RST SOFTWARE

V1.0.43

User Manual

RACING SIM TOOLS

Web: RacingSimTools.com
Discord: RST Discord Channel
Twitter: twitter.com/sim_tools
Email: support@racingsimtools.com

Preface

Welcome and thank you for purchasing our new RST Software.

This new software is a complete revamp of the PC2Tuner app with highly expanded functionality that'll provide you far more tools to optimize your car setups effectively.

With expanded functionality comes increased complexity. So, don't be surprised if you feel a bit lost at first, even if you're already familiar with the PC2Tuner app. Please take your time and study this manual carefully. It'll guide you through the process of installation and initial telemetry recording, provides some tuning essentials and gives a detailed overview of all the tools available to help you become familiar with the new app.

We hope you'll enjoy using this tool as much as we did, building it!

Additional Video Guides

In addition to this guide you can find even more great advice on how to use the app effectively on RST's YouTube and Twitch channels.

1) Official RST YouTube Channel
   https://www.youtube.com/channel/UCRhu6lIt9a3-d36i7iligVQ
2) Official RST Twitch Channel
   https://www.twitch.tv/zeraxx

The Racing Sim Tools Team

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Acknowledgements

We would like to thank our staff members and affiliates AbeWoz, Brandon Dove, cSam, GIXXER_osg, Reiche, Hayden McLaren, Peter Stefani, Sloskimo, Speeddmon91, Velvet Torpedo, Voodoo, all beta testers and all the other good people on our Discord channel we may have forgotten to mention, for their continuous hard work and contributions to our awesome community and their feedback on the early drafts of this document.

Table of Contents

1. Getting Started

This section will guide you through the initial setup of the app, from installation to recording your first telemetry data.

Please be aware that you need an active internet connection to log into your RST account and use the app.

1.1. Installation and In-game Settings

1) Download the RST Software from the [Racing Sim Tools website]

2) Once the download is complete, double click on the setup file to install the app.

3) Start the app and create your RST account by clicking on the "Create Account" button

