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1. Turbocharger Boost Pressure Monitoring Method (see pages 2 to 6 of the present bulletin)

The method refers to the Checking Algorithm of the Maximum Absolute Supercharging Pressures published in the TCR TB no. 12 from 14.06.2017.

Eventual question to the “TCR Turbocharger Boost Pressure Monitoring Method” can be answered by the authors.

2. Errata for VW Golf GTI TCR SEQ and DSG for following articles of the TCR Technical Form 2017:

- Art. 202.a) Overall Length: 4597mm (instead of 4564mm)
- Art. 209.b) Overhang Rear: 1035mm (instead of 1002mm)

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TCR Turbocharger Boost Pressure Monitoring Method

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1 Introduction

Turbocharger boost pressure is an important Balance of Performance (BoP) parameter and must therefore be monitored adequately. In this paper, we present the monitoring method we have developed on the basis of the monitoring method described by the *LED boost control strategy* by the FIA GT Committee [1]. It is currently used by technical delegates to check the legality of cars in TCR International. Our implementation provides to the technical delegate the information of

- when (outing, lap, minute, second, millisecond) the boost limit was violated
- duration of boost limit violation
- engine speed (RPM) at the beginning and end of the violation
- throttle position (%) at the beginning and end of the violation
- amount of boost limit violation (mbar) at the beginning and end of the violation

if a boost limit violation occurred.

The conditions which must be met for the boost pressure monitoring method to be applicable are described in section 2. The boost pressure monitoring method itself is described in section 3. For a summary of all parameters, see section 4.

2 Conditions

First of all, there are two conditions introduced to discard meaningless results and exclude unnecessary

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edge cases from the analysis using the monitoring method.

- Engine speed is 2000 RPM.
- Throttle pedal position is at least at 25% of its total travel.

The following condition has been defined in order to fairly treat the physical properties of different technical solutions used in TCR vehicles.

- No gearshift window (described in section 2.1) is currently active.

IF AND ONLY IF all of these conditions are met the boost pressure monitoring method is applied.

2.1 Gearshift Window

Due to the physical properties of a turbocharger, overshoots of the boost pressure after a gear upshift are common in some systems. The beginning and the length of the overshoot vary between different systems. Therefore we define the *gearshift window* as follows.

A gearshift window is detected *IF AND ONLY IF*

- a gear upshift (described in section 2.2) has been completed within the last 1000 ms.
- the beginning of an overboost event (i.e. the rolling average of the boost pressure being over the permitted limit) has been detected within the last 300 ms.
- a gearshift window has not already been detected since the last gear upshift has been completed, i.e. only one gearshift window can be detected per gear upshift.

