

TCR Turbocharger Boost Monitoring Method

2021-03-29 | This document describes the turbocharger boost monitoring method applicable in TCR series. For clarification requests, please contact the authors.

1 Method Description

The purpose of this method is to detect violations of allowed values, which are derived from the certification procedure introduced by WSC technical department and published in *TCR Technical Bulletins*, whilst taking into consideration the characteristic behaviour of turbocharger boost pressure in an internal combustion engine.

1.1 Measurement

Manifold air pressure and temperature are measured via TCR scrutineering sensor at a sampling rate of 100 Hz and 10 Hz respectively. Engine speed, throttle pedal position and front brake pressure are collected from the engine control unit of the car at a sampling rate of 100 Hz. In this document, measurements are referred to using the following names and units (in order as above): $p_{ManifoldScrut}$ [mbar], $t_{ManifoldScrut}$ [°C], f_{EngRpm} [1/min], r_{Pedal} [%], p_{BrakeF} [bar]. The current time step at any given moment is referred to using the letter t .

Should a car not be equipped with a scrutineering sensor for manifold air temperature, the manufacturer installed sensor may be used as a fallback solution to be used in this method **at the explicit responsibility of the technical delegate**.

1.2 Core Working Principle

Rapid fluctuations on the measurements are removed via a smoothing strategy. The smoothed value $p_{ManifoldSmooth}$ is then compared to a limit $p_{ManifoldLimit}$. The limit is a function f_{EngRpm} and $t_{ManifoldScrut}$.

If $p_{ManifoldSmooth}$ exceeds $p_{ManifoldLimit}$, the delta is normalized on a 1 s time span and added to the *overboostMemory*, which fills up until it reaches its capacity limit and triggers a *boost violation*. If $p_{ManifoldSmooth}$ does not exceed $p_{ManifoldLimit}$, the memory slowly drains. Additionally, conditions exist which empty the memory immediately or enforce drainage of the memory.

1.3 Conditions

(a) *driverCondition* is true if

$$rPedal(t) \geq 50.0\% \quad \text{AND NOT} \quad pBrakeF(t) > 10.0\text{bar} \quad (1)$$

(b) *fEngRpmSteady* is true if

$$-1500 \text{ 1/min} < fEngRpm(t) - fEngRpm(t - 15) < 2500 \text{ 1/min} \quad (2)$$

for at least 15 time steps with a hysteresis of 5 time steps

1.4 Smoothing

The boost pressure is smoothed using *Exponential Moving Average* with an alpha of 0.1, i.e.

$$\begin{aligned} pManifoldSmooth(0) &= pManifoldScrut(0) \\ pManifoldSmooth(t) &= 0.1 \cdot pManifoldScrut(t) + 0.9 \cdot pManifoldSmooth(t - 1) \end{aligned} \quad (3)$$

1.5 Limit

The limit *pManifoldLimit* as specified by WSC is defined by

- a set of interpolation support points *supportPoints* for manifold air pressure ([mbar]) at different engine speeds ([1 / min]), published via *TCR Technical Bulletins*
- a correction factor (*cFactor*, [mbar/°C]) used in a formula which is function of *tManifoldScrut*

and calculated via linear interpolation between the interpolation points using *fEngRpm* at time step *t* and adding an offset for temperature correction, i.e.

$$pManifoldLimit(t) = interpolation(supportPoints, fEngRpm(t)) + correction(t) \quad (4)$$

where *interpolation(supports, fEngRpm(t))* is not further explained and

$$correction(t) = max\{cFactor \cdot (tManifold(t) - 40^\circ\text{C}), 0.0\} \quad (5)$$

Be advised:

- Below the RPM range where limit support points are defined in the technical bulletin, the first limit support point will be used as a limit.
- Above the RPM range where limit support points are defined in the technical bulletin, the last limit support point will be used as a limit.

1.6 Overboost and Memory

An overboost is calculated by subtracting $pManifoldLimit$ from $pManifoldSmooth$ and normalizing the result on the execution frequency of 100 Hz. The normalization adjusts for the boost violation tolerance of 30 mbar/s.

$$overboost(t) = (pManifoldSmooth(t) - pManifoldLimit(t)) / 100 \quad (6)$$

If $driverCondition$ is false, the memory is emptied. If $overboost$ is ≤ 0 or $fEngRpmSteady$ is false, the memory is drained by 5 mbar/s (as long as there is something in the memory). Otherwise, $overboost$ is added to the memory.