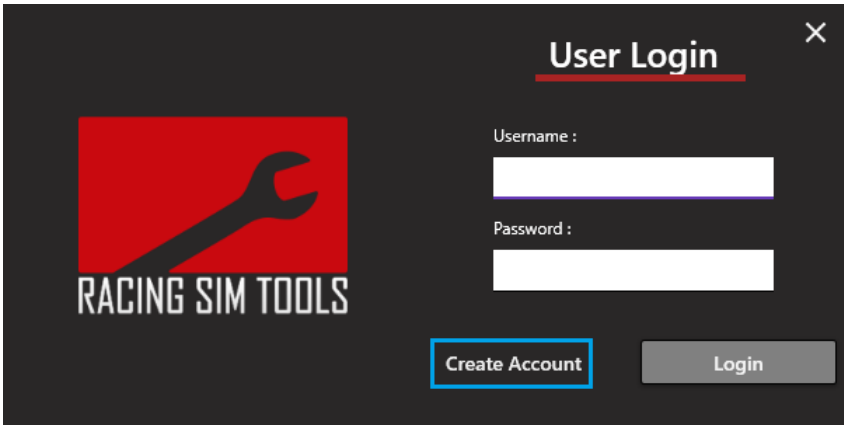

Figure 1.1: User Login

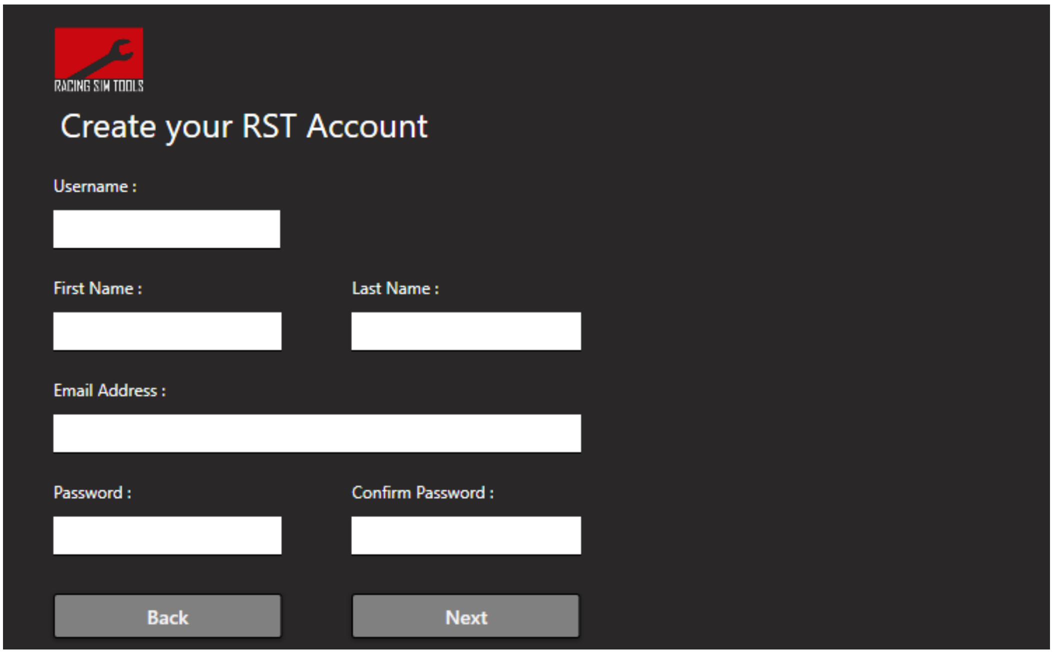

Figure 1.2: Account Creation

4) Choose your Username wisely because you won’t be able to change it and your purchased licenses are directly connected to it.

5) Navigate to the License Store by clicking on the shopping cart symbol at the top right and purchase the desired license(s).

6) Restart the app after purchase to register your new license.

7) Before using the RST software for the first time, make sure your games are configured as followed:

Project CARS 2

To allow the RST Software to receive telemetry data from PCARS 2, make sure that your UDP protocol is configured correctly in the game’s “System Options”:

Figure 1.3: In-Game UDP Settings for Project CARS 2

In addition to that you should add an exception for the “RST Software.exe” to your AV – Software and Firewall.

Note: Some routers may have issues with the high data volume of UDP Freq. = 1. If your router is affected by this, you should either turn UDP off during online races or increase the value. Be aware though that the latter one will result in less reliable telemetry data in the RST Software.

iRacing

There's no need to configure anything in iRacing.

Instead of live recording data with the RST Software you can simply load an ibt file into the app. Make sure to set the file type to “iRacing Telemetry (.ibt)”, otherwise you won’t be able to find your ibt files:

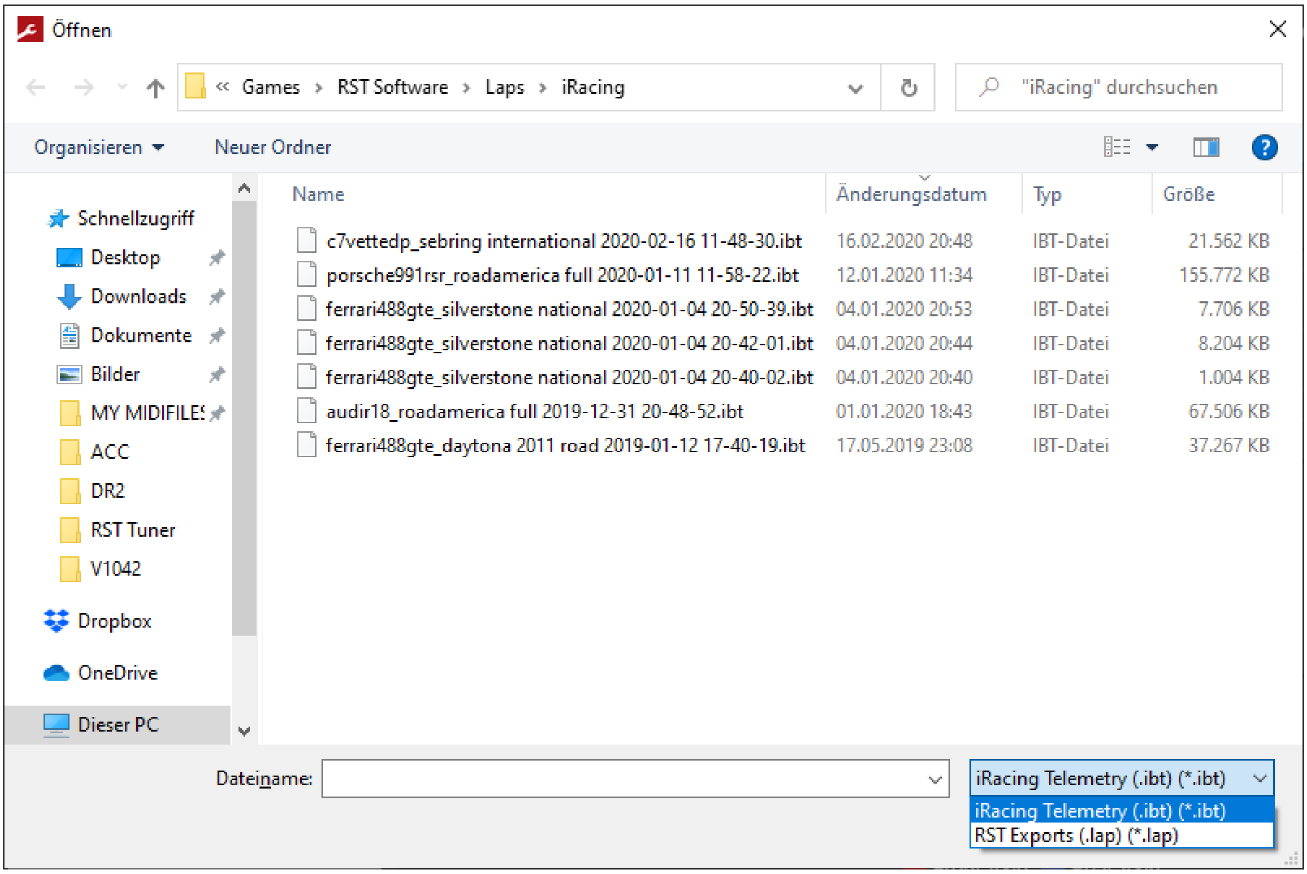

Figure 1.4: Session File Type Selection

F1 2019

This is the official guide from Codemasters on how to configure the UDP in F1 2019:

In F1 2019, UDP telemetry output is controlled via the in-game menus. To enable this, enter the options menu from the main menu (triangle / Y), then enter the settings menu - the UDP option will be at the bottom of the list. From there you will be able to enable / disable the UDP output, configure the IP address and port for the receiving application, toggle broadcast mode and set the send rate. Broadcast mode transmits the data across the network subnet to allow multiple devices on the same subnet to be able to receive this information. When using broadcast mode, it is not necessary to set a target IP address, just a target port for applications to listen on.

Advanced PC Users: You can additionally edit the game's configuration XML file to configure UDP output. The file is located here (after an initial boot of the game):

...\Documents\My Games\<game_folder>\hardwaresettings\hardware_settings_config.xml

You should see the tag:

<motion>

...

<udp enabled="**true**" broadcast="false" ip="127.0.0.1" port="20777" sendRate="20" format="2019" yourTelemetry="**public**" />

...

</motion>

Here you can set the values manually. Note that any changes made within the game when it is running will overwrite any changes made manually.

Dirt Rally 2.0

Unlike F1 2019, Dirt Rally 2.0’s UDP setup can’t be controlled via in-game menus. Therefore, you need to edit the game’s configuration XML file to configure the UDP output. The file is located here (after an initial boot of the game):

...\Documents\My Games\DiRT Rally 2.0\hardwaresettings\hardware_settings_config.xml

Search for the following tag and adjust the settings as followed:

<motion_platform>

...

