On the throttle

OptimumG's data master expands our knowledge of data analysis techniques

By CLAUDE ROUELLE

Racecars have come a long way since this 1960 Formula 2-winning Porsche 718/2 but driver throttle input through corners remains a critical part of race technique

If you've been following this year's series of articles from OptimumG, you know we have shared some of the data analysis techniques used by our engineers in their day-to-day racing activities. So far, we have presented steering and braking performance metrics, and this article will focus on the throttle channel.

Of the three driver inputs, the throttle has two main functions: accelerating the car and, in some cases, using longitudinal tyre grip to balance it.

The tricky part is applying the *correct* amount of throttle. A driver can easily apply too much, too little, too fast or too slow. As a driver moves to higher racing series, which typically means more engine power, the more difficult it is to find the perfect throttle modulation.

Before we start looking at ways to analyse the throttle channel, using key performance metrics, it is important to first understand what a throttle trace looks like. **Figure 1** shows a throttle trace for a long corner.

A throttle chart will have throttle percentage on the y-axis, the value going from zero to 100 per cent. Zero means the throttle is closed, at 100 per cent the throttle is fully open. The x-axis can either be in distance or time.

In **Figure 1**, the driver is applying full throttle up until the 3750m marker, but then releases the throttle and is braking to enter the corner. The driver picks up the throttle at 3825m on corner exit.

Similar to the V29N4 edition where we broke down the different stages of braking, we will be applying the same methodology in this article for the throttle by looking at the different stages during corner exit: 'Start Corner Exit', 'Middle Corner Exit' and 'End Corner Exit'.

Start Corner Exit begins with the initial application of the throttle. Being smooth on the throttle is crucial here (see *RE* V29N1 to further understand what we mean by smooth). If the driver applies too much throttle, or too quickly, it can create an understeer behaviour in the car due to longitudinal weight transfer from the front to the rear axle. Additionally, the driver could be creating unnecessary wheelspin.

On the other hand, if the driver doesn't apply *enough* throttle, or at a slow rate, it could be an indication of driver / lap time improvement, or not enough available grip, either from the road or tyres.

Middle Corner Exit is the longest section. The driver gradually increases the throttle as they are exiting the corner. In **Figure 1**, the corner we are analysing has a peculiarity and is characterised by having a late apex. This is confirmed by the fact that, from