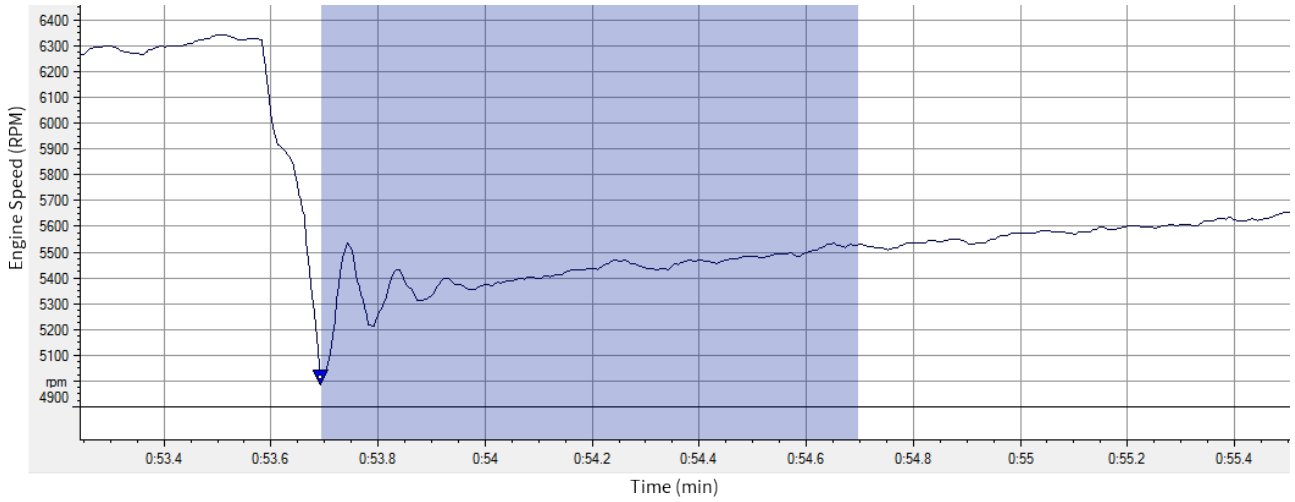


Figure 1: Time range where the gearshift window can be activated

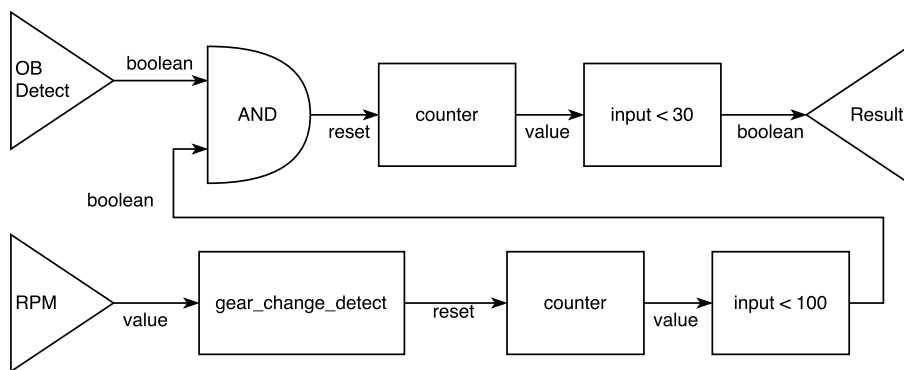


Figure 2: Gearshift Window Detection

See figure 1 for an illustration of the time range when a gearshift window can be detected. If during this time range an overboost event is detected, the boost pressure monitoring method is suspended for 300 ms. We define this as the *gearshift window*. The gearshift window detection is shown in figure 2.

2.2 Gear Upshift Detection

To detect a gear upshift, the end of the falling edge of the engine speed must be detected (see figure 1). The falling edge is detected by calculating the drop of the engine speed as follows:

$$drop(t) = rpm(t - 20) - rpm(t) \quad (1)$$

where t is measured in ms. If $drop(t)$ is greater than 200 RPM, the falling edge is detected. The end of the falling edge is then found by determining the point in time when $drop(t)$ is again less than 200 RPM. Figure 3 shows the method by which the gear upshift is detected.

3 Boost Pressure Monitoring Method

The boost pressure is measured with a resolution of 1 mbar and a sampling rate of 100 Hz.

The boost pressure monitoring method is composed of several steps, each of which is described in the sections below. It is loosely modeled after the monitoring method described by the *LED boost control strategy* by the FIA GT Committee [1].

3.1 Rolling Average

- Static set of 50 values.
- Setting at check start: set is filled with zeroes. This means that the result of the algorithm is only meaningful after 50 measurements have been captured.
- Implemented as circular buffer [2], i.e. the values in the set are overwritten from the beginning to end of the set again and again.
- The average is always calculated by building the sum of the values in the set and dividing it by 50.

- The set is never emptied, i.e. when the conditions (see section 2) are not met the set remains static and when the conditions are again met the overwriting process restarts from where it was stopped.

3.2 Overboost Condition

The overboost is detected by subtracting the maximum permitted boost pressure from the result of the rolling average calculation.

$$OB = P_{\text{rolling average}} - P_{\text{limit}} \quad (2)$$

IF AND ONLY IF OB is greater than 0, the result is forwarded.

3.3 High and Low Overboost Detection

The value resulting from the overboost condition described in section 3.2 is evaluated. Two thresholds are used for this evaluation:

- High Overboost Threshold: 100 mbar
- Low Overboost Threshold: 30 mbar

These thresholds are used for the evaluation of the monitoring method, which is executed at 100 Hz. The car is legal *IF AND ONLY IF*

- the High Overboost Threshold never surpassed, i.e. the overboost value has always been less than 100 mbar.
- the Low Overboost Threshold is surpassed at most 5 times, i.e. the overboost value is higher than 30 mbar at most 5 times per outing.

3.4 Monitoring Method

Figure 4 shows the entire boost pressure monitoring method including all condition verifications. If all conditions are met, the conditional pass through forwards the boost pressure value from the sensor to the rolling average, after which the boost limit as per BoP is subtracted. If the resulting value is greater than 30 mbar, a counter is incremented. As long as the counter is below or equal to 5 and the value after subtraction is below 100 mbar, the monitoring method evaluates to **true**, meaning that the car is legal.

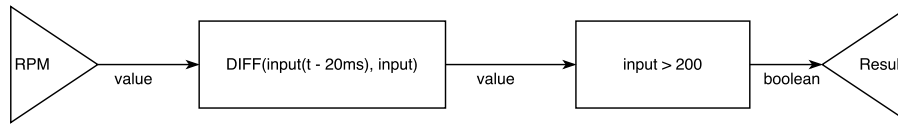


Figure 3: Gear Upshift Detection

4 Summary

In this paper, a monitoring method for the turbocharger boost pressure has been presented. It enables monitoring a vehicle’s legality during a race (online), given suitable electronic hardware is available, or after the race (offline) using logged data, albeit with much greater effort.