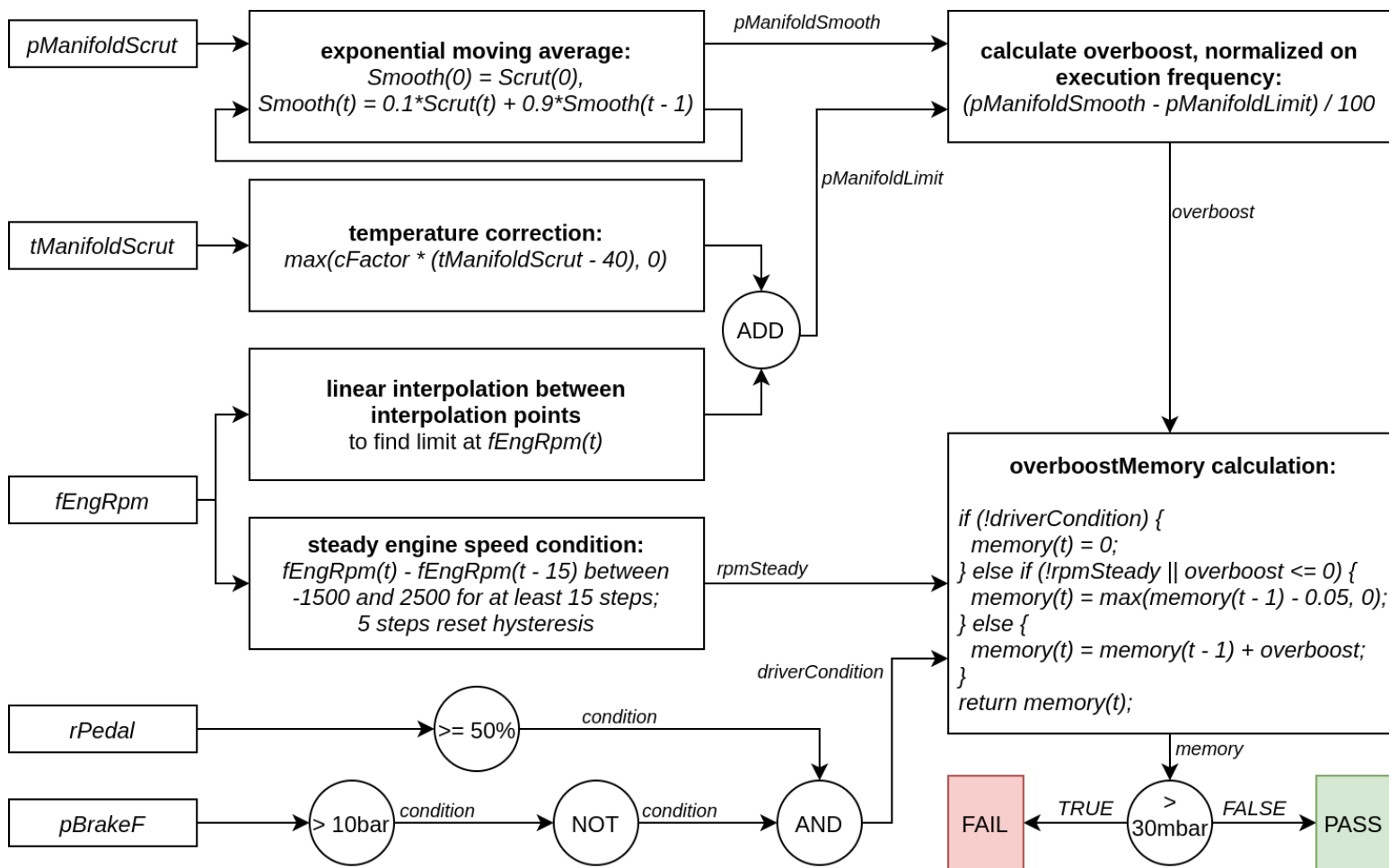
$$memory(t) = \begin{cases} 0.0 & \text{if NOT } driverCondition(t) \\ \max\{memory(t-1) - 0.05, 0.0\} & \text{if NOT } fEngRpmSteady(t) \text{ OR } overboost(t) \leq 0 \\ memory(t-1) + overboost(t) & \text{otherwise} \end{cases} \quad (7)$$

1.7 Violation

A boost violation for a lap is registered if the memory exceeds 30 mbar.

2 Block Diagram

The following block diagram is executed for every time step t . $pManifoldScrut$ and $pManifoldSmooth$ are shortened to $Scrut$ and $Smooth$ in the exponential moving average block. $fEngRpmSteady$ is shortened to $rpmSteady$ in the memory calculation block.



3 Document Information

This decision is with immediate application and valid until further notice on the subject.

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