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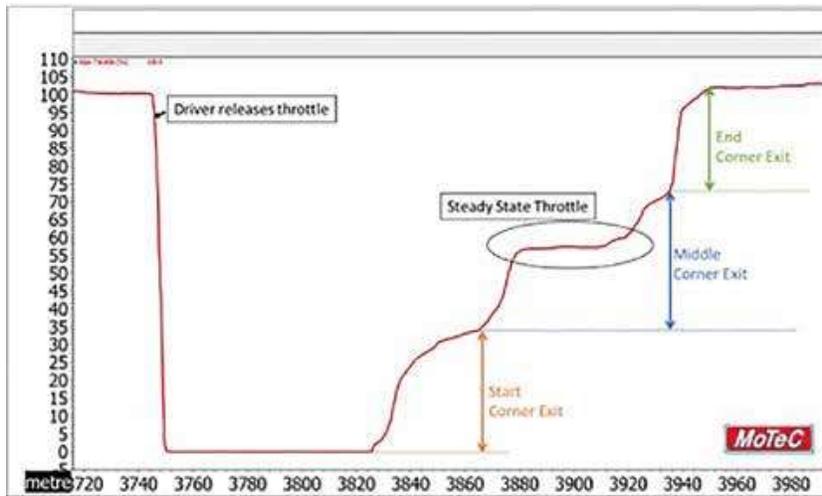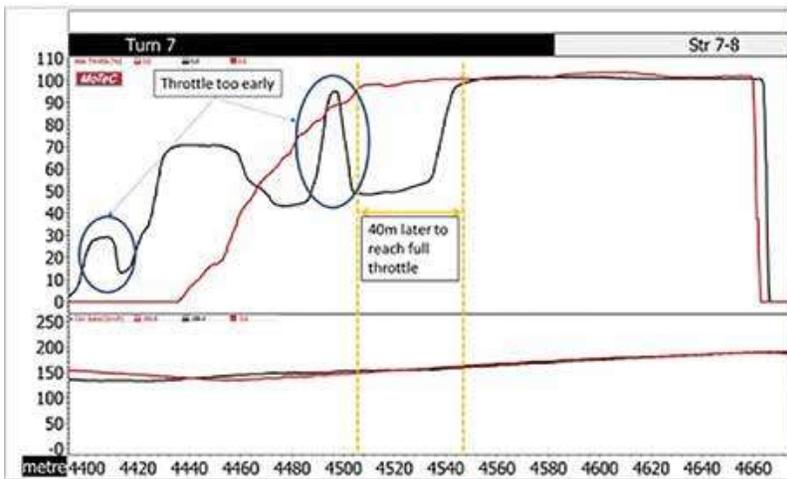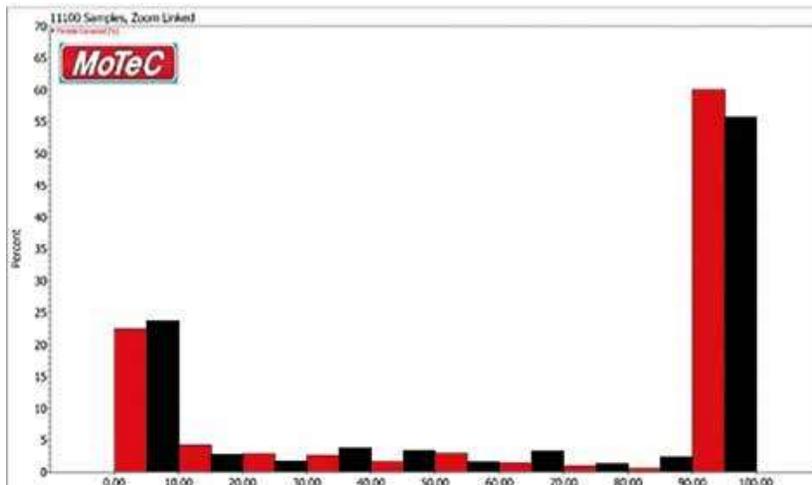
3880m to 3920m, the driver is maintaining a constant ('steady state') throttle, keeping the car at a relatively constant speed. The driver reaching a steady state (equilibrium) point of the car tells the race engineer there probably isn't any additional grip available.

The length of the corner, as well as the type of trajectory used, will play an effect on how long this steady state throttle will be.

End of Corner Exit is the final section, characterised by a rapid increase to 100 per cent of the track trace, which is possible because the driver is no longer tyre limited. In that state, the driver can apply 100 per cent throttle without having to worry about wheelspin.

Smooth and steady

With the throttle trace sections defined, and an understanding of what a throttle trace looks like, let's make an exercise and analyse the throttle trace of two drivers. **Figure 2** shows the data of two drivers negotiating the same corner. The upper chart contains the throttle trace, the lower chart the car's velocity.

Already at the beginning, we can see both drivers have different throttle traces. The driver with the black trace applies the throttle sooner than his counterpart. This happened because they braked too hard and / or too early, so reached the corner later than expected. The driver then tries to compensate by applying the throttle earlier. With the traction ellipse definition in mind, the driver then has limited longitudinal grip available because the tyres are probably close to their maximum lateral grip. When the driver tries to accelerate, if the wheels spin, they need to lift off the throttle, creating that up and down throttle trace. In the end, the driver gets back to full throttle 40m later compared to the red driver.

The red driver, had a smoother and quicker rise of the throttle and exits the corner with a higher speed compared to their peer. The red driver has a higher average throttle position compared to the black driver.

Throttle histogram

A typical first analysis of the throttle trace is a throttle histogram. A histogram represents a distribution of data. The values are separated into bins, which represent a series of intervals, and we can count how many values are in each interval. For convenience, MoTec i2 comes with a pre-built histogram, the user just needs to click on Add -> Histogram. A window will pop up, and the user selects which channel they want to create a histogram for. In **Figure 3** (a histogram obtained from MoTec i2), we separated in bins of 10 per cent.

In **Figure 3**, we are comparing two different drivers on their fastest lap.

The red driver had a faster lap time compared to the driver in black. By looking at the histogram, we can see the red driver has a higher percentage at full throttle (90-100 per cent) and a lower percentage at no throttle (zero-10 per cent).

If we look at partial throttle (11-89 per cent), we can see the black driver spent more time in that area compared with the red, and that the driver was modulating the throttle, which we saw in **Figure 2**.