<udp enabled="**true**" extradata="**3**" ip="**127.0.0.1**" port="**20777**" delay="**1**" />

...

</motion_platform>

Assetto Corsa (PC), Assetto Corsa Competizione and RaceRoom Racing Experience

There's no need to configure anything in AC, ACC and R3E. The data stream is essentially always running, and the RST Software will work immediately.

1.2. User Interface and Session Recording

The app UI consists of the main sections shown in the image below:

Figure 1.5: The RST Software UI Sections

1) File: Set your initial car parameters; manage your account and preferences.

2) Help: Open the RST manual or contact RST Staff.

3) Strategy: Optimize your pit strategy.

4) Game Selection: Choose the game you want to collect telemetry data for.

5) License Store: Purchase additional licenses for supported games.

6) Pin: Set the app to always stay on top.

7) Main Tabs: Select the main section of data you want to analyze.

8) Lap Tree: Switch between laps (and sessions) you want to analyze.
Edit car parameters per session and delete single laps.

9) Load / Save Session: Load / Save the currently selected session (car parameters included).
You can also load iRacing's ibt files with this function.

10) Telemetry Sub Tabs: Choose which data channels to review.

11) Telemetry Data Section: Displays the recorded (and calculated) telemetry data.

12) Zoom & Timeline: Adjust the data channel zoom factor, set the cursor position, switch X – Axis data type and check telemetry data rate.

On initial start-up not all sections are visible. You will notice that it says "No Game Selected" at the bottom left:

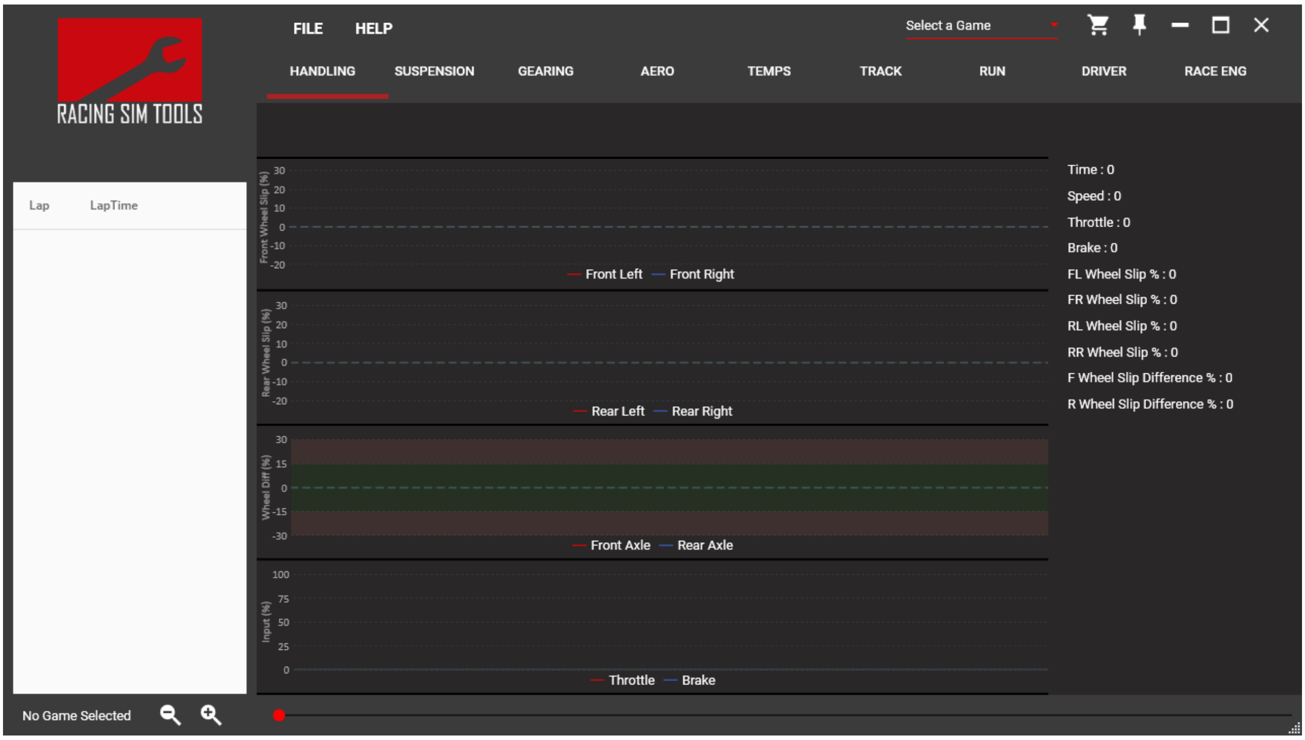

Figure 1.6: App View After Initial Start-Up

To prepare recording select your preferred game from the dropdown list at the top.

Go to "File" → "Next Session Car Params" and set the initial car parameters (see chapter 1.3) for your next session.

Now the app is ready to record a driving session (or load a previously saved one).

Note: For **iRacing**, you don't need to record live data with the app. You can simply load an ibt file by choosing iRacing in the Game Selection, clicking the Load button and selecting the file.

How to create an ibt file in iRacing

1) When in game, press “ALT + L”. This will start recording and you will see a small icon saying "Telemetry" that lets you know about this.

2) After you completed your race, Press "ALT+L" to stop the telemetry recording or get out of the session and the telemetry file will then be saved. You can find the ibt file in the following path: C:\Users\%USERNAME%\Documents\iRacing\telemetry

With every completed lap, the lap tree and telemetry data section will be populated. Once you're done with your first session, the data is displayed like this:

Figure 1.7: App View After Successful Data Recording

Before starting telemetry analysis, you should **double check your car parameters first** by clicking on the car icon next to the session name in the lap tree (see chapter 1.3). Otherwise most of the data will be incorrect.

Once you've made sure your car parameters are correct, you can select the lap you want to analyze in the lap tree.

Check out chapter 2 for a quick guide about initial setup tuning.

Initial RST Software Workflow

1) Select the game you want to collect telemetry data for in the "Select a Game" dropdown menu
2) Go to "File" → "Next Session Car Params" and set the initial car parameters for the next session
3) Now you can drive a practice stint. The app will record telemetry data automatically.
4) Analyze the recorded telemetry data and double check your car parameters for this session by clicking on the car icon in the lap tree.
5) Save the session file for later review/comparison if you wish. Your car parameters will be saved with it.

1.3. Car Parameters

As the title suggests you'll enter car parameters that are vital for telemetry data in this window. Most parameters can be taken directly from the in-game setup, but some must be acquired from external sources and can be difficult to come by.

You can load and save your car parameters with the two buttons at the top (separately from the currently selected session) and it's highly recommended to do this after every setup change.

Every parameter is crucial to achieve correctly calculated telemetry data. Make sure that the correct setup is loaded for every single session since car parameters don't work globally but are tied to the session.