The key parameters are:

- The monitoring method is viable whenever the throttle pedal is at least at 25% travel and the engine is operating at more than 2000 RPM outside a gearshift window.
- A gearshift window can be detected for up to 1000 ms after a gear upshift has been completed and lasts for 300 ms.
- A gear upshift is detected if the engine speed drops by 200 RPM or more within 20 ms.
- The boost pressure is averaged over 50 measurements which are stored in a circular buffer and never lost.
- If the difference between the boost pressure limit according to the BoP and the averaged boost pressure goes
 - over a threshold of 30 mbar a counter is incremented. If the counter is bigger than 5, the car is illegal.
 - over a threshold of 100 mbar the car is illegal.

We believe this monitoring method is fair to all vehicles homologated according to TCR technical regulations [3].

References

[1] FIA GT Committee, *LED Boost Control Strategy 20.01.2017*, <http://www.fia.com/file/53189/download?token=KQCDQIP5>

[2] Wikipedia, *Circular Buffer*, https://en.wikipedia.org/wiki/Circular_buffer

[3] TCR International Technical Department, *TCR Technical Regulations 2017*, http://tcr-series.com/pdf/2017_TCR_International_Series_Technical_Regulations-2017_01_28.pdf, 2017

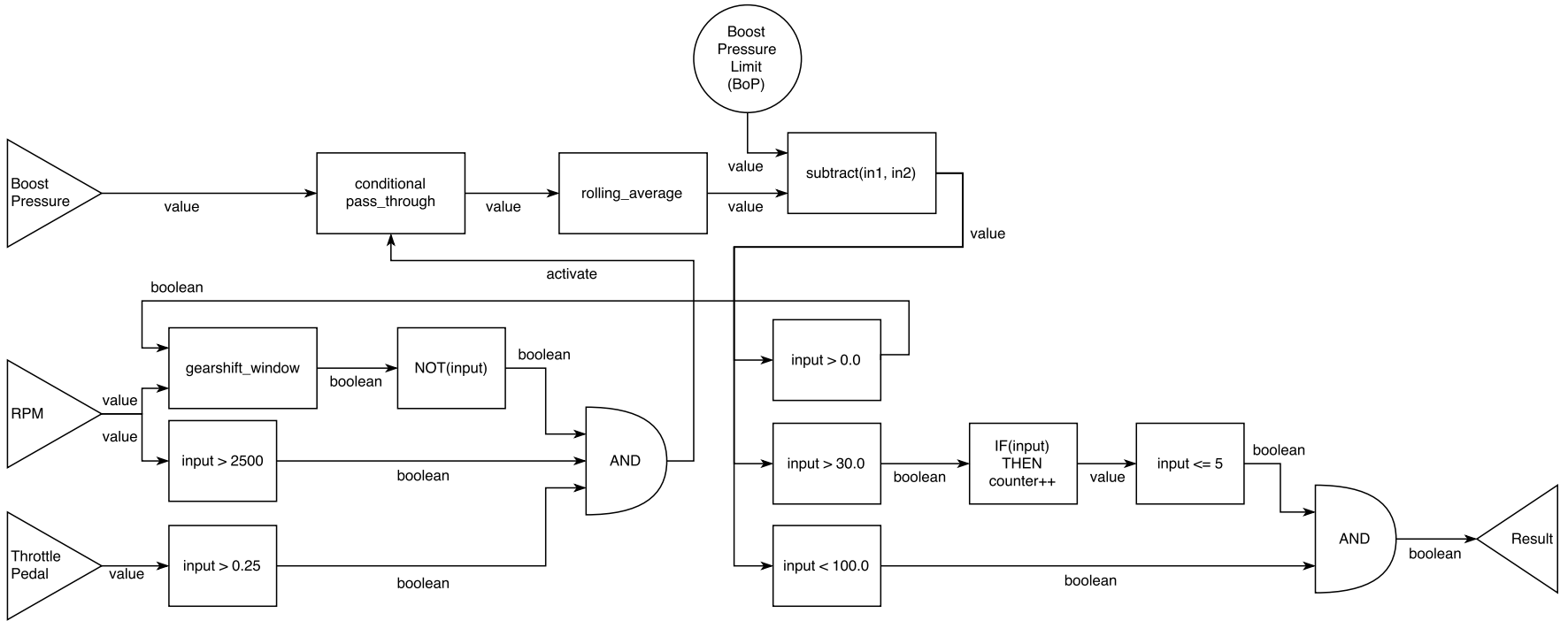


Figure 4: Turbocharger Boost Pressure Monitoring Method