Alternative view

A histogram provides an alternative to a time / distance chart. It offers an overview of the complete lap. Unfortunately, in a fast-paced environment, a data engineer doesn't always have time to look at each lap's throttle histogram but, to obtain an overview of the lap section, a simple and useful performance indicator is to calculate the throttle average (see **Table 1**).
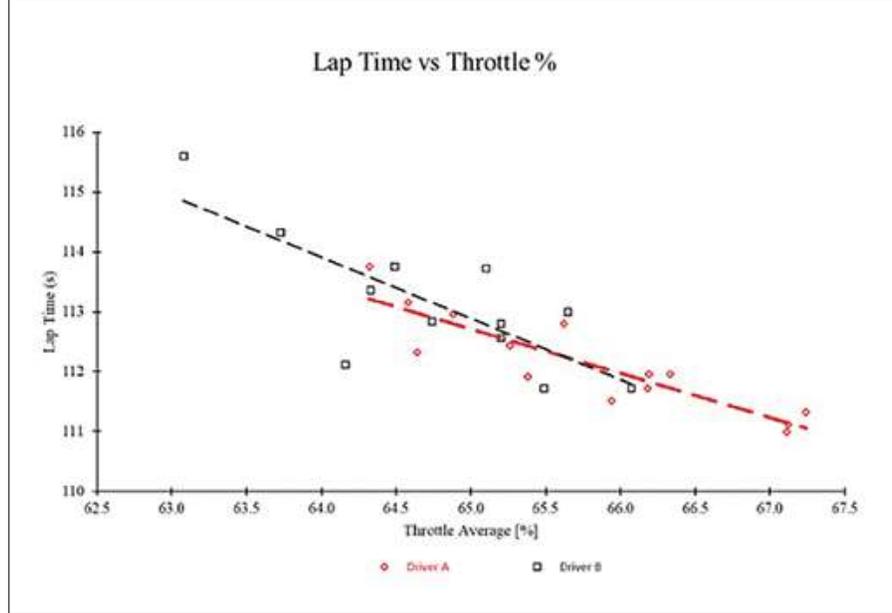
Again, for convenience, MoTeC i2 allows users to create the maths channels to calculate the throttle average.

'Wtat_mean' is the function that calculates the average by summing all the select channel values and dividing them by the total number of data points. Alternatively, in MoTeC i2 by going to Add-> Channel report, the user can create a channel report and select the average. This option will show a table with the average per lap, which is easier to further analyse.

Figure 4 shows the results of using the throttle average maths channel and plotting it against lap time.

At first, the obvious conclusion is that the more time on average the driver spends on throttle, the lower his lap time is. We can also see that, depending on the driver, there could be a stronger correlation with the throttle average. In this case, by looking at the slopes we can see driver B has a higher

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Figure 4: Driver A (red) and B (black) comparison between lap time and throttle average

sensitivity to the throttle average on his lap time compared to driver A. Also, notice that driver B has a wider variation of lap time, which could indicate the driver is modulating the throttle. If the values are lower than the driver's throttle average, it's an indication that a safety car has been deployed, or the driver is trying to save fuel or tyre wear.

Key points

Most data analysis software have an option to calculate the average for each lap. This number will be different depending on the circuit, car and driver. In general, the more time spent at full, or nearly full, throttle, the lower the lap time. This might not always be the case, though, as a driver who carries more speed in the corner will get on the throttle later, which will lower the throttle average. It is up to the engineer to look at multiple laps and find a baseline to compare drivers.

A histogram is a useful tool to quickly assess the driver's throttle profile, as long as he is being smooth or modulating the throttle.

Throttle position is one of the simplest channels that can be used, and shows us one of the vehicle's main controls.

Naturally, we have simplified our observations here by only looking at the throttle channel. To perform a complete analysis, it is necessary to plot at least one more channel to get a fuller picture of what is happening in the corner. Some other channels we suggest are rpm, GG Diagram and speed.

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As a tip for the reader, you might create a key performance indicator called throttle smoothness to smooth the throttle channel and compare it with the raw channel. Look up our article in *RE* V29N1 and you will see how to apply what you learn for steering smoothness to the throttle metric. ®

Table 1: Average throttle maths channel	
Maths channel name	**Maths channel equation**
Throttle average	stat_mean(**'Throttle'** [%])