

The Effects of Toe Angle on a Race Car

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Abstract

This report looks into the effects of toe angle. A GP2 car was driven around Silverstone with different toe angles and the fastest laps of each setup were then compared. Finally some contingency runs were done with a smaller range of values based on the initial results to see not only the fastest lap but the consistency of the laps and the difference between tyre wear for each setup. A conclusion is then drawn to find out which toe angle is the best for the car, the driver and the tyres.

Nomenclature

S^2 : Variance

S : Standard Deviation

X_i : Term in Data Set

$\bar{X}$: Sample mean

Σ : Sum

n : Sample size

1-Introduction

The dissertation will focus on toe angle, why it has been chosen for the dissertation and how the toe angle is going to affect the performance of the car. The toe angle is probably one of the more overlooked parts of the car and hopefully this report should provide insight into how much of an impact toe angle makes on a car's handling characteristics. This paper will also explain how the toe angle will be tested and the equipment used for the testing. The aims of this assignment are to see what toe angle is best for producing the fastest lap overall and what toe angle will produce the best setup for the driver as the fastest setup may prove to be less controllable and therefore less consistent which in a racing scenario.

2-Toe Angle

Toe angle is the angle of the wheels along the longitudinal axis of the vehicle. Toe-out occurs when the wheels are angle so the front of the wheel points outwards, this causes the car to turn in more quickly, however this reduces the car's straight-line stability possibly making the car more twitchy. Having toe in, when the front of the wheel is facing inwards, can reduce this problem as it gives more straight-line stability but at the cost of reduced turn in. Toe angle is usually measured in degrees and can be both positive and negative. The more negative the toe angle, the greater the toe out, the more positive the toe angle, the greater the toe in. Another thing to note is that a more toe in or toe out generally produces more tyre wear as it produces more friction with the tyres although this can potentially be used to heat up the tyres more quickly. An important thing to note that toe is usually measured when the vehicle is static because the toe angle is dynamic when driving and can change constantly.

2.1-Applications of Toe Angle

Toe angle can be used in a racing environment to improve turn-in on corner entry or improve controllability of the car. This can also help with developing cars that are safer by improving the car's ability to avoid accidents or improve stability reducing the chance of crashes. Understanding toe angle can also help reduce tyre wear which can be helpful in racing situations where getting the tyres to keep going another few laps might allow for a wider range of strategies and can also save money for both racing teams and people driving on the roads if the wear is minimized. The reduced tyre wear can also help the environment as reduced tyre wear means less tyres needed over the lifespan of a car and therefore less of the planet's resources are needed to make tyres.

3-Background information

3.1-Driver in the Loop

The testing procedure will be done on a simulator using a method of testing known as driver in the loop. Driver in the loop is basically when a driver tests a vehicle virtually. In the case of this experiment it involves a driver using a simulator to test the car but can also be used as a means of improving the driver.

One of the advantages of this are that some variable e.g. track temperature can be controlled that otherwise wouldn't be able to. This is backed up by a report by J.C.F. de Winter which states that it improves not only controllability but reproducibility and standardization of test conditions. The report also states that it is easier to collect data, allow more extreme conditions to be tested whilst removing potential physical risks and a good opportunity for feedback and instruction. The ease of collecting data in testing is immediately noticeable and very useful for collecting more data in a shorter space of time. The extreme conditions is another obvious advantage as the extreme conditions could be potentially dangerous or even fatal in real life but in a simulator the risks are significantly reduced. The improved feedback ties into the ease of collecting as it allows easier, quicker and more efficient and potentially accurate data analysis which allows the testers to give more informed information to the driver.

There are however also downsides to using this method of testing. De Winter states a lack of fidelity on a simulator. This can be a problem as it may affect the results as well as demoralize the driver as they may not be satisfied with the lack of feel with the simulator. Another downside is that the simulator will not be 100% accurate when compared to real life conditions, it is very close in accuracy, therefore the differences will be small but may be enough to create a large effect on the results. De Winter also suggests that there is a "lack of research demonstrating validity of using simulators" However this report was made in 2012 and simulators have improved since then and more research has been done into the validity of simulators.

3.2-Design of Experiment

Design of experiment is a method of creating an experiment while minimizing errors in the experiment while maximizing the efficiency and speed of the experiment. This is achieved

by looking at the factors that affect the experiment and how those factors affect the results of the experiment. These factors are split into controllable factors and uncontrollable factors. Controllable factors are factors that can be changed or kept constant and do not change by themselves. Uncontrollable factors cannot be controlled and can potentially have affect the results if not properly accounted for.

3.2.1-Variance and Standard Deviation

One way to check how much the uncontrollable and controllable variables affect the results is to work out the variance and standard deviation of the results. The variance is calculated by using the equation $S^2 = \frac{\sum(X_i - \bar{X})^2}{n-1}$. This equation basically means finding the difference between each term in the data set and the mean squared then adding them altogether then dividing it all by the sample size minus 1. The mean is calculated by adding every term in the data set then dividing it by the sample size.

The next part is to work out the standard deviation. Thankfully the standard deviation is just the square root of the variance so the equation works out to be $S = \sqrt{S^2}$. The standard deviation is the normal range from the mean. If the term lies within the standard deviation it is a normal data term. If it lays outside the standard deviation it is a more extreme data term. Generally the less data terms that lay outside the standard deviation, the more consistent the data is.

4-Equipment

4.1-Motec

The software that is being used to analyze the data is called Motec i2 Pro. The software was made by Motec and is designed with a simple user interface to show the data as clearly as possible and provide the user with a wide range of possibilities of graphs, gauges and reports.

The simulator itself is based on a f1 chassis tub with motors for force feedback and pedal adjustment inside the nose. The screen is curved to provide the driver with a more realistic view of the track. And monitors are used to show a life feed along with other live data which is then stored in a data log folder to be saved and then used on Motec.

4.2-R Factor

The simulator runs on a professional version of R factor which was first released back in 2004 which provides very realistic handling physics along with low latency and ease of use. It is also compatible with Motec meaning the data can be logged and transferred very quickly Motec allowing for more time for analysis. F1 teams like Ferrari, Alfa Romeo Sauber and Mercedes use R factor and there is even a quote from the head of simulation at Ferrari on the R factor pro website praising the simulator saying "The way in which TerrainServer captures every LiDAR scanned data-point within the tyre contact patch, and integrates them all to provide our vehicle model with accurate road input, improves correlation with our measured data and also feels more realistic for the driver". (Giacomo Tortora, 2018)

4.3-Car

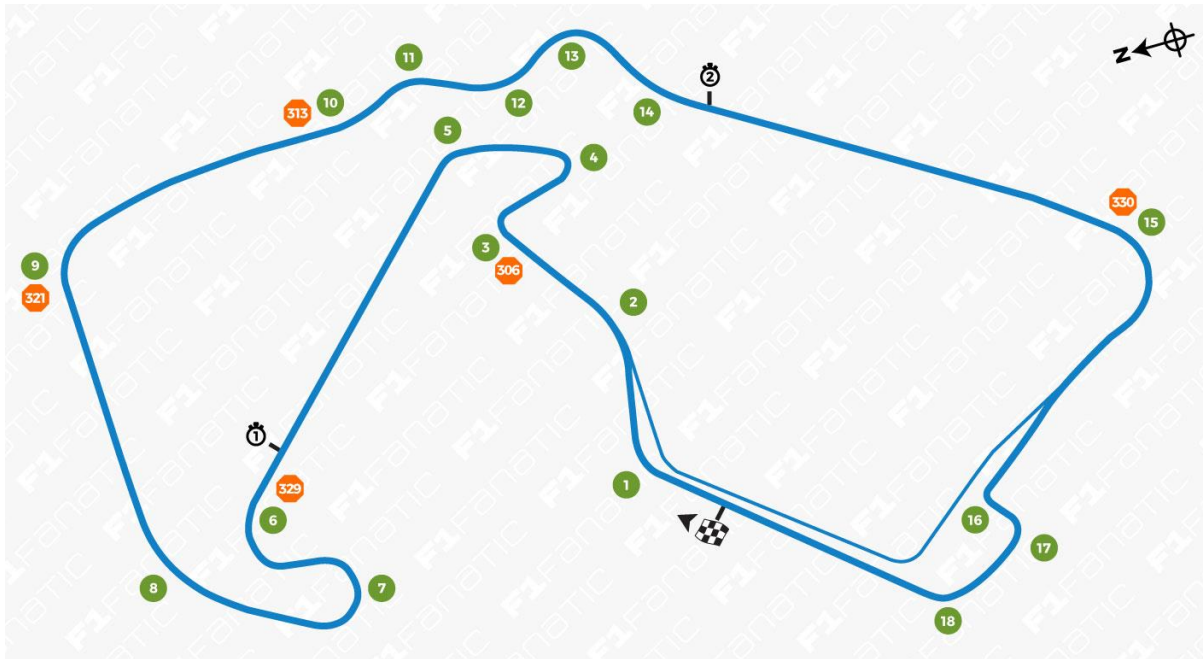
The car being used for the test is the GP2 car. The GP2 car in question was introduced in 2011 and its chassis is made by Dallara which is 5065mm long, 1800mm wide and has a height of 1072mm. The 4 litre naturally aspirated V8 produces 612bhp and can rev up to 10,000RPM. This power lets the GP2 car accelerate from 0-60mph in just 2.9 seconds and reach a top speed of 209mph. The power is delivered through a longitudinal 6 speed sequential box and paddles are used to change gear. (Jack Leslie, 2015) DRS (Drag reduction system) was introduced to the car in 2015 however the model used in the simulator does is before the 2015 season and does not have DRS. The car ran from 2011 to 2017 running in the GP2 series from 2011 to 2016 and then ran in the first season of Formula 2.



Callum Rows (2011)

4.4-Track

The track used for the test is the Silverstone GP circuit. Silverstone was first created in 1943 out of an old WW2 bomber station. Over the years it has hosted many major motorsport events including Moto GP and Formula 1. The current iteration of the circuit has been in use since 2010 and consists of 18 corners over 3.7 miles. The track was chosen for this experiment because it has a good mixture of high and low speed corners which will allow the toe angle to be thoroughly tested as well as producing high tyre wear which will allow the differences in degradation of the tyre to become more noticeable more quickly. It is also a track that the driver has become very familiar with which allows for more consistent results.



Race fans (2016)

5-Methodology

5.1-Testing procedure

The initial plan of the test consists of 2 laps (outlap and 1 lap) to warm up the car and a 5 lap stint which would be done at race pace so we could see both the pace and consistency of the setup. The reason for going for multiple laps is to see how consistent the setup is and to reduce the risk of driver errors affecting the results as they would appear as outliers. Doing multiple laps also allows us to see the tyre wear more clearly. This would then be repeated for every single setup starting with the front toe angle, then the rear toe angle and finally both front and rear toe angles together. At the end of the stint the driver was asked for feedback on how the car felt and how it compared to the previous setups. The reason qualifying pace was not chosen was that there was not enough time to do both and a qualifying stint would give us an idea of pace but not consistency.

The things being looked at during each of the stints initially was the best lap, lap consistency and tyre wear.

The first alteration made was to reduce the number of warm up laps to 1 as the driver said that only 1 lap was needed to warm up the car which also saves time as well allowing more stints to be done in more quickly. The second alteration happened during testing when the tyre wear was discovered not to be on, as it was discovered deep into testing the decision was made to turn tyre wear on for the contingency stints.

The final testing procedure involves a 1 lap warm up followed by a 5-lap stint at race pace. The fastest lap and lap consistency will be looked at but tyre wear will only be looked at for the contingency runs.

The range of toe angles being used is between 2 and -2 degrees decreasing in 0.5-degree increments. The reason for this is that that is the maximum range that can be implemented on R Factor. The first run will be done using the stock setup will become the control for the experiment, then the car will be setup with a toe angle of 0 degrees on the front and rear for the second stint. The next set of stints will be for the front toe angle gradually decreasing each stint in 0.5 degree increments from 2 to -2 degrees. The front toe is then zeroed and the test is repeated but this time adjusting the rear toe angle and then again with front and rear toe angle being adjusted simultaneously. The setups were labelled using the format 'Front toe angle, Rear toe angle'. For example a setup with 1 degree of toe at the front and 0.5 degrees of toe angle at the rear would be labelled '1,0.5'.

Contingencies have also been put in place depending on how the data turns out and will be implemented if there is enough time. The first contingency is if the data peaks at a certain toe angle within the test range. The next step will be to look at the toe angles between the optimal toe angle and the other toe angles tested either side in 0.1-degree increments, for example if the optimal toe angle of the angles tested was -1 degrees, then the test will be done in 0.1 degree increments between -0.5 and -1.5 degrees. The second contingency is if the pace for the toe angle doesn't seem to peak which is to use the data to predict where the data would eventually peak and therefore where the optimal toe angle will potentially lie. The increments were changed to 0.25 degree increments to save time as later on in testing time became a problem. The best front toe angle and the best rear toe angle from the contingency will then be combined which will be compared to the best setup adjusting both toe angles from the contingency. The lap times will be analyzed on Motec and 2 or 3 points during the lap will be highlighted and looked under more detail in this report. Each lap time will be compared to 2 other lap times including the fastest lap. The screenshot in the appendix will include the channels in the following order from top to bottom:

- Lap delta between 3 setups
- Engine RPM
- Corrected Speed
- Throttle position
- Steering wheel percentage
- Brake pedal Position

5.2-Control Variables

The control variables are the variables kept the same to improve the consistency and accuracy of the results. The control variables are as follows:

- Car
- Track
- Conditions
- Driver
- Setup (except Toe angle)
- Tyres
- Simulator

The car being used is the GP2 car which was used from the 2011-2017 (see 4.3 for more details). The track being used is Silverstone GP layout (see 4.4 for more details).

The track conditions are kept the same (e.g. air and track temperature, time of day etc.). This needs to be kept constant as changes in the conditions can affect the tyre temperature and wear which can influence how the car handles which could affect the lap times and the tyre wear. For example, if the the track temperature was higher, the tyres would heat up more quickly which will potentially increase tyre wear and affect tyre performance which can influence the final results.

Using the same driver improves the consistency of the results as a different driver will could be faster or slower or even less or more consistent. It is important to pick a driver who is both fast and consistent as a driver who lacks consistency may affect the results especially across the whole stint. Another thing to note is driver fatigue which can be solved by making sure not to test for too long in one go as the longer the testing sessions, the higher the chance for driver fatigue which will make the driver slower and less consistent. The simulator sessions generally lasted for 1-2 hours each which is enough to get plenty of data but should not be enough to cause significant driver fatigue.

To make sure only the toe angle is measured, all other parts of the setup must be kept the same throughout the whole experiment because the results could be affected by the other setup changes and it is harder to tell whether the change in performance is because of the change in toe angle or something else changing like camber, gear ratios, wing angles etc. The stock setup will also be run as a control to make sure that the experiment is accurate.

The tyres must also be kept the same as different tyre compounds produce different amounts of wear and handle differently as well as may run at a different operating temperature. Even taking all possible precautions the tyre may not be the exact same temperature everytime as the driver may warm the tyres up differently and may not take the corner 100% consistently which will cause minor changes in tyre temperature but the tyres should generally be at the same temperature during each run.

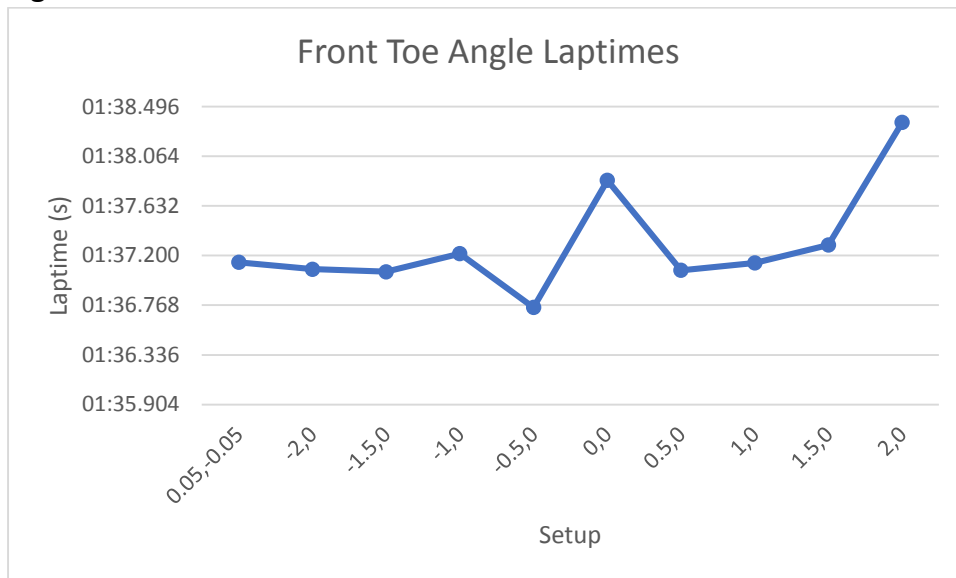
The simulator must be kept the same as the physics model can sometimes perform slightly differently which may influence the results. It is also important to pick a simulator that is as close to real life as possible which R factor definitely is. This also means that the car models and track models have to be as accurate as possible. The tracks are laser scanned in and the GP2 car model is also very accurate which means it is likely to perform very similar to how it would in real life.

6-Results and analysis

6.1-Initial Results front

The first thing to do is to compare the fastest laps of each setup which will give an idea of what setup was the best overall. Fig1 below shows the fastest lap of each setup. Note that the 0.05,-0.05 setup is the stock setup being used as a control.

Fig1



Looking at this graph the optimal toe angle for the front appears to be -0.5 degrees. The general trend shown from the graph is that the lap time decreases until it reaches the fastest time which was set with 0.5 degrees of toe at the front, the lap times start to generally increase again. The lap times seem to be generally close across the different setups indicating that the difference in toe angle at the front may cause a small difference in overall handling. However if we look at the driver feedback for the setups the car does appear to change handling characteristics fairly significantly. The turn in generally improves for the driver as at 2,0 the car understeers greatly but at -2,0 the car is very good on turn in. However the driver also notes that the car is also twitchier the more negative the toe is which is likely becoming too detrimental to the lap time beyond -0.5,0 or at least this is what the initial results are showing. The graph however shows 2 possible anomalies in the data. These are 0 degrees of toe angle and -1 degrees of toe angle. The first thing to be looked at in detail is why these anomalies exist. This will be done by comparing both anomaly setups with the closest comparisons setup wise.

6.1.1-0,0 compared to 0.5,0 and -0.5,0

The first comparison is between 0,0 to -0.5,0 (which is also the fastest setup) and 0.5,0. In the screenshot of the comparison in Motec (Ap1) the red lines and dotted line on the delta is 0,0 while the black lines are for -0.5,0 while the green lines are for 0.5,0. The driver set a lap time of 1:36.749 with -0.5,0, a 1:37.855 with 0,0 and a 1:37.073 with 0.5,0. This is a very large difference in time especially when compared to the other lap times set by the other setups indication either a large driver error or a series of smaller driver errors may have occurred that may have affected the lap time. Looking at the data the 0,0 setup loses out in 3 key areas of the track. The first area is through turns 3-5. The evidence for what may have caused this loss of time lies in the steering wheel percentage where the driver suddenly steers in the opposite direction very briefly whilst driving through turn 3 for the 0,0 setup only. This is an indication of oversteer occurring mid corner. This seems to be further backed up by a small increase by the brake position as the brake position is reduced when the oversteer occurs and is then slightly increased by about 10% to help reduce the oversteer.

The throttle is not on when the oversteer occurs indicating off throttle oversteer. An interesting thing to note however is that the throttle and brake positions overall remain very similar to 0.5,0 setup during this corner however the driver does lift and applies the brakes slightly earlier than -0.5,0 which does have a small effect as well. Checking the other lap times produced with the 0,0 setup do not show the steering angle like on the fastest lap indicating that the oversteer moment is most likely driver error especially as the driver stated that the car was very good on entry with this setup. The driver does gain some time back over the other 2 setups through turn 4 by being able to get on the throttle sooner however by the entry of turn 6, the 0,0 setup has lost about 0.337s to the -0.5,0 and 0.446s to 0.5,0

The second section that 0,0 lost time is through turn 7. 0,0 actually gains time through turn 6 as the driver is able to get on full throttle sooner through this corner than with the other 2 setups which means the driver exits the corner with more speed. However, 0,0 loses time through turn 7 by carrying more speed mid corner. This seems to have caused the car to understeer wide on the exit of the corner which is evident in the increased steering angle and the fact that it took longer for the driver to apply full throttle which results in 0,0 losing about 3 tenths of a second through turn 7 and being 0.550s behind 0.5,0 and 0.591s behind -0.5,0.

0,0 loses another large chunk of time to the other 2 setups is through turn 13 and 14. This is the end of a sequence of corners which consists of turns 10-14. The first thing noticeable is the fact that 0,0 carries a lot less speed mid corner reaching a minimum speed of just 170.8km/h compared to the 185.0km/h for 0.5,0 and 191.8km/h for -0.5,0. One factor of this reduced speed is the fact that the driver is braking more heavily than the other 2 setups through turn 12 which reduces the speed carried through turn 13. Another piece of evidence for the reduced speed is the throttle percentage where 0,0 is the slowest of the 3 to get on the throttle. Finally the reason for the loss in speed could be shown in the steering wheel percentage as the steering angle peaks before the other 2 setups as well as reducing earlier too. This seems to suggest a wider entry to turn 13 which does allow for a better exit however not getting on the throttle quickly enough means that the driver is still travelling at a similar speed on the exit of the corner indicating that this line through the corner did not work. Further evidence for the different line through the corner can be shown in the brake position where through turn 13 the driver uses a very small amount of brakes for a very short period of time while not using the brakes at all through turn 13 for the other setups which was most likely done to help the nose turn in more.

6.1.2—1,0 compared to -0.5,0 and -1.5,0

The next anomaly to compare is -1,0 which will be compared to -0.5,0 and -1.5,0. In the screenshot from Motec (Ap2), the red/dotted lines are of -1,0 while -0.5,0 is in black and -1.5,0 is in green. As stated in the previous comparison, the driver was able to set a time of 1:36.749 with the -0.5,0 setup. The driver was able to get a 1:37.217 with the -1,0 setup and a 1:37.060 with the -1.5,0 setup. The driver was actually fairly close to the other 2 setups with the -1,0 setup indicating that if there was any driver error it would have likely to have been small.

-1,0 pretty much stays neck and neck with the other 2 setups only really fluctuating once or twice before turn 9 where the driver loses a little bit of speed through the corner compared to the other 2 setups. This could be down to some slight understeer indicated by the steering angle being generally higher and there is also a spike in the steering angle too which is backed up by the driver feedback stating that the car was twitchier although they did specify through turns 10-14 however I could have also been the case through turn 9 too as it is also a high speed corner.

However they are able to gain a very small amount of time over -0.5,0 and a lot of time over -1.5,0 through turns 11 and 12. This is shown by the speed as the driver carries a little more speed through turn 11 and 12 with -1,0 than with -0.5,0 and a lot more speed than -1.5,0. This is due to the driver being able to get on the throttle sooner with -1,0 than the other 2 setups which means they are accelerating for a longer period of time. -1.5,0 also brakes more than the other 2 setups before turn 12 which is why they carry less speed through the corner and lose significantly more time. The steering angle is also less for -1,0 indicating a much smoother line through the corners while the other 2 setups seem to need a higher steering angle to make the corner indicating that the line through turn 12 is not as smooth for -0.5,0 and -1.5,0 which also shows in turn 13 where the steering angle is greater overall for both -0.5,0 and -1.5,0 which is probably due to the worse line through the previous corner.

-1,0 also loses time during turns 17 and 18. -1,0 is actually faster than the other 2 setups through turn 16 which could be due to being slightly later off the throttle and slightly later on the brakes which causes the driver to carry more speed through the corner with -1,0. However the driver has to steer for slightly longer and gets on the throttle more slowly which causes the driver to carry less speed through turns 17 and 18 which results in the -1,0 going from 0.032s behind -0.5,0 and 0.423s ahead of -1.5,0 to 0.468s behind -0.5,0 and 0.157s behind -1.5,0 at the start finish line. There doesn't seem to be any evidence in the data of any significant moment happening however which means that it is most likely the driver not getting on the throttle quickly enough as the differences in the other driver inputs indicated there was not a significant difference in how the car handled through this corner meaning that the hesitation on the throttle most likely caused the lap time to become an anomaly. This is backed up by the fact that the driver said that the turn in was actually really good so it is most likely driver error.

The next step will be comparing the fastest laps of each setup compared to the fastest setup overall which is -0.5,0 to work out why it was the fastest setup. For each comparison 2 of the other setups will be compared to -0.5,0 at the same time.

6.1.3:-0.5,0 compared to 2,0 and 1.5,0

For the screenshot of this comparison (Ap3) The red/dotted line is the -0.5,0 setup while the black lines are the 2,0 setup and the green lines are the 1.5,0 setup. As stated earlier the driver was able to achieve a lap time of 1:36.749 while they were only able to achieve a lap time of 1:37.292 with 1.5,0 and only a 1:38.360 with 2,0 which is over 1.5 seconds slower than -0.5,0.

The first section where both 2,0 and 1.5,0 lose time to -0.5,0 is through turns 3-5. -0.5,0 starts with a lead of just 0.044s to 2,0 and 0.055s to 1.5,0 however by the entry of turn 6 is 0.261s ahead of 2,0 and 0.105s ahead of 1.5,0. Initially the driver gets off the throttle noticeably later and applies the brakes noticeably later with the -0.5,0 setup compared to the other 2 setups. This initially gives the -0.5,0 setup a lead of 0.559s to 2,0 and 0.450s to 1.5,0. However the driver is not able to get on the throttle as quickly on the exit of turn 3 losing -0.5,0 a little bit of time compared to the other 2 setups before turn 4. The driver also brakes harder into turn 4 with the -0.5,0 setup as well using more steering angle and not being able to get on full throttle as quickly despite getting on the throttle as quickly indicating that the car understeered wide with -0.5,0 which is different to what the driver feedback would suggest. However, I think the most likely explanation is that the extra speed carried through the corner is the reason for the unusual understeer moment.

-0.5,0 maintains the gap to 1.5,0 through turn 7 however 2,0 seems to lose a significant amount of time through this corner compared to the other 2 setups. The driver brakes earlier with 1.5,0 compared to the other 2 setups and loses a bit of time mid corner as the driver is not carrying as much speed. However, this allows the driver to apply the throttle sooner which allows the car to accelerate out of the corner earlier allowing the driver to carry more speed through turn 8 and down the old start finish straight before turn 9 which means that 1.5,0 is still only 0.140s behind -0.5,0 by the entry of turn 9. The driver brakes at about the same time with -0.5,0 and 2,0 however the driver uses about 28% less brakes into the corner which initially allows the driver to carry more speed into the corner. This backfires however as the car appears to understeer wide with the driver having to apply the steering for much longer and taking noticeably longer to apply full throttle causing the car to be significantly slower on the exit of turn 7 and through turn 8 and the old start finish straight. This results in the driver being 0.792s behind -0.5,0 with the 2,0 setup by the time the car reaches turn 9.

The driver loses an extra tenth in the 2,0 setup to the -0.5,0 setup although the steering inputs seem to be very similar, although -0.5,0 is able to stop turning more quickly indicating slightly more understeer in the 2,0 car compared to the -0.5,0 car indicating that the time loss is most likely due to the lack of exit speed out of turn 7 as turns 8 and 9 are both taken at full throttle. 1.5,0 loses a larger chunk of time going from just 0.140s behind at the entry of turn 9 to 0.889s down at the entry to turn 10. There has likely been a larger understeer moment which is evident by the steering angle being much greater through turn 9. This is also evident in the driver feedback as the driver states that the car understeers more with the 1.5,0 setup compared to the -0.5,0 setup.

Both 1.5,0 and 2,0 lose more time through turn 12 which is mainly down to the driver braking less with -0.5,0 compared to the other 2 setups. This allows the car to carry more speed through turn 12 which allows -0.5,0 to extend its lead to 0.526s to 1.5,0 and 1.226s to 2,0. However, it appears that the extra speed causes the driver to go wide on the exit which is evident in the increased steering angle on the exit of turn 13 and the fact it takes a lot longer to get to full throttle. 2,0 also appears to go wide at turn 13 but this appears to be earlier in the corner as that is where the steering angle peak is and the driver is able to get on the throttle sooner than -0.5,0. 1.5,0 however takes the best line through the corner as

shown by the lower steering angle required through the corner and the fact it was the quickest to apply full throttle indicating that the driver took a very good line through the corner on that lap reducing the gap to -0.5,0 to just 0.354 on the entry to turn 15 while the 2,0 is 1.425s behind by the entry of turn 15.

6.1.3:-0.5,0 compared to 1,0 and 0.5,0

The driver was able to achieve a time of 1:37.137 with 1,0 and a lap time of 1:37.073 with the 0.5,0 setup which is close to the 1:36.749 produced with the -0.5,0 setup.

The first notable corners are turns 3-5 where 0.5,0 is able to get a slight edge over the -0.5,0 and large chunk of time over the 1,0 setup. 0.5,0 actually lifts first leaving the setup 0.316s behind -0.5,0 at the middle of turn 3 while 1,0 does not get off the throttle as quickly but still does so before -0.5,0 leaving the car just 0.096s behind -0.5,0 at the same section. 0.5,0 however gets on the throttle much sooner out of turn 3 which cancels out the time lost from the entry to turn 3 then -0.5,0 brakes harder into turn 4 losing more time which results in -0.5,0 losing time to 0.5,0, in fact 0.5,0 has a 0.114s lead over -0.5,0 heading into turn 5 while 1,0 gets a similar exit to -0.5,0 resulting in 1,0 being 0.280s behind -0.5,0.

-0.5,0 does gain back time through turns 10-14. At the start of turn 10 -0.5,0 is ahead of both 1,0 and 0.5,0 by 0.262s and 0.136s respectively. By the start of 15 however the lead has been extended to 0.348s and 0.303s respectively. 1,0 first loses time through turn 12 where they carry much less speed through the corner. This could be due to the fact that 1,0 is slower going into turn 12 and also the slightly higher steering angle used through turns 11 and 12. 0.5,0 however stays at a similar gap to -0.5,0 which is interesting as it means the extra braking is cancelled out by getting off the throttle later into the corner. -0.5,0 then brakes less through turn 13 which allows it to gain an advantage despite losing a bit of time on the exit of the corner by not being able to apply full throttle quickly enough.

6.1.4:-0.5,0 compared to -1.5,0 and -2,0

In the screenshot from Motec (Ap5) the red/dotted lines are for -0.5,0, the black lines are for -1.5,0 and the green lines are for 2,0. The best lap with -1.5,0 and -2,0 was a 1:37.060 and a 1:37.082 respectively which is slower than the time set by the -0.5,0 which is 1:36.749.

The comparison between the times seem to show like with the previous comparisons that -0.5,0 seems to be quick through turn 3 but slower through turns 4 and 5. Like in previous comparisons -0.5,0 is later off the accelerator and later on the brakes than the other 2 setups. However, -0.5,0 is the last of the 3 setups to get on the throttle and is slower to get on the throttle out of turn 4 too compared to -1.5,0 however was able to achieve full throttle faster than -2,0 meaning that -0.5,0 gained time over -2,0 on the exit of turn 4 but lost a bit of time to -1.5,0 at the same section. Overall at the entry to turn 6 -0.5,0 has a lead of just 0.041s to -1.5,0 and 0.234s to -2,0. -2,0 does not seem to get the same advantage out of turn 3 as -1.5,0. This could possibly be explained by a small spike in steering angle in the opposite direction at the exit of turn 3 for -2,0. This is evidence of oversteer occurring on the exit of turn 3 which is backed up by the quotes made by the driver of -2,0 being the twitchiest of the setups which could explain the oversteer moment. Interestingly the oversteer moment isn't large enough that the driver has to get off the throttle but is

significant enough that the delta shows that -2,0 does not gain as much time between turns 3 and 4 as -1.5,0 does.

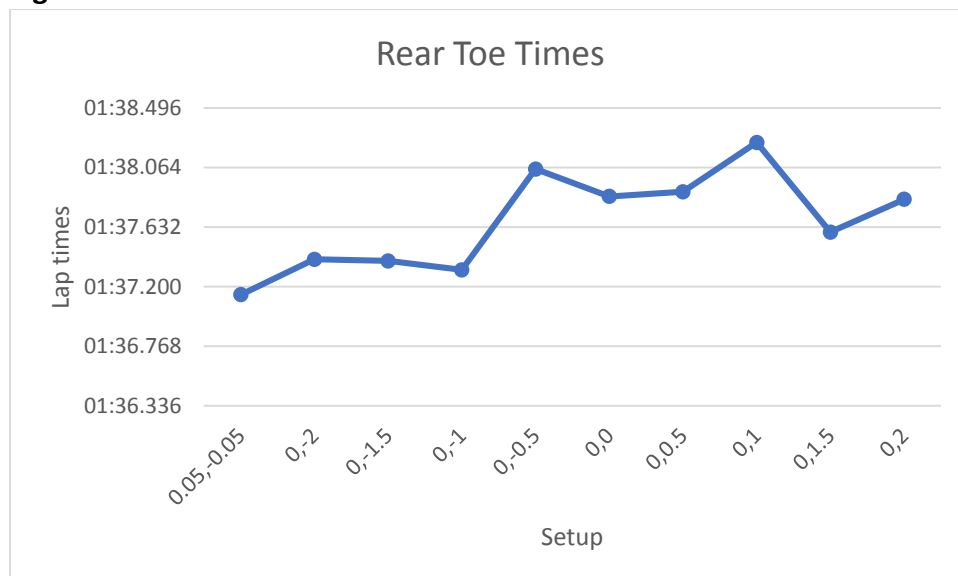
Like in previous comparisons, -0.5,0 seems to have a very strong turn 12 but loses out a little bit through turn 13. At the start of turn 12 -0.5,0 has a lead of 0.128s to -1.5,0 and 0.453s to -2,0. -0.5,0 carries much more speed than the other 2 setups through turn 12 allowing -0.5,0 to increase it's lead to 0.346s to -1.5,0 and 0.569s to -2,0. However the hesitation to get to full throttle and the increased steering angle needed later on in the corner because the car was understeering wide which was shown when -0.5,0 was compared to 1,0 and 0.5,0 caused -0.5,0 to lose a bit of time to -1.5,0 and -2,0 as well. As a result by the entry of turn 15 the lead of -0.5,0 has been cut down to just 0.414s for -2,0. However the lead is greater against -1.5,0 at 0.397s despite being slower down the straight. This is likely due to the extra speed carried through turn 13 before going wide. -2,0 seems to take a better line through turn 13 compared to the other 2 setups. This is backed up by -2,0 being able to apply the throttle sooner and also having a consistent steering angle throughout turn 13 compared to the other 2 setups. -0.5,0 had to use more steering angle on the exit of turn 13 and -1.5,0 had to use more steering angle on the entry of turn 13.

Overall the optimal toe at the front appears to be -0.5 degrees. The lap time was generally faster especially through turns 3, 7, 12 and 16-18. However the car did struggle through turns 4 and 13.

6.2-Initial results rear

The next step is to compare the fastest laps of the rear toe angles. Fig2 below shows how the lap times compare for all the setups that changed the rear toe angle only.

Fig2



Looking at this graph the optimal rear toe angle appears to be at -1 degrees. The strange thing about this graph is that from 0,1 to 0,0.5 the lap times seem to be significantly slower than the rest of the data. All of these lap times are most likely anomalies as the 0,0 setup was an anomaly data for the fronts too so the lap times of the other 3 setups are most likely

Another thing to note is that all of the lap times are slower than the stock setup which is not the case for the front toe angle only setups which 4 of the 8 setups (not including 0,0 as it there is no toe angle present on this setup and it is present on both graphs) are faster than the stock setup. This indicates that adjusting the front toe angle is more effective at improving lap time than adjusting the rear toe angle.

The first thing to do is to compare the anomalies to the fastest lap time to see why they are so much slower.

6.2.1-Comparing 0,-1 to 0,1 and 0,0.5

In the screenshot (Ap6) 0,-1 is in the red/dotted lines while the 0,1 and 0,0.5 are shown as black lines and green lines respectively. 0,-1 achieved a time of 1:37.321 while 0,1 and 0,0.5 achieved lap times of 1:38.246 and 1:37.888 respectively.

0,1 seems to pull away from the other 2 setups through turns 6 and 7. 0,1 starts to pull away half way through turn 6 by applying the throttle sooner. 0,0.5 seems to use much higher steering angle through turns 6 and 7 than the other 2 setups however 0,0.5 is at a similar pace through the turns 6 and 7. This indicates that the driver is taking a different line through turns 6 and 7 which judging by the increase is at the entry to the corner suggests that the driver is taking a wider line on entry to get a better exit out of the corner. The driver was later on the throttle which is odd given that the line should be better on exit getting on the throttle later has affected the lap time which may have attributed to why the lap time is slower. 0,1 also seems to take a wider line through turns 6 and 7 although the steering angle is not as great and the driver does get on the throttle a little bit quicker but still not as fast as with 0,-1. Turn 6 and 7 is most likely the reason why these 2 lap times are slower than they should be.

Another sequence of corners where 0,-1 is faster is from turns 11-14. Initially 0,-1 loses a bit of time through turn 11 by lifting off slightly earlier than the other 2 setups. However 0,-1 then gets on the throttle much sooner than the other 2 setups which allows the car to gain back the time lost through turns 12-14. This result in 0,-1 and 0,0.5 maintaining a similar gap to when the sequence of corners started. 1,0 however loses more speed as the driver does not apply the throttle as quickly which results in 1,0 carrying less speed on the exit of turn 13 into turn 14.

6.2.2-0,-1 compared to 0,0 and 0,-0.5

In the screenshot (Ap7) 0,-1 are the red/dotted lines, 0,0 are the black lines and 0,-0.5 are the green lines. As stated before the driver was able to achieve a lap time of 1:37.321 with the 0,-1 setup while they were only able to achieve a lap time of 1:37.855 with a 0,0 setup and a lap time of 1:38.053 with the 0,-0.5 setup.

0,-1 firstly gains an advantage through turns 3-5. 0,-1 initially gets off the throttle and brakes earlier than the other 2 setups which causes 0,-1 to lose a decent chunk of time to 0,0. However the appears to be an oversteer moment mid corner for 0,0 which causes the driver to be unable to get on the throttle as quickly which causes 0,0 to carry less speed out of turn 3 which results in a 0.153s lead turns to a 0.432s deficit. 0,0 is then able to get on the throttle sooner than the other 2 setups through turn 4 which allows 0,0 to reduce the gap

back down to 0.190. 0,-0.5 is slower through turns 1 and 2 so is not as able to capitalize on the earlier braking meaning that it only maintains the gap to 0,-1. Through turn 4 0,-0.5 brakes at the same point as 0,-1 but gets off the brakes earlier allowing 0,-0.5 to gain a small advantage however 0,-1 is able to get to full throttle sooner which allows car to accelerate more which increases the gap from 0.048s to 0.162s to 0,-0.5. The slowness to get on full throttle also allows 0,0 to close right up to 0,-5 with a gap of just 0.028s on the exit of turn 4 into turn 5.

0,-1 also gains time through turns 6 and 7. 0,-1 releases the throttle and brakes at a similar time to 0,-0.5. 0,0 however gets off the throttle and brakes later which gains 0,0 time through turn 6. However 0,0 and 0,-0.5 brake harder than 0,-1 which allows 0,-1 to gain time on both setups. 0,0 does get on the throttle sooner but takes longer to get to full throttle indicating that the driver got on the throttle too quickly and understeered wide, this is also evident by the driver steering for longer at the exit of turn 7. 0,-0.5 however gets on the throttle more slowly which costs time as 0,-1 accelerates earlier.

The next step now is to look at the rest of the data for the rear compared to the fastest time set by any of the rear toe angles which was with 0,-1.

6.3-0,-1 compared to 0,2 and 0,1.5

In the screenshot (Ap8) The green lines are 0,2, The black lines are 0,1.5 and the red/dotted lines are 0,-1. 0,-1 has a lap time of 1:37.321 while the best lap with 0,1.5 is 1:37.595 and the best lap with 0,2 was a 1:37.833

0,-1 gains time over 0,2 through turns 3-5. 0,-1 initially lifts off the throttle earlier than the other 2 setups, however 0,-1 does not lose much time to 0,2 as the driver was carrying more speed into the corner. 0,1.5 does however brake later as well as lifting off the throttle later which allows 0,1.5 to gain an advantage of 0.337s to 0,-1 by the middle of turn 3. 0,-1 then gets off the brakes more quickly and gets on the throttle more quickly allowing 0,-1 to gain back the time lost. 0,-1 then brakes later into turn 4 initially extending its lead, however 0,1.5 is able to get off the brakes quicker and on the throttle more quickly which allows 0,1.5 to gain a lot of time and to take the lead by 0.245 by the entry to turn 6. 0,2 appears to have an oversteer moment in the middle of turn 3 which is shown by the spike of steering angle in the opposite direction to the corner which would be done to prevent the oversteer from spinning the car. 0,2 then appears to have a massive oversteer moment into turn 4 which is evident by the opposite steering angle occurring through the whole corner. These oversteer moments are odd considering the driver stated that the car was prone to understeer through especially through the slower corners so it may possibly be down to driver error. 0,2 is then slower on the throttle compared to 0,1.5 but does get on the throttle earlier than 0,-1 which allows 0,2 to reduce the damage done time wise by the oversteer moments. As a result of turns 3-5 0,2 is 0.461s behind 0,-1 by the entry of turn 6.

0,-1 regains the lead over 0,1.5 through turns 6 and 7. 0,1.5 initially gains time over 0,-1 through turn 6 because the driver brakes later and lifts off the throttle later with 0,1.5 than 0,-1. 0,-1 is able to get off the brakes fully sooner than 0,1.5 and 0,1.5 appears to understeer wide which is indicated by the steering wheel angle being much higher throughout the corner. The understeer is further backed up by the driver feedback as the driver stated that

the car was prone to understeer. Finally 0,-1 is able to get on the throttle quicker than 0,1.5 allowing 0,-1 to regain the advantage by just 0.023s by the entry of turn 9. 0,2 maintains a similar gap to 0,-1 throughout turns 6 and 7 which as a result leaves a gap of just 0.417s by the entry of turn 9 between them.

6.4-0,-1 compared to 0,-1.5 and 0,-2

In the screenshot for this comparison (Ap9) 0,-1 are the red/dotted lines, 0,-1.5 are the black lines and 0,-2 are the green lines. This is the closest comparison so far with 0,-1, 0,-1.5 and 0,-2 achieving times of 1:37.321, 1:37.387 and 1:37.398 respectively.

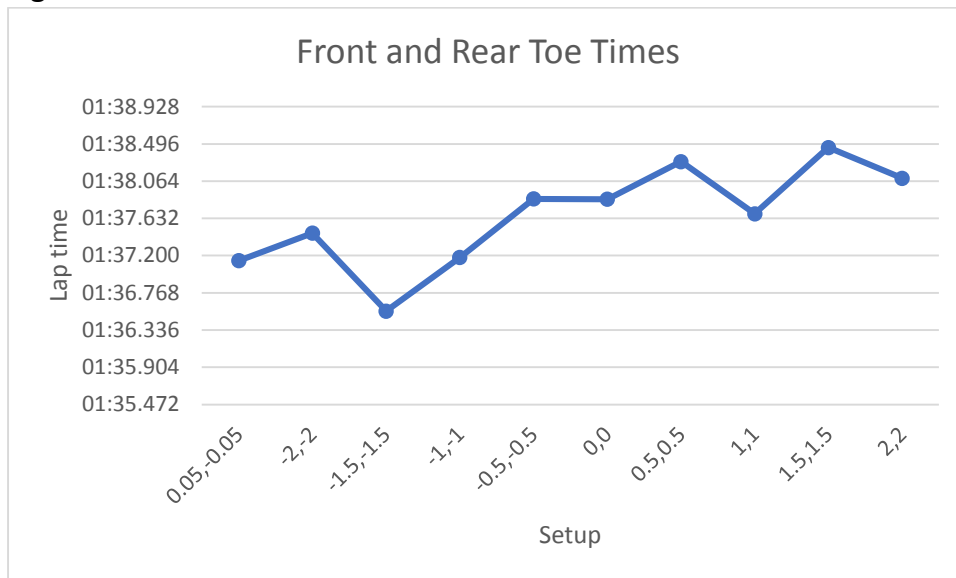
0,-1 gains time over 0,2 through turns 6 and 7. Initially loses time through turn 6 as 0,-2 is able to get off the brakes earlier which allows the driver to carry more speed through the corner. However 0,-1 has a smoother steering input through turn 6 which allows 0,-1 to get on the throttle quicker and gain time on the exit of turn 6. This also means that 0,-2 carries less speed into turn 7 which initially loses 0,-2 a substantial amount of time compared to 0,-1 by the middle of turn 7. The driver then however gets on the throttle sooner with 0,-2 which allows it to gain some time over 0,-1. Overall though 0,-2 loses out across turns 6 and 7 and by the time we reach the entry of turn 9, 0,-1 has a lead of 0.231s. 0,-1.5 is able to gain time in the same section. 0,-1.5 is actually the first off the throttle and on the brakes which results in 0,-1.5 losing time initially to the other 2 setups. 0,-1.5 is then quickest on the throttle out of turn 6 which allows to gain an advantage over the other 2 setups. 0,-1.5 then is able to get on the throttle quicker out of turn 7 as well compared to 0,-1 but not as quickly as 0,-2. However 0,-1.5 is unable to get to full throttle quicker than the other 2 setups resulting in the time gained for initially getting on the throttle sooner to be cancelled out. However 0,-1.5 is in the lead by turn 9 with a lead of just 0.031s.

0,-1 gains time over 0,-1.5 through turn 9. 0,-1.5 has to use more steering angle through turn 9 than 0,-1. This indicates that 0,-1.5 understeered more through turn 9. This results in 0,-1.5 being able to carry noticeably less speed through turn 9 which means by the entry to turn 10, 0,-1 now has a lead of 0.145s to 0,-1.5. 0,-1 also gains more time to 0,-2, however the increase is quite small increasing from 0.231s to 0.251s. This is interesting as 0,-2 turns into turn 9 earlier but is able to stop steering sooner on the exit which cancels out the time lost meaning that the 2 different lines provide similar results.

6.3-Front and Rear Toe Angles

The next step is to look at both the front and rear toe angles. Fig3 shows the lap times produced by each setup along with the stock setup.

Fig3



Looking at the graph the general trend is that the setups seem to get faster the more negative the toe angle. This reaches it's peak at -1.5,-1.5 as -2,-2 is slower. Both 2,2 and 1,1 seem to be potential outliers as they are faster than the rest of the graph would suggest. Another thing to note is that the times are more spread out, this suggests that changing the toe angles for the front and rear has a much larger effect on the lap time than changing just the front toe angle only or the rear toe angle only.

The first thing to do will be to compare the 2 potential anomalies (2,2 and 1,1) to the fastest setup (-1.5,-1.5) to see what may have caused them to occur.

6.3.1- -1.5,-1.5 compared to 1,1 and 2,2

In the screenshot (Ap10) -1.5,-1.5 is the red/dotted lines, 1,1 is the green lines and 2,2 is the black lines. -1.5,-1.5 set a lap time of 1:36.557, 1,1 set a lap of 1:37.686 and 2,2 set a lap of 1:38.097.

-1.5,-1.5 gains time against the other 2 setups through turns 6 and 7. -1.5,-1.5 gets off the accelerator and brakes earlier into turn 6 giving it an initial advantage. -1.5,-1.5 is slower on the throttle out of turn 6 allowing the other 2 setups to gain some time back. A similar story happens in turn 7 where -1.5,-1.5 is the last one off the throttle but is also the last one back on the throttle on the exit. However despite this 1,1 is only able to gain a small amount back and 2,2 is actually losing a bit of time. This is partly due to -1.5,-1.5 carrying more speed but also because it is able to use less steering input overall which shows that as expected the more negative toe angle allows the car to turn in better. This is further backed up by the driver stating that -1.5,-1.5 is the best setup they drove especially on turn in. overall -1.5,-1.5 gains time over 1,1 and 2,2 going from 0.211s and 0.229s respectively to 0.375s and 0.530s respectively.

-1.5,-1.5 also gains time through turn 15. -1.5,-1.5 lifts off the throttle and brakes later into turn 15 but is also able to use the throttle earlier out of turn 15. This indicates that the driver could have applied full throttle earlier for the other 2 setups. 1,1 does get on the throttle mid corner but has to lift off and is ultimately the last to get back to full throttle that

costs it time. 1,1 also uses the most steering angle through turn 15 no doubt not helped by getting on the throttle earlier. 2,2 uses the least turning angle but this is most like because the driver carries much less speed through turn 15 with this setup which could have contributed it to being an outlier.

The next step is to compare the other lap times to the fastest time (-1.5,-1.5).

6.3.2- -1.5,-1.5 compared to 1.5,1.5 and 0.5,0.5

The screenshot for this comparison (Ap11) -1.5,-1.5 is the red/dotted lines, 1.5,1.5 is the black lines and 0.5,0.5 is the green lines. The driver was able to get a 1:36.557, 1:38.455 and 1:38.291 out of the -1.5,-1.5, 0.5,0.5 and 1.5,1.5 respectively.

Through turns 3-5 -1.5,-1.5 is able to gain time over the other 2 setups. Looking at the data most of the time is gained through turn 3. This is likely due to the fact that the driver gets off the throttle and brakes much later with -1.5,-1.5 compared to the other 2 setups. The other 2 setups do gain some time on the exit but it is a very short run between turns 3 and 4 preventing any significant gain. The driver then lifts off and brakes earlier into turn 4 with -1.5,-1.5 too allowing the setup to gain the time back. 1.5,1.5 is able to get on the throttle earlier however is only able to gain a little bit of time back through the exit of turn 4 and turn 5. Meanwhile 0.5,0.5 actually gets on the throttle at the same time as -1.5,-1.5 causing the gap to remain the same all the way to the entry of turn 6. Overall the that -1.5,-1.5 has over 0.5,0.5 and 1.5,1.5 is 0.377s and 0.515s respectively by the entry to turn 6.

By the braking point to turn 15 -1.5,-1.5 already has a lead of 1.421s to 1.5,1.5 and 1.416s to 0.5,0.5. The driver brakes at a similar point for all 3 setups although they do brake slightly later for -1.5,-1.5. However the driver does brake noticeably harder for 0.5,0.5 than the other 2 setups. This actually results in 0.5,0.5 losing time to the other 2 setups. The driver interestingly takes a very different line through turn 15 with -1.5,-1.5 compared to the other 2 setups. This is evident in the steering angle being much smaller but for much longer indicating a tighter line through the corner the other 2 setups have a larger steering angle at the entry of turn 15 but gets off the steering much more quickly indicating that the driver is going wide with these setups possibly to get a better exit. The tighter line however allows -1.5,-1.5 to maintain the throttle more and is able to gain more time out of turn 15. By the entry to turn 16 -1.5,-1.5 has extended it's lead to 1.684s to 1.5,1.5 and 1.727 to 0.5,0.5.

6.3.3- -1.5,-1.5 compared to 0,0 and -0.5,-0.5

In the screenshot for this comparison (Ap12) -1.5,-1.5 is the red/dotted lines, 0,0 is the black lines and -0.5,-0.5 is the green lines. -1.5,-1.5 has a lap time of 1:36.557, 0,0 has a lap time of 1:37.855 and -0.5,-0.5 has a time of 1:37.858.

On the entry to turn 6, -1.5,-1.5 actually brakes the earliest. This allows -0.5,-0.5 to gain a little bit of time over -1.5,-1.5. 0,0 however brakes harder into the same corner so is unable to gain any time from braking later. However it appears that -0.5,-0.5 braking later and not as much causes it to run wide. This is shown in the data by the higher steering angle compared to the other 2 setups, which both have similar steering angles through the corner, and the fact that -0.5,-0.5 takes the longest to get to full throttle. As a result -0.5,-0.5 loses a large chunk of time over the other 2 setups. -1.5,-1.5 is slower to get on the throttle

however the driver has to be hesitant on the throttle for the other 2 setups indicating that they are going wide which allows -1.5,-1.5 to extend it's lead further. This is evident in the steering percentage where -1.5,-1.5 reduces the steering angle much more quickly. Overall by turn 9 -1.5,-1.5 has a lead of 0.637s to 0,0 and 0.619s to -0.5,-0.5.

-1.5,-1.5 also gains time through turns 16-18 over the other 2 setups. -1.5,-1.5 is initially on the brakes much sooner which causes it to lose a bit on the entry to turn 16. -1.5,-1.5 is able to use more throttle out of turn 16 into 17 as well as use less steering angle allowing it to gain even more time. -0.5,-0.5 lose a considerable amount of time through these corners. This appears to be because of an oversteer moment through turns 16 and 17. The steering angle backs this up as there is an initial spike in steering angle out of turn 16 which indicating a massive oversteer moment followed by a smaller spike in steering angle at turn 17 indicating that the car oversteered in the opposite direction when the driver tried to correct the initial oversteer. This then causes, -0.5,-0.5 to lose time on the exit resulting in it being the slowest time of the 3 by just 0.003s. Overall -1.5,-1.5 has a lead of 1.298s to 0,0 and 1.301s to -0.5,-0.5. Without the oversteer moment -0.5,-0.5 would have likely been much closer.

6.3.4- -1.5,-1.5 compared to -1,-1 and -2,-2

In the screenshot for this comparison (Ap13) -1.5,-1.5 is the red/dotted lines, -1,-1 is the black lines and -2,-2 is the green lines. -1.5,-1.5 has a lap time of 1:36.557, -1,-1 has a lap time of 1:37.178 and -2,-2 has a time of 1:37.461.

-1.5,-1.5 loses a bit of time over the previous setups through turns 6 and 7. Like in previous comparisons -1.5,-1.5 lifts off later and brakes later which causes it to gain time into turn 6 initially. -1.5,-1.5 then has to use more steering angle and cannot get back on the throttle as quickly which loses -1.5,-1.5 the time gained on the entry to turn 6. The driver then makes the same mistake again which again causes -1.5,-1.5 to initially gain time but then lose it again on the exit of turn and through turn 8. Overall -1.5,-1.5 loses time to the other 2 setups being 0.021s behind -1,-1 and 0.081s behind -2,-2.

-1.5,-1.5 actually gains time over the other 2 setups through turn 15. On the entrance to turn 15 it has a lead of 0.167s over -2,-2 and 0.175s to -1,-1. -1,-1 loses a lot of time compared to the other 2 setups. One obvious reason is the significantly less speed carried through turn 15. This is not helped by the fact that it is also the last back on full throttle, as a result -1,-1 trails -1.5,-1.5 by 0.671s by the entry to turn 16. -2,-2 lifts off and brakes slightly earlier than -1.5,-1.5 which loses it a bit of time. The driver then tries to get on the throttle earlier but has to lift off slightly losing more time to -1.5,-1.5. Overall by the entry to turn 16 -2,-2 is 0.302s behind -1.5,-1.5.

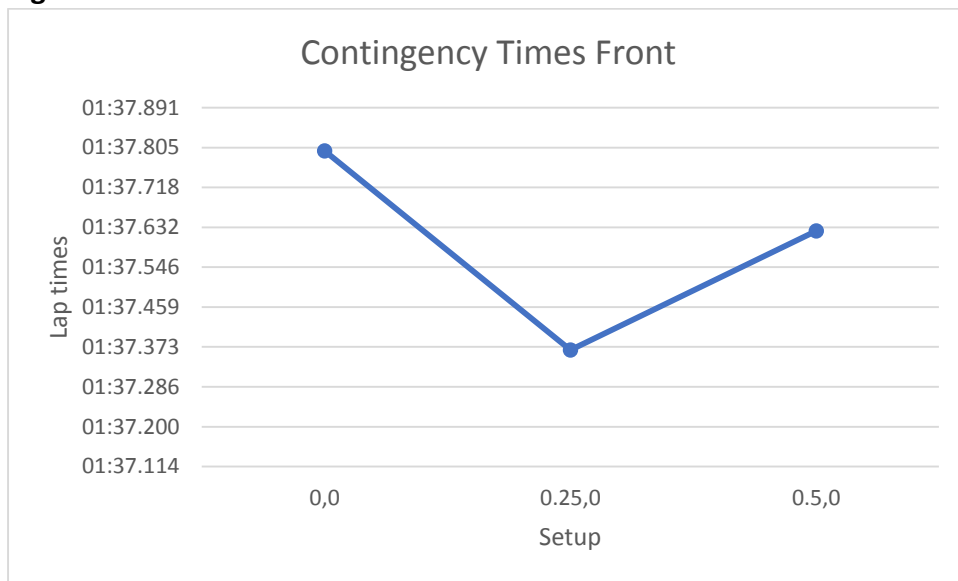
6.4-Contingency results Front

Unfortunately, there are only 3 contingency runs done. This is due to not having enough time in the simulator which is due to not being able to use the simulator enough due to various reasons.

These 3 runs are the only runs with tyre wear too so this section will not focus on the fastest laps and instead on tyre wear.

Fig 4 shows the fastest times from each session side by side.

Fig4



Looking at the fastest laps from the 3 setups seems to indicate that 0.25,0 seems to be the optimal setup with the fastest lap time which suggests that the optimal setup for one lap pace seems to be 0.25,0. 0,5 however had a faster lap time in the initial results but tyre wear could have also been a factor why the lap time is not as fast here.

Fig 5 shows each lap across each of the setups while Fig 6 shows the average lap for each of the runs.

Fig 5

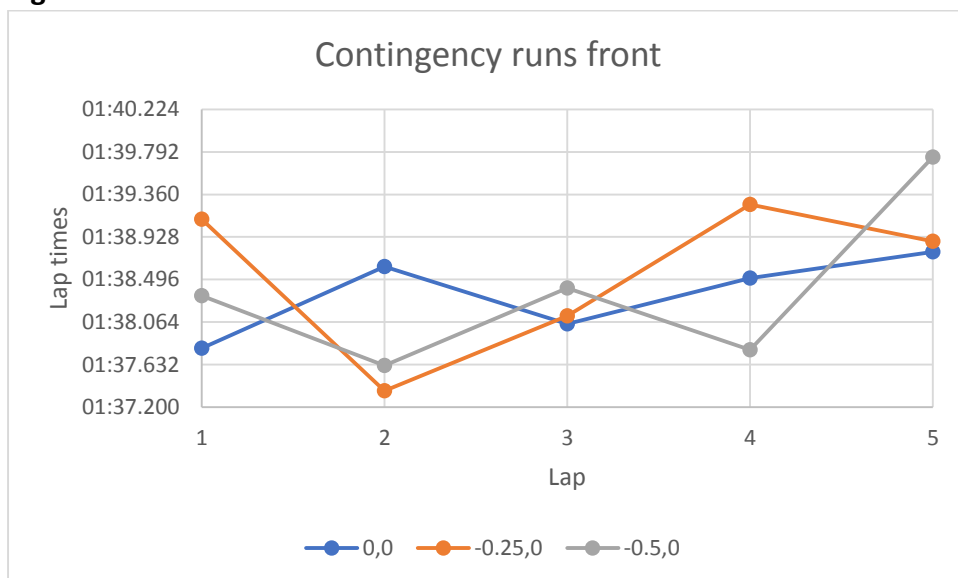
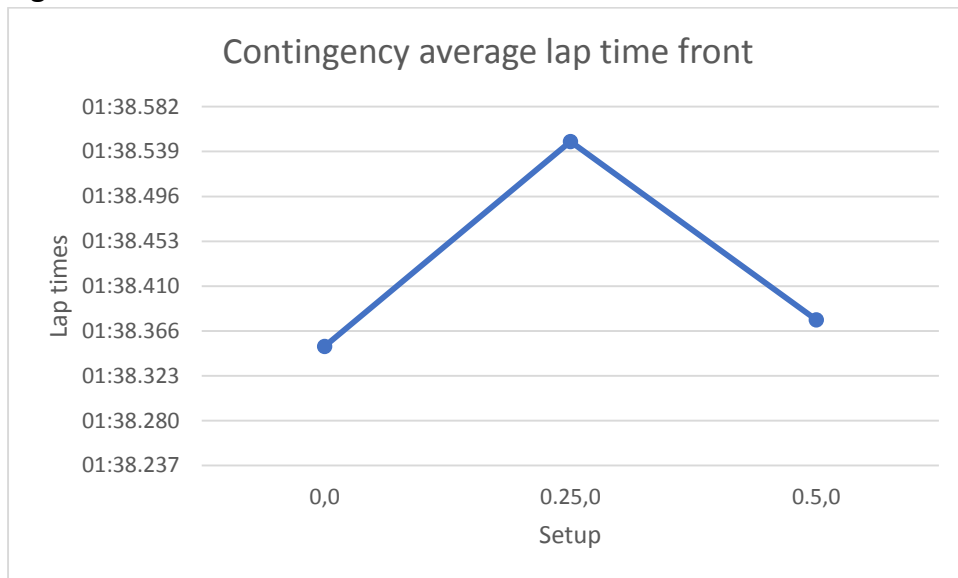
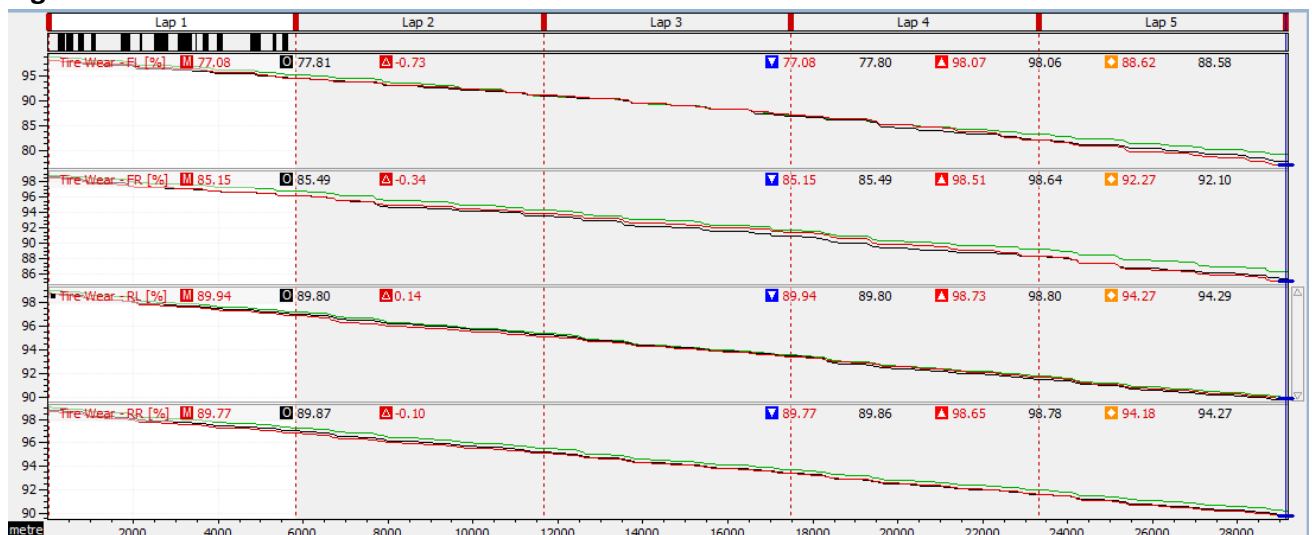


Fig6

Interestingly the opposite is true to the conclusion from the fastest laps showing that 0,0 was by far the most consistent setup with the best average lap too. -0.5,0 is only slightly slower than on average 0,0, in fact the 2 average laps are separated by just 0.026s. The lap times are noticeably more spread out though indicating it to be slightly harder to stay consistent over the stint.

The final thing to look at is the tyre wear which is shown in the screenshot from Motec below (Fig7)

Fig7

Overall there is not a massive amount of tyre wear over the 5 laps, but it is large enough for the driver to notice a small difference over the 5 laps. The front left tyre wore the most with the less than 80% of the tyre left for all 3 setups. The front right wore slightly better with 85-86% of the tyre left for the 3 setups and both rears wore the least with 89-90% of the tyres left for these setups. The front Unsurprisingly 0,0 has better tyre wear as expected over - 0.25,0 with the extra tyre wear most likely being caused by the greater toe angle although

the difference between them is very small with less than 1% difference on all tyres between the 2 setups. Interestingly though -0.5,0 has the best tyre wear of the 3 with 1% less tyre wear on both the rears and the front right and a 2% better tyre wear on the front left tyre. The driver suggested that this could be due to being able to turn in better meaning they were not pushing the tyres as much on turn in which could cause less tyre wear. The difference doesn't sound like much but it could allow the driver to go on an extra few laps in a longer race opening up more strategy options.

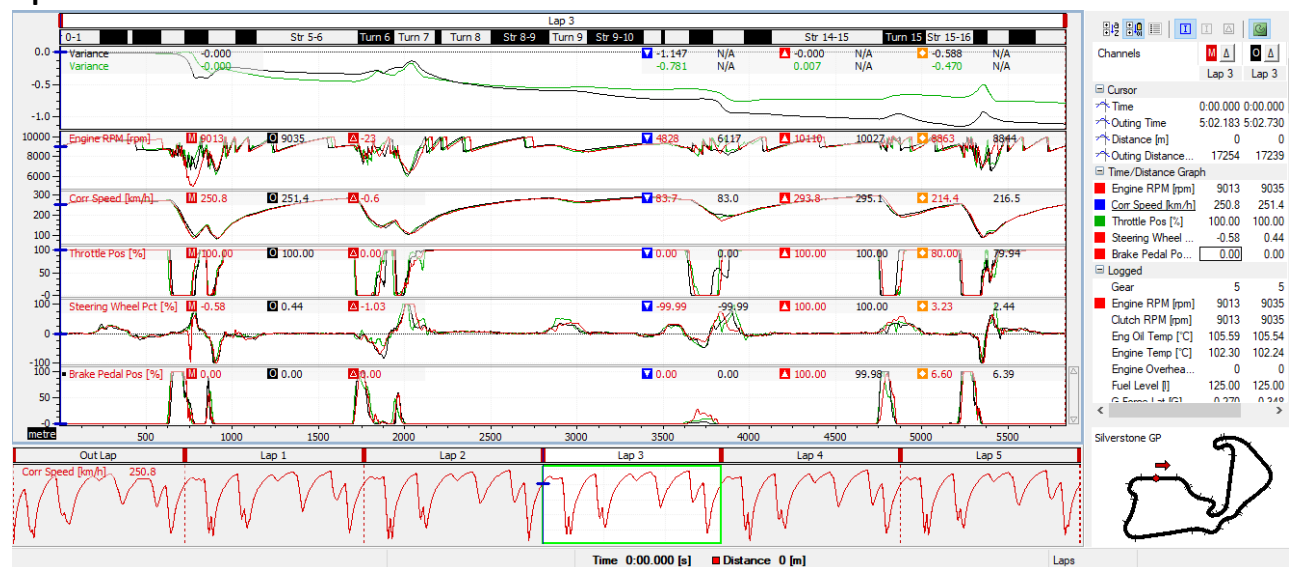
Overall the optimal setup appears to be -0.5,0 on the fronts given that it had the best tyre wear. Although -0.25,0 had a faster lap and 0,0 was more consistent and 0,0 was slightly more consistent, -0.5,0 performed the best over the 3 comparisons being the second best for fastest lap and average lap and having the best tyre wear.

7-Conclusion

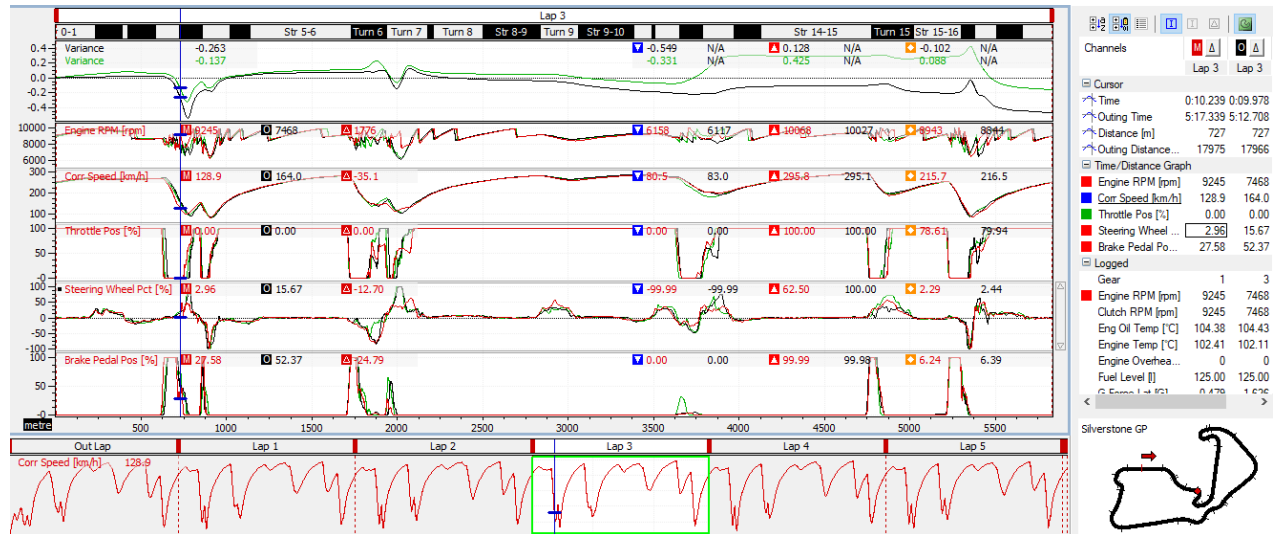
In conclusion is that -0.5,0 is the best of the setups that was also tested on the contingency. Out of all the setups -1.5,-1.5 seems to be the best setup for toe angle overall given that the fastest lap was with this setup. It is likely the best setup for the driver too given that it was the setup they felt happiest with. More testing would be required to see whether with tyre wear this setup would still be the go to option.

8-Appendix

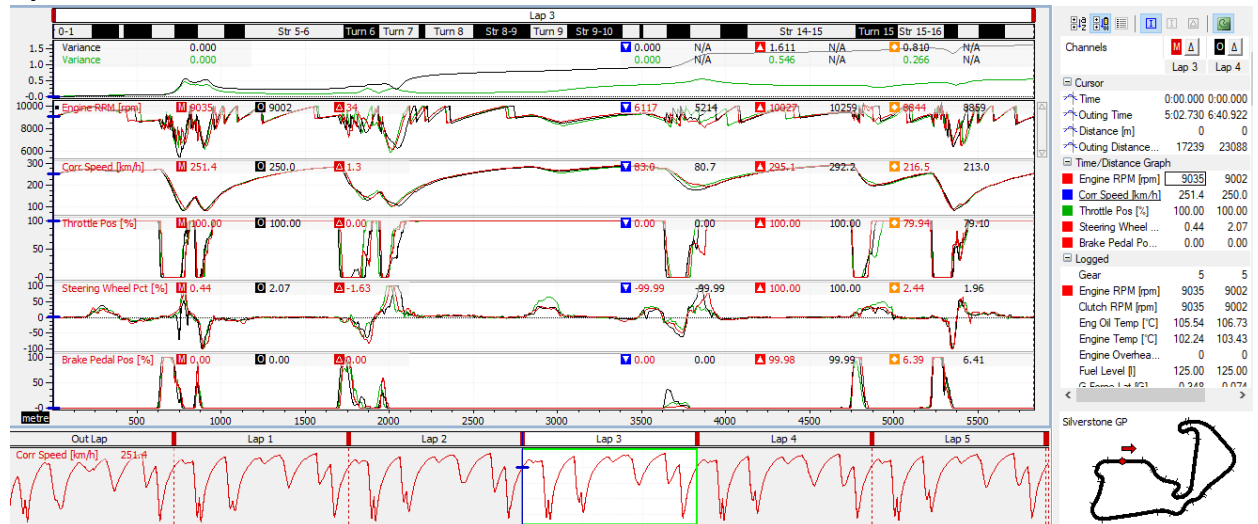
Ap1



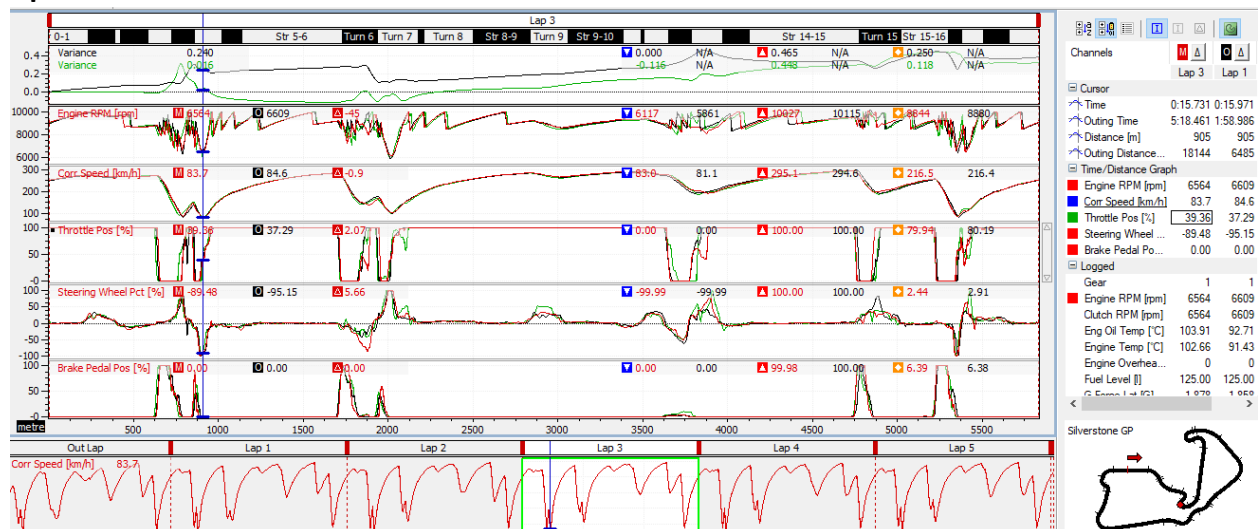
Ap2



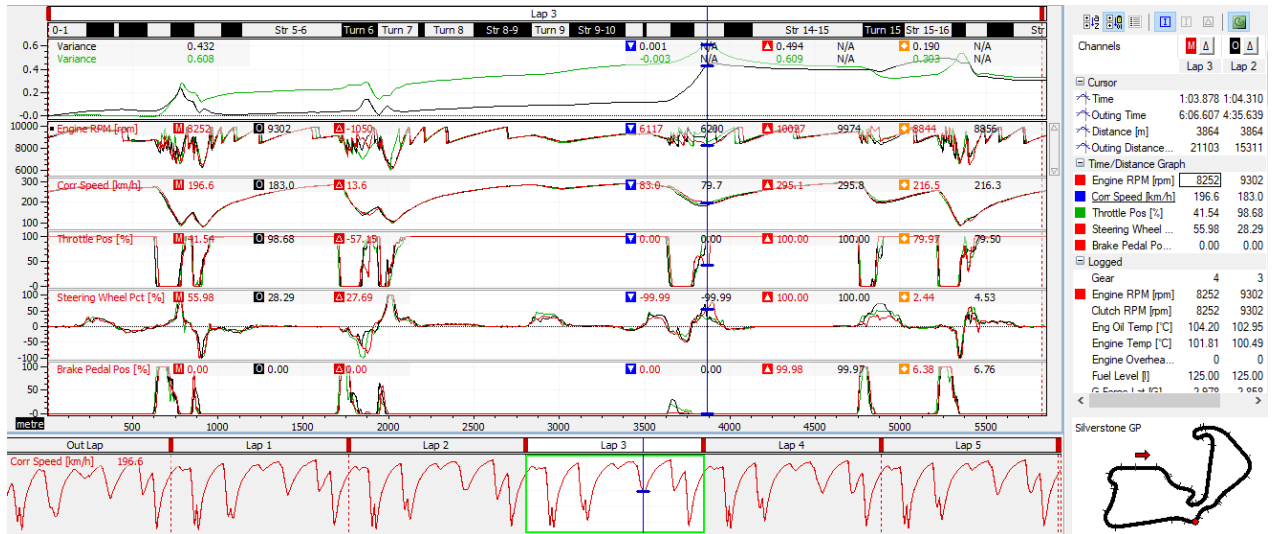
Ap3



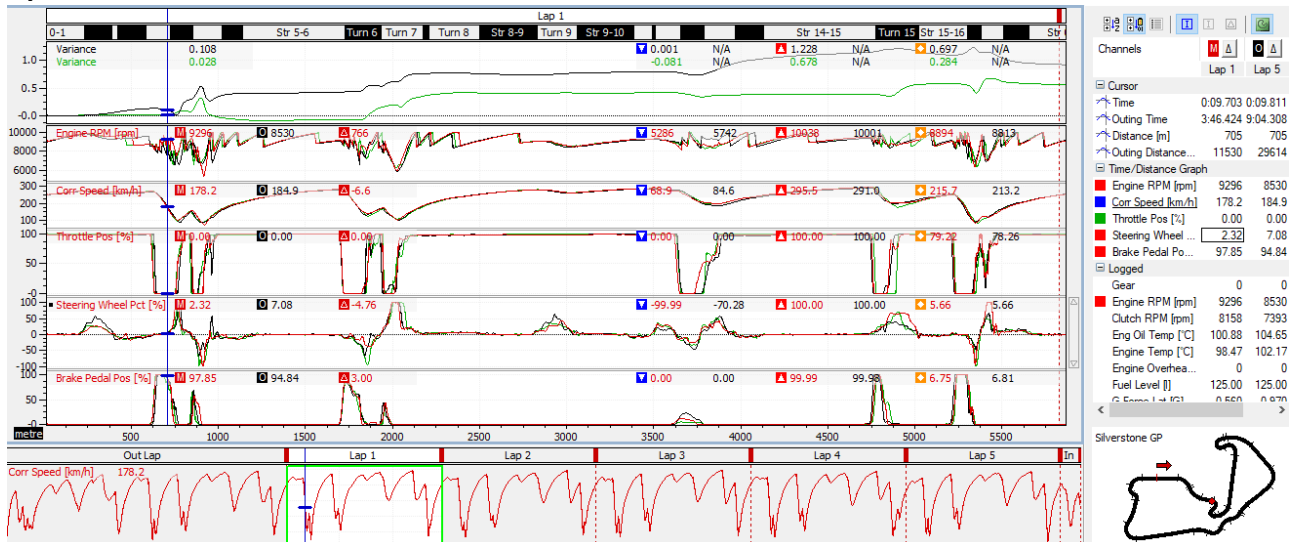
Ap4



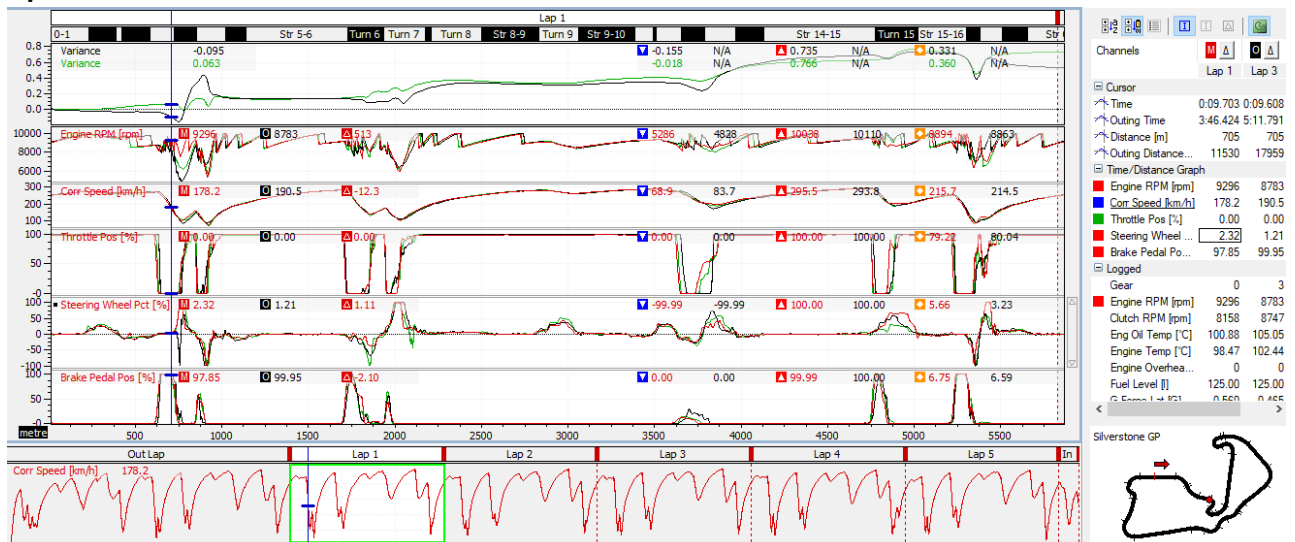
Ap5



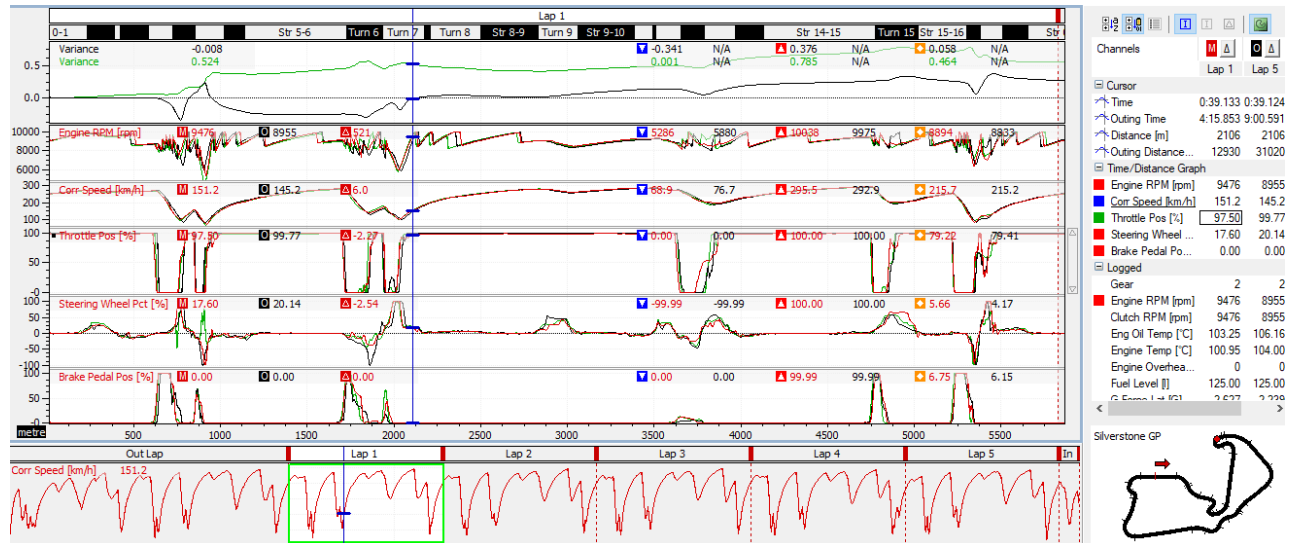
