Accelerated learning

Throttle control is a vital part of the driver's skill set, so it's important that engineers have the understanding and the tools to measure it

By CLAUDE ROUELLE

Even the very best can get a bit greedy on the throttle – this is Michael Schumacher winding on some opposite lock to deal with power oversteer at Silverstone back in 2005

If you've been following this series of articles from OptimumG during the last year, you will know that we have shared some of the data analysis techniques used by our engineers in their day-to-day racing activities. These have mainly been on the race driver's inputs: steering, braking, and throttle. So far, we have presented the steering and the braking performance metrics. But this month we're going to focus on the throttle channel.

Throttle control

The throttle has two main functions: accelerating the racecar and, in some situations, using the longitudinal tyre grip to balance it.

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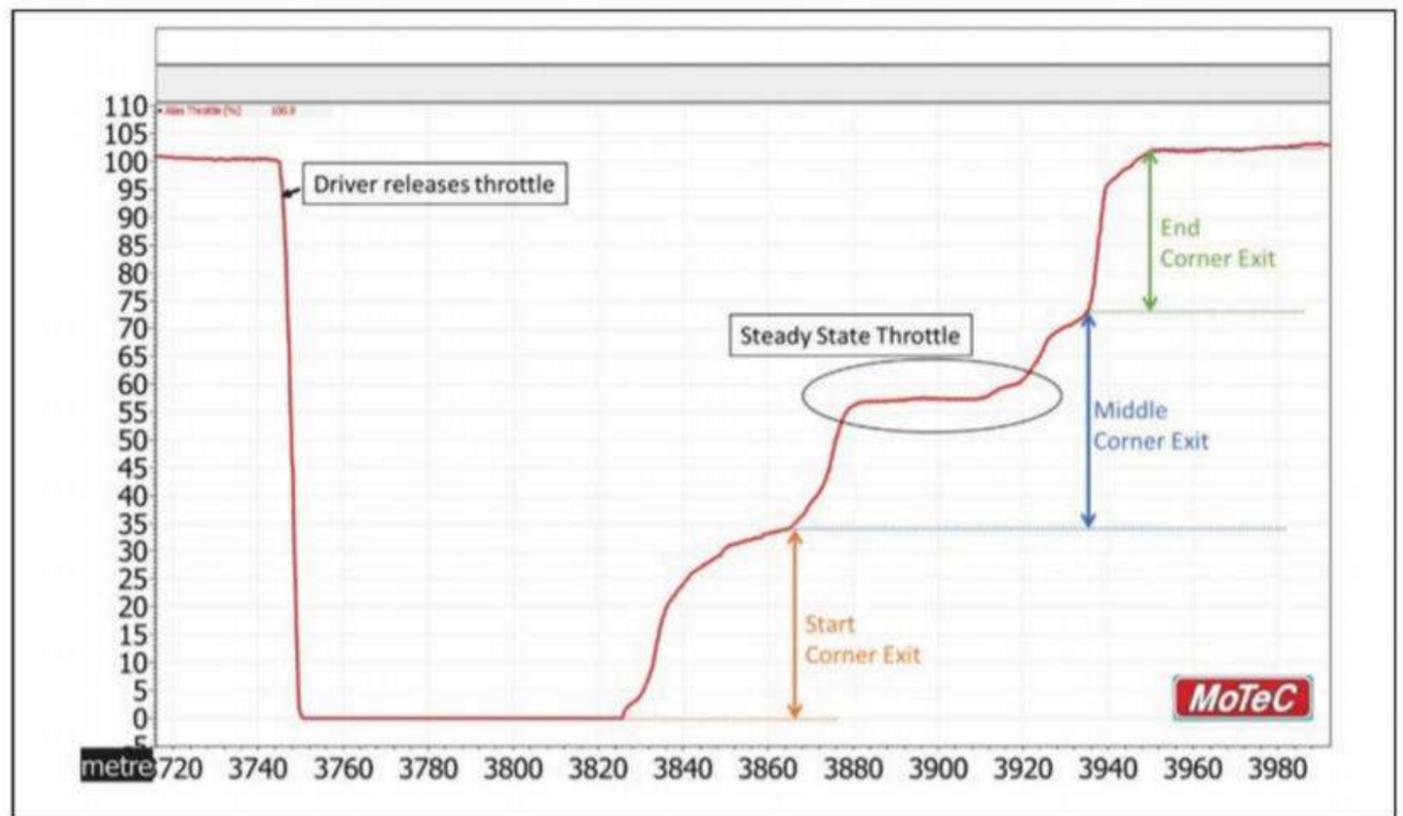

Figure 1: Throttle trace by sections through a long corner with a late apex; the latter is indicated by the steady state throttle period

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 trace for a long corner.

A throttle chart will have on the *y*-axis the throttle percentage, the value going from zero per cent to 100 per cent, where zero means the throttle is closed and at 100 per cent the throttle is fully open. Values in the middle represent part of the throttle opening. As for the *x*-axis, that can either be in distance or time.

In **Figure 1**, up until the 3750m marker the driver is applying full throttle (straight line). At the 3750m

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marker the driver releases the throttle and is braking to enter the corner. The driver then picks up the throttle at 3825m, the corner exit.

Similar to the April 2019 edition (V29N4) where we broke down the different stages of braking, we will be applying the same methodology for the throttle by looking at the different stages during the corner exit: *Start Corner Exit*; *Middle Corner Exit*; and *End Corner Exit*.

Smooth application

Start Corner Exit begins with the initial application of the throttle. Being smooth on the throttle is crucial (see January 2019's edition, V29N1, to further understand what we mean by being smooth). If the driver applies too much throttle, or applies it too quickly, it can create an understeer behaviour in the car due to the longitudinal weight transfer from the front to the rear axle. Additionally, the driver could be creating unnecessary wheel spin. On the other hand, if the driver doesn't apply enough throttle, or at a slow rate, it could be an indication of room for driver/lap time improvement, or simply that there's not enough grip available.

The Middle Corner Exit is the longest section. The driver gradually increases the throttle while exiting the corner. In **Figure 1**, the corner that we are analysing has a late apex. This is confirmed because, from 3880m to 3920m, the driver is maintaining a constant throttle (steady state throttle). The driver is providing the necessary amount of throttle that keeps the racecar at a relatively constant speed. The driver reached a steady state (equilibrium) point of the car, which tells the race engineer that there probably isn't any more additional grip available. The length of the corner, as well as the type of trajectory used, will have an effect on how long this throttle will be held in a steady state.

After we exit the Middle Corner Exit we enter the final section: End of Corner Exit. This is characterised by a rapid increase to 100 per cent of the track trace, which is possible because the driver is no longer tyre limited. It means they can apply 100 per cent throttle without having to worry about wheel spin.

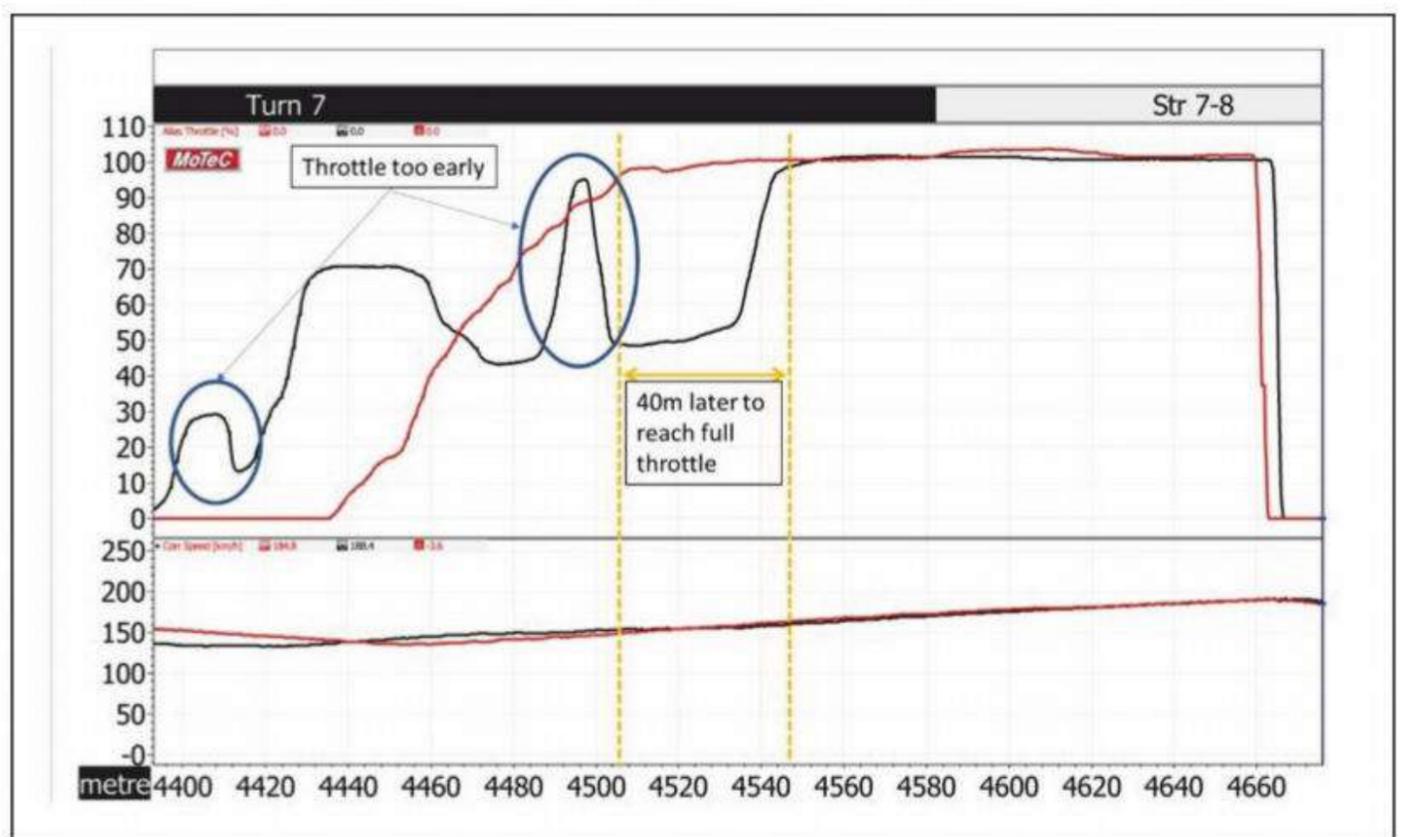With the throttle trace sections defined, and having gained an understanding of what a throttle

Figure 2: Throttle comparison between two drivers. Note how the black trace shows an early application, while red is much smoother
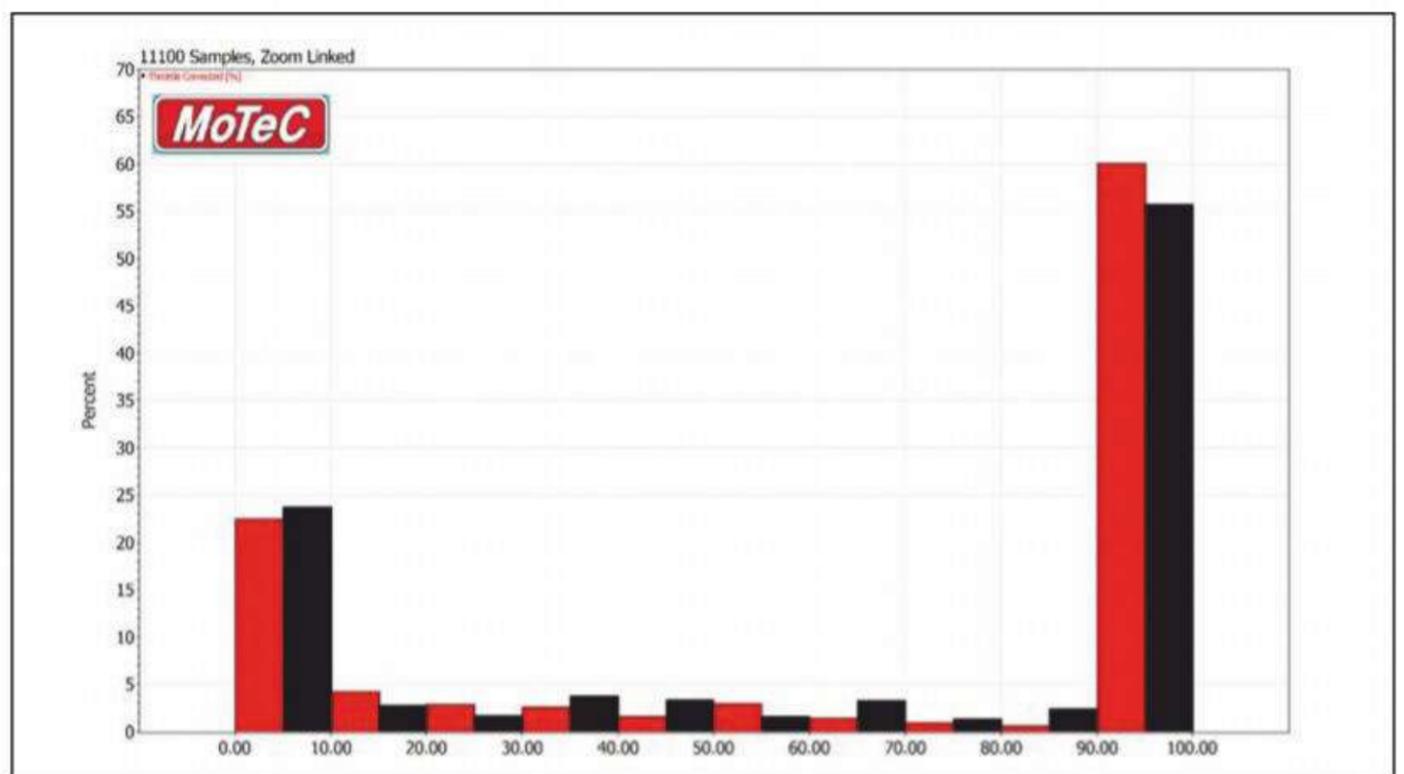

Figure 3: Throttle histogram for the two different drivers on their fastest lap. The red driver has a higher percentage of full throttle

The driver is no longer tyre limited, and this means they can apply 100 per cent throttle

trace looks like, let's now analyse the throttle trace of two drivers. **Figure 2** shows the data of our pair negotiating the same corner. The upper chart is the throttle trace; the lower chart shows the car's velocity.

Tracing drivers

Right at the beginning we can see that both drivers have different throttle traces. The driver with the black trace applies the throttle sooner than their counterpart. This happened because they braked too hard and/or too early. Therefore, they reached the corner much earlier than expected. The

driver then tries to compensate by applying the throttle earlier. With the traction ellipse definition in mind, the problem is that the driver has a limited longitudinal grip available because the tyres are probably close to the maximum lateral grip. When the driver tries to accelerate, if the wheels spin, they need to lift off the throttle, thus creating that up and down throttle trace. In the end, the driver gets back to full throttle 40m later compared to the red driver.

On the other hand, the red driver had a smoother and quicker rise of the throttle, and exits the corner with a higher speed compared to

the black driver. The red driver has a higher average throttle position compared to the black.

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. We can count how many values are in each interval. For our convenience MoTec i2 already comes with a pre-built histogram. The user just needs to click on *Add -> Histogram*. A window will pop up, and the user just selects which channel they want to create a histogram for. In **Figure 3** (the

To obtain an overview of the lap section, a simple and useful performance indicator is to calculate the throttle average

histogram obtained from MoTec i2), we separated in bins of 10 per cent. From 0-10 to 11-20, etc.

Here 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 that the red driver has a higher percentage at full throttle (90 to 100 per cent), and lower percentage at no throttle (0 to 10 per cent). If we look at partial throttle (11 to 89 per cent), we can see that the black driver spent more time in that area compared with the red driver, and was modulating the throttle, which we noted in Figure 2.

Throttle average

A histogram provides an alternative to a time/distance chart. It provides an overview of the complete lap. Unfortunately, in the fast-paced environment of a race day a data engineer doesn't always have the 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.

For our convenience, MoTeC i2 allows users to create math channels to calculate the throttle average (described in **Table 1**). *Stat_mean* is the function that calculates the average. The average is calculated 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 math 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
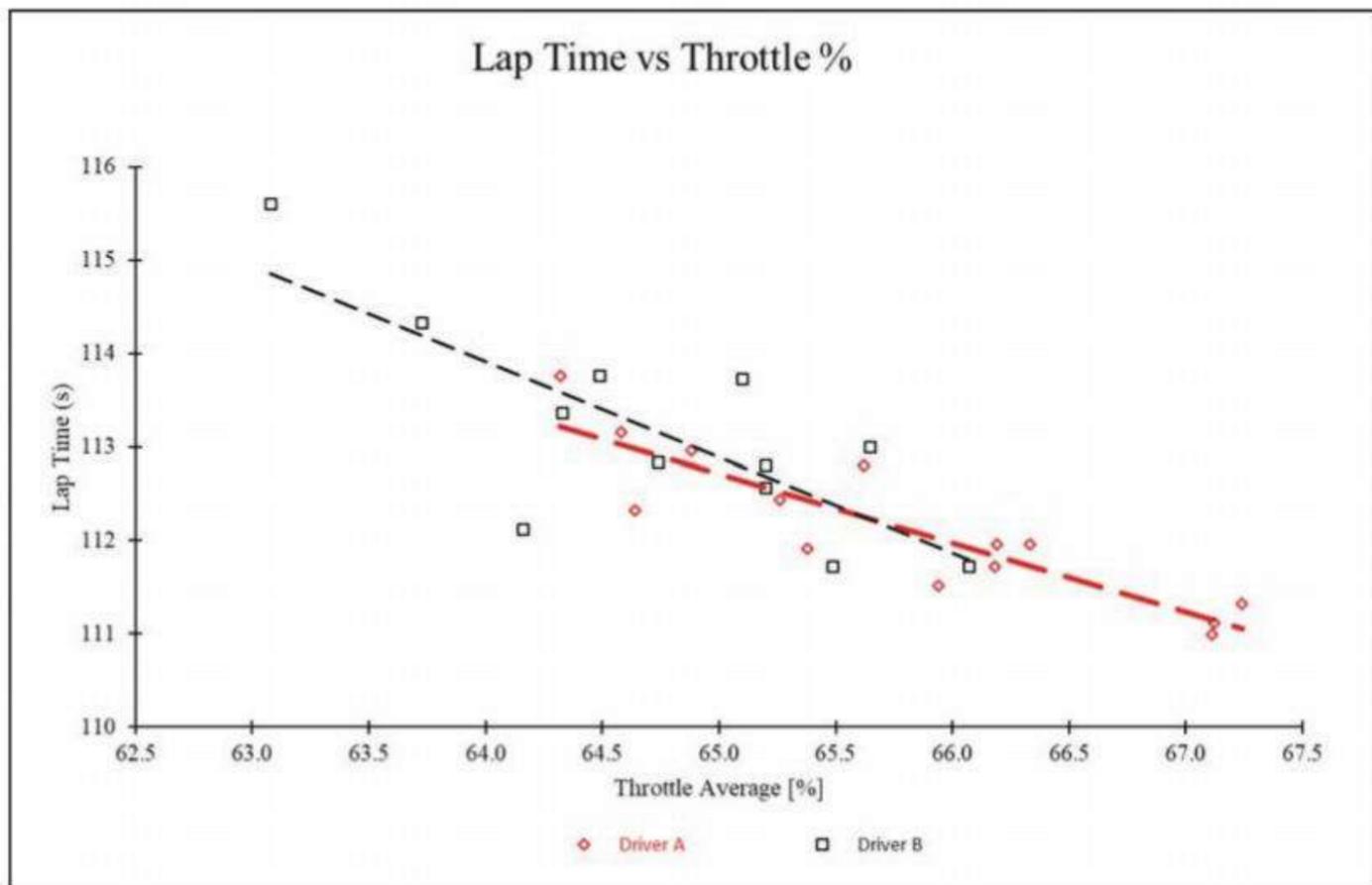

Figure 4: Driver A and B comparison between the lap time and throttle average. Note that driver B has a wider lap time variation

Table 1: Average throttle math channel

Math channel name	Math channel equation
Throttle average	stat_mean('Throttle' [%])

throttle average. In this case, we can see, by looking at the slopes, that driver B has a higher sensitivity to the throttle average on their lap time compared to driver A. Also, notice that driver B has a wider variation of lap time, which might indicate that the driver could be 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 decrease tyre wear.

Key points

To summarise the key points made above, most data analysis software packages 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 on full or nearly full throttle, the lower the lap time. But this might not always be the case, as a driver who carries more speed in the corner

will then get on the throttle later, which will lower the throttle average. It is up to the engineers to look at multiple laps and find a baseline to compare their drivers.

A histogram is a useful tool to quickly assess the driver's throttle profile, as long as that driver is being smooth or modulating the throttle. Also, throttle position is one of the simplest channels that can be used, and it shows us one of the vehicle's main controls.

Although we simplified our observations by only looking at the throttle channel, it is necessary to plot at least one more channel to get a full picture of what is happening in the corner. Some other channels you might look at are: RPM, GG diagram and speed, for example.

As a final tip for the reader, you might want to create a key performance indicator called *throttle smoothness* to smooth out the throttle channel and compare it with

the raw channel. Consult the steering smoothness article in January 2019 edition, V29N1, and you will get an idea of how you can apply what you learn for the steering smoothness metric to the throttle. ®

Slip Angle is a summary of Claude Rouelle's OptimumG seminars.

OptimumG seminars are held worldwide throughout the year. The Data Driven Performance Engineering (DDPE) seminar presents several data acquisitions and analysis techniques which can be used by engineers when making decisions on how to improve racecar and race driver performance.

The next DDPE seminars will be taught in Indianapolis, Indiana, USA (09-11 December) and in Birmingham, UK (11-13 January 2020). Register by sending an email to: seminars@optimumg.com

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