching down to a map intended for a lower octane level, such as to the 91 octane map if you’ve been using the 93 octane map. You should also try the “LWG” mapping version, as this will help to lower boost levels. Assuming you are using normal pump gasoline, be sure you are using the highest grade pump fuel available in your area (please see below for more information about octane rating); discount gas retailers often have inconsistent quality or come from varied sources.

Common mechanical causes worthy of inspection are worn MAF or front O2 sensors, boost/intake tract leaks, excessive blow-by, etc. Additionally, please be sure to review the map notes to ensure the hardware on the vehicle properly matches the chosen map and that the boost levels being achieved are within the acceptable ranges for that particular map. If overboosting is occurring, detonation/knock may be more prevalent.

Q: If detonation or knock is detected, how is it addressed by the ECU?

A: The first line of defense for the ECU to protect the engine is to actively retard ignition timing as this will decrease cylinder pressures and increase the charge’s resistance to detonation. Depending on certain conditions (primarily Dynamic Advance Multiplier), if the current level of resistance to detonation is poor enough to warrant additional actions, an alternate richer fueling table will be activated and the boost control will be disabled. A richer mixture, to a point, will have a higher resistance to detonation and helps removes heat from the combustion chamber. Conversely, an overly rich mixture can induce detonation as well, especially without properly advanced ignition timing to account for the longer combustion times.

Q: What is pre-ignition? Is it different than detonation?

A: While often used interchangeably, the terms detonation, knock, and pre-ignition, depending on interpretation, can refer to different events. It generally refers to the complete loss of control over the full combustion event. “Pre-ignition (or preignition) in a spark-ignition engine is a technically different phenomenon from engine knocking, and describes the event wherein the air/fuel mixture in the cylinder
ignites before the spark plug fires. Pre-ignition is initiated by an ignition source other than the spark, such as hot spots in the combustion chamber, a spark plug that runs too hot for the application, or carbonaceous deposits in the combustion chamber heated to incandescence by previous engine combustion events.\textsuperscript{iv} Again, the succinct technical description as given by Atkins: “Pre-ignition, or runaway ignition, is ignition in the combustion chamber prior to spark discharge.”\textsuperscript{v} As a very general rule of thumb, small and singular observed timing corrections are caused by light detonation events; any event that is observed to require a “rapid-fire” response of multiple increments is likely due to severe knock or outright pre-ignition.

Q: What is octane rating and how does it affect detonation and knock?

A: By definition, octane rating is determined by the fuel’s ability to resist uncontrolled ignition; it is quite literally referred to as the “anti-knock index” (AKI) and is an average of two different methods for determining the theoretical resistance to detonation/knock relative to a reference fuel or engine operation conditions (RON and MON; AKI is calculated as “(RON+MON)/2”, which is the common marking on fuel dispensing pumps). “Higher octane ratings correlate to higher activation energies: This being the amount of applied energy required to initiate combustion. Since higher octane fuels have higher activation energy requirements, it is less likely that a given compression will cause uncontrolled ignition, otherwise known as autoignition or detonation.”\textsuperscript{vi} Thus, the octane rating of the fuel being used will have a direct impact on the engine’s ability to resist detonation and knock. You should always use the “premium” pump fuel available in your area; we also suggest the exclusive use of fuels from Top Tier Retailers\textsuperscript{vii}, when possible. Due to the differences in burn times when octane is raised significantly, you should consult your tuner before running fuels with octane ratings that appreciably exceed those of normal pump fuels (100+ octane).

Q: I am monitoring “Knock Sum” for each cylinder on my car and see values over 100! What’s wrong with my car and/or tune?

A: In all likelihood, nothing! The knock sum value itself is meaningless because it will increment even at idle/low RPM where the Subaru knock detection set-up cannot accurately distinguish between combustion detonation/knock and other engine noise. You need to look at when it is incrementing, putting more emphasis on consistent reported knock at higher load (such as during wide-open throttle). Keep in mind that every tune (even the factory tune on a bone stock car) will report knock events on occasion. Some of these will be false knock (especially if it is at lower RPM/load) and some may be actual knock where the ECU takes the appropriate steps to decrease timing (and learn those corrections depending on the conditions). Also, some cylinders will be naturally more prone to incrementing this value where the system is not accurate. Fear not, your car did NOT knock 100 times!


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