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. Changes since last version are marked.

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.

~~The purpose of this monitoring method is the detection of advantages gained by competitors beyond the parameters set by the Balance of Performance definition. For practical purposes in the context of turbocharger boost pressure, the following is defined:~~

~~*The competitor has gained an advantage when the turbocharger boost pressure produced by the engine of the car exceeds the limit defined by WSC technical department on more than 0.3 % of all measured data points per lap.*~~

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**. ~~Measurements of turbocharger boost pressure are taken in the intake manifold of the engine using the "TCR Scrutineering Turbocharger Boost Pressure Sensor" as specified in the TCR ECU Installation Manual, hereinafter referred to as the "boost sensor". The sampling rate is 100 Hz for the boost sensor. Engine speed (RPM) is sampled at 100 Hz. Intake air temperature measured via TCR scrutineering sensor is sampled at 10 Hz.~~

~~In the following, the boost sensor values are also referred to as *pManifoldScrut* and the values measured by the scrutineering intake air temperature sensor are also referred to as *tManifoldScrut*~~

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respectively, as these names are the names of the channels in the scrutineering data logger. All values are given in their original naming.

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.

1.3 Conditions

(a) *driverCondition* is true if

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

The monitoring will be applied if

(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

- the launch limiter is not active
- the speed of fastest front wheel does not exceed speed of fastest rear wheel by more than 8 km/h (wheel spin detection)
- more than 300 ms have passed since the last gear shift request

1.4 Smoothing

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

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

where *pManifoldSmooth* is the smoothed value and *t* is one time step.

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1.5 Limit

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

- a set of interpolation support points *supportPoints* for manifold air~~turbocharger boost~~ 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*~~engine speed~~ 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

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

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.

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.

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

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1.7 Violation

A boost violation~~violation of the boost limit~~ for a lap is registered if the memory exceeds 30 mbar ~~at more than 0.3 % of all time steps t in a lap the limit is exceeded by *pManifoldSmooth*. A "lap" is defined as the collection of data points at all time steps between two lap trigger events as recorded by the scrutineering data logger.~~

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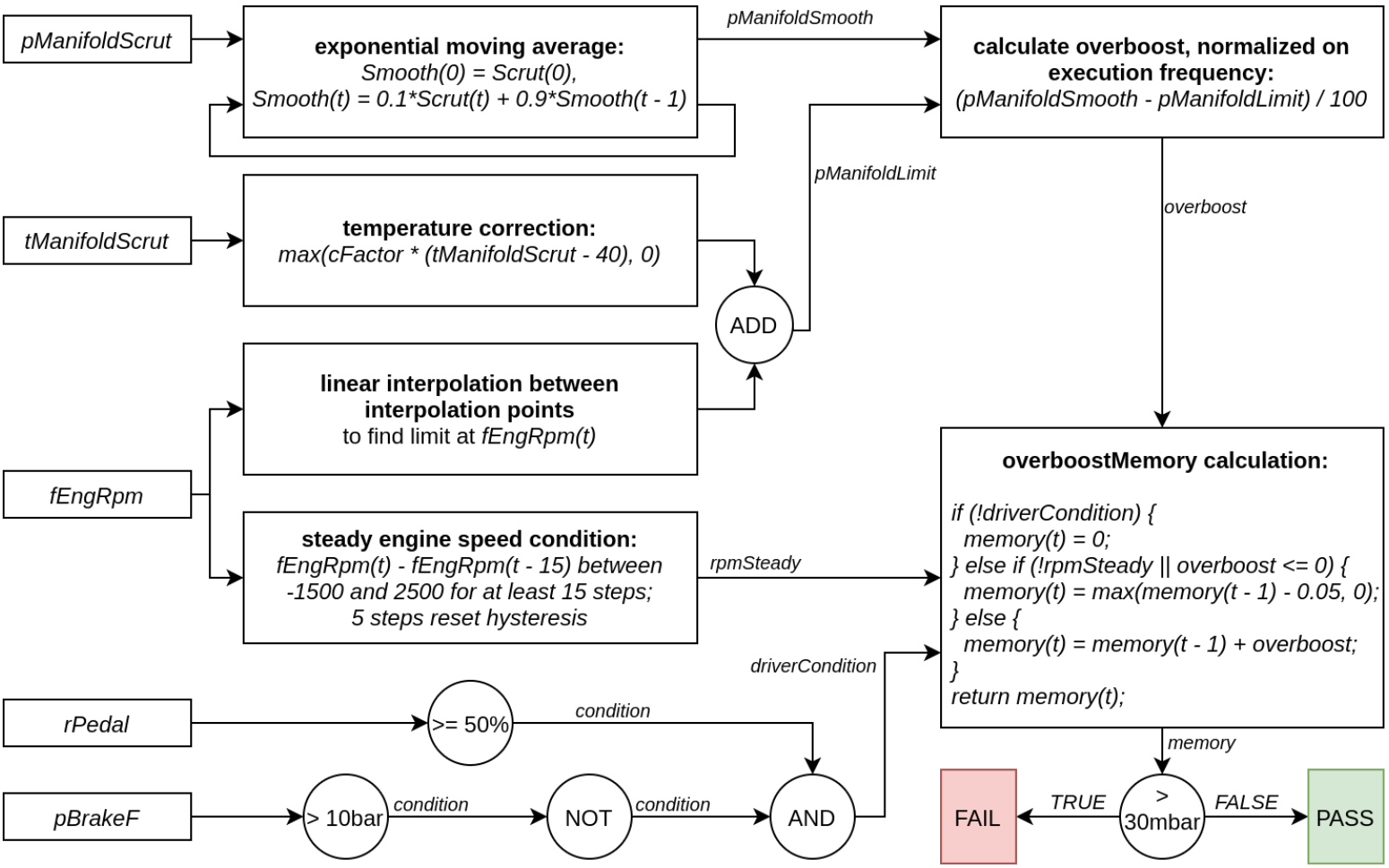
2 Block Diagram

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. ~~The *counter* is initialized with the value 0 and reset to 0 after each lap.~~



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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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