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): *pManifoldScrut* [mbar], *tManifoldScrut* [°C], *fEngRpm* [1/min], *rPedal* [%], *pBrakeF* [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 *pManifoldSmooth* is then compared to a limit *pManifoldLimit*. The limit is a function *fEngRpm* and *tManifoldScrut*.

If *pManifoldSmooth* exceeds *pManifoldLimit*, 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 *pManifoldSmooth* does not exceed *pManifoldLimit*, the memory slowly drains. Additionally, conditions exist which empty the memory immediately or enforce drainage of the memory.

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1.3 Conditions

(a) *driverCondition* is true if

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

(b) *fEngRpmSteady* is true if

$$-1500\,{}^{1}/_{\text{min}} \;<\; fEngRpm(t) - fEngRpm(t-15) \;<\; 2500\,{}^{1}/_{\text{min}} \tag{2}$$

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.

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

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.

$$pManifoldLimit(t) = interpolation(supportPoints, fEngRpm(t)) + correction(t) \tag{4}$$

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

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

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.

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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.

$$overboost(t) = (pManifoldSmooth(t) - pManifoldLimit(t)) \,/\, 100 \tag{6}$$

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.

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

1.7 Violation

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

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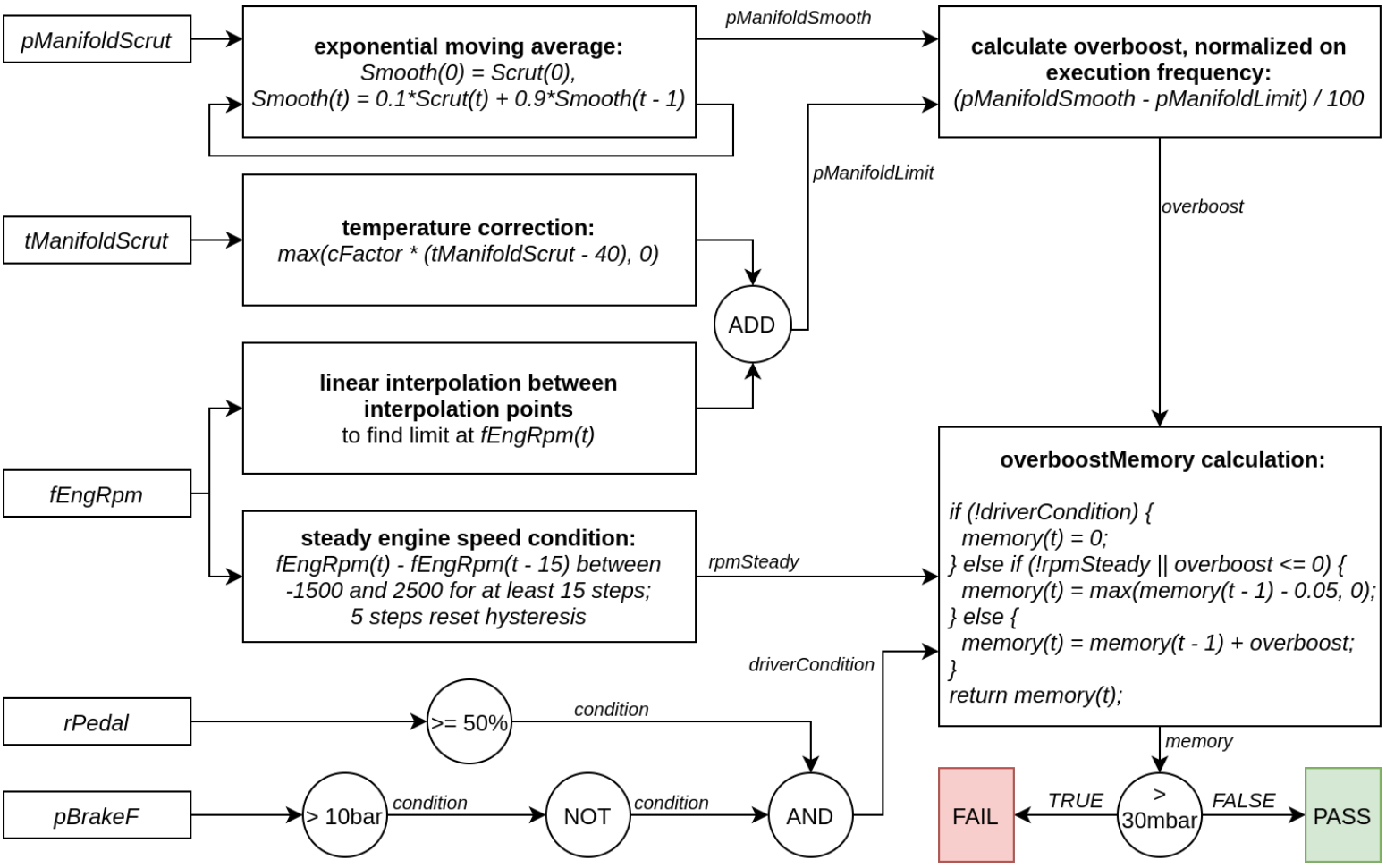
2 Block Diagram

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.



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3 Document Information

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

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