1.3.1. Project CARS 2

<u>Chassis</u>

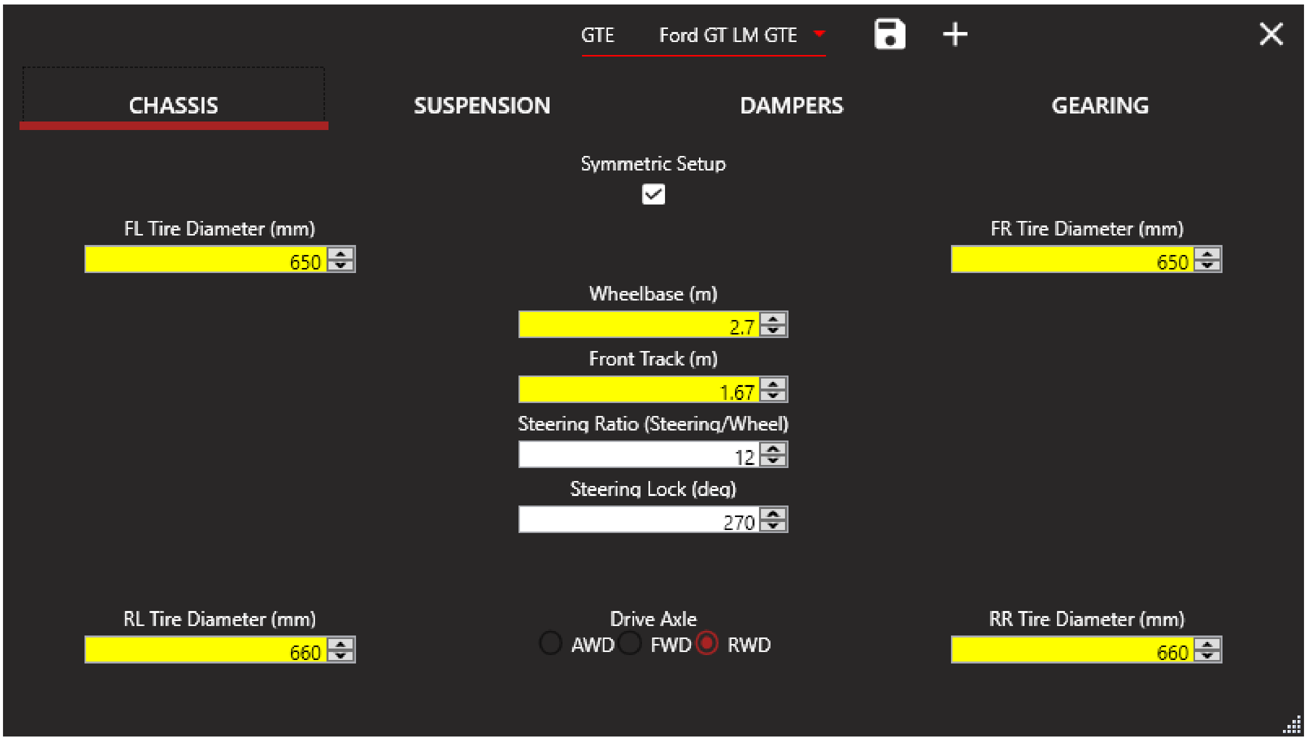

Figure 1.8: Car Parameters: Chassis

If you select a car from the dropdown list the yellow cells will be updated automatically, otherwise you have to enter the correct values yourself.

Steering ratio is part of the in-game car setup and should be taken from there.

For steering lock, you'll have to enter the actual steering lock from the in-game car. To do this, **turn the car's steering wheel fully to one side while standing still, estimate the steered angle and multiply it by 2**.

Front track width is difficult to find for many cars (unlike wheelbase), but a value of **1.6 m** is a close enough approximation for most cars.

Tire Diameters:

To assure that tire diameters are correct, check the Wheel Slip % Charts in the Differential screen.

If the tire diameters are correct, the wheel slip % will be close to zero when driving in a straight line, as shown in the image below:

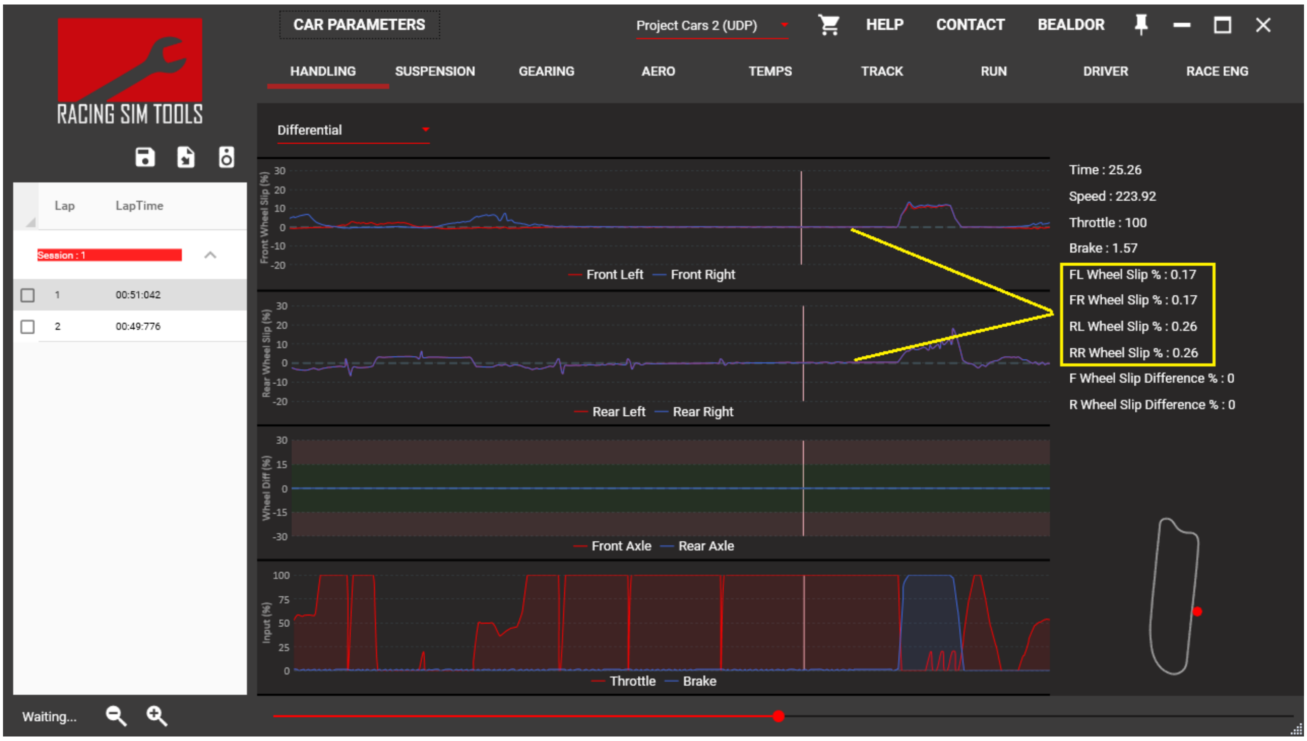

Figure 1.9: Wheel Slip % = 0 with Correct Tire Diameters

Suspension

Figure 1.10: Car Parameters: Suspension

Most values can be directly taken from the game's setup except for Installation Ratio (IR).

The IR is the inverse of the Motion Ratio (MR) and is defined as

$$IR = \frac{Spring\ Travel}{Wheel\ Travel}$$

Many sources (falsely) refer to it as MR, so be careful when searching for data on the web. Unfortunately, data for this is hard to find because it's confidential for most (race) cars.

If you select a car from the dropdown list the IRs will be entered automatically (and hidden), but you can also enter them manually by clicking on the "Manually Edit IRs" button.

Transition Speeds:

It is recommended to even out your bump and rebound transition speeds to avoid damper imbalances. If the game won't let you tune transition speeds but forces, you can easily calculate them with the following formulas:

$$v_{trans,bump} = \frac{F_{trans,bump}}{C_{LS,bump}} \cdot 1000$$

$$v_{trans,rbd} = \frac{F_{trans,rbd}}{C_{LS,rbd}} \cdot 1000$$

With: $v_{trans,bump}$, $v_{trans,rbd}$ = Transition speeds [mm/s]

$F_{trans,bump}$, $F_{trans,rbd}$ = Damper transition forces [N]

$C_{LS,bump}$, $C_{LS,rbd}$ = Low Speed Damping rates [Ns/m]

For most race cars, transition speeds between **50 mm/s (≈2 in/s) – 75 mm/s (≈3 in/s)** are recommended.

Ride Height:

To assure the correct ride height in PCARS 2 you need to use the sum of Bump and Travel from the Telemetry HUD (see image below) **while standing still** instead of the setup value, otherwise your downforce calculations can be off.

For most cars both values (telemetry and car setup) will match but there's a significant difference on a few cars you need to be aware of.

Figure 1.11: Ride Height Calculation

The reason for those differences is currently unknown but please be aware that the app always uses the formula

$$RH = \text{Bump} + \text{Travel}$$

for calculations and NOT the static ride height from your car setup.

Dampers