Ap6



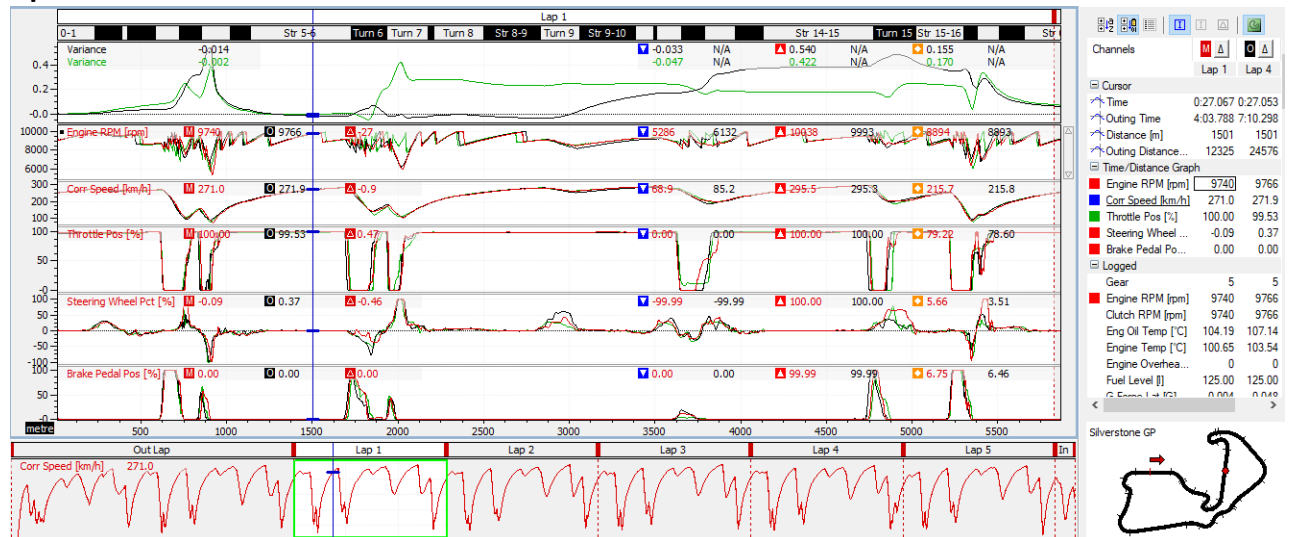
Ap7



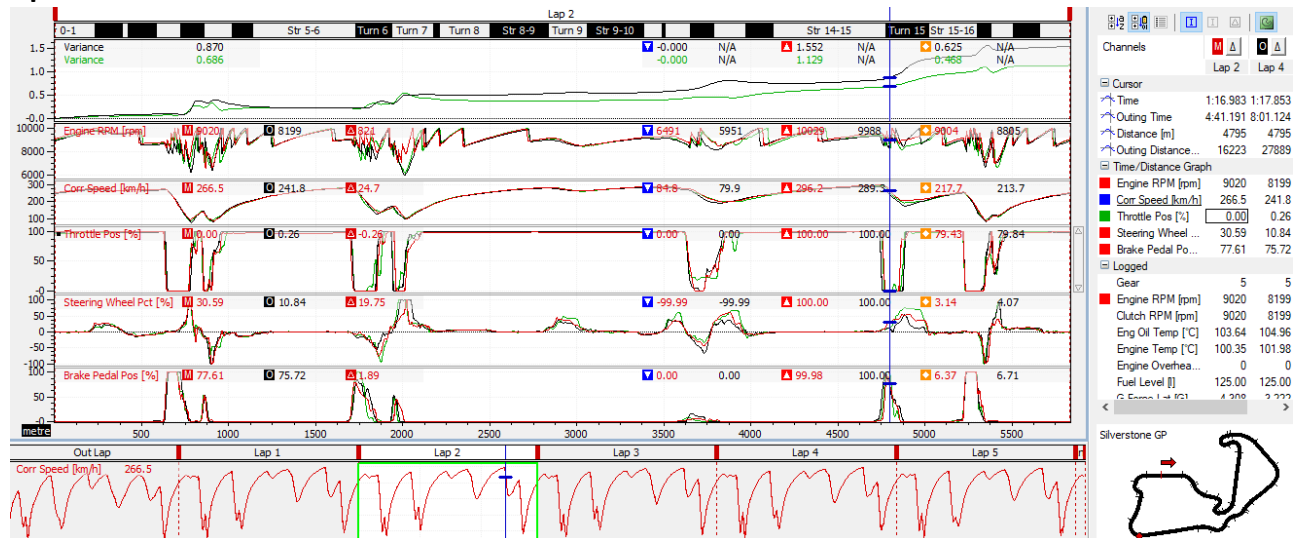
Ap8



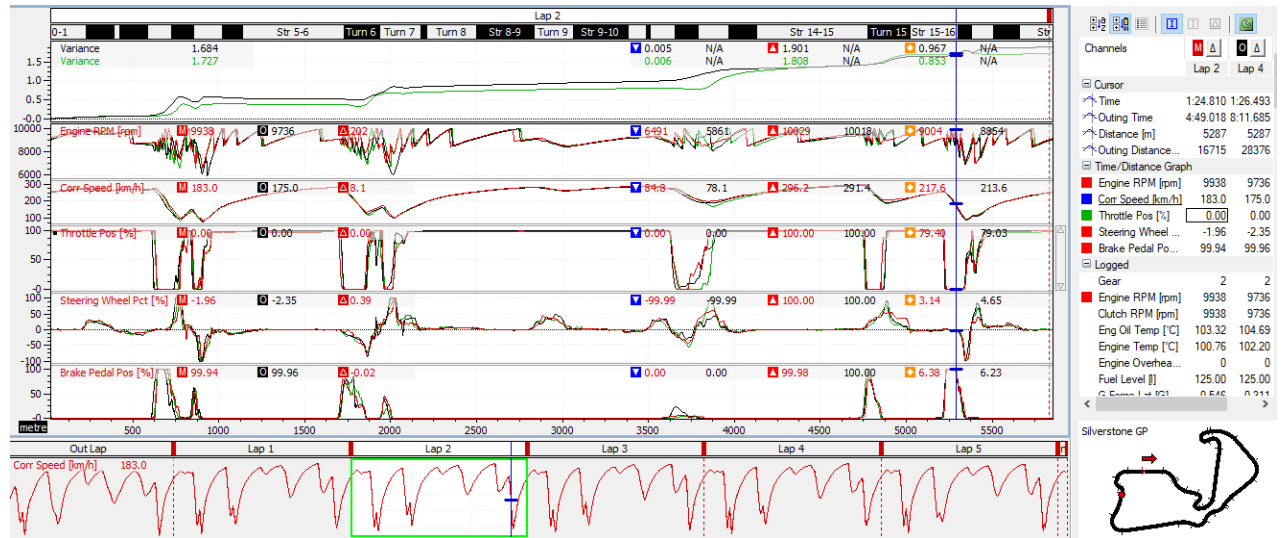
Ap9



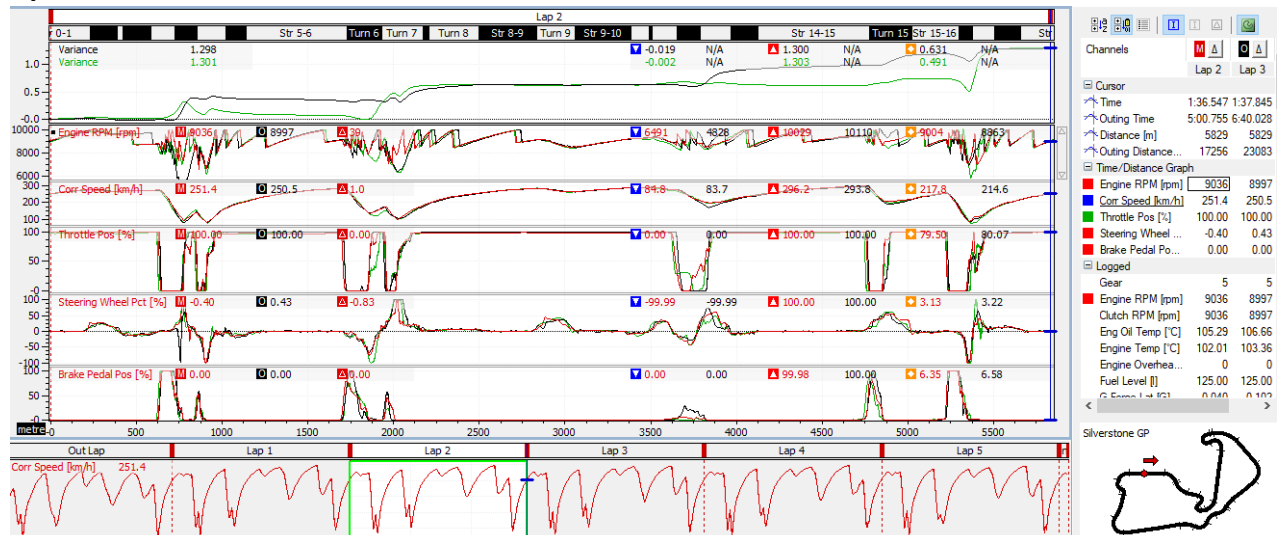
Ap10



Ap11



Ap12



Ap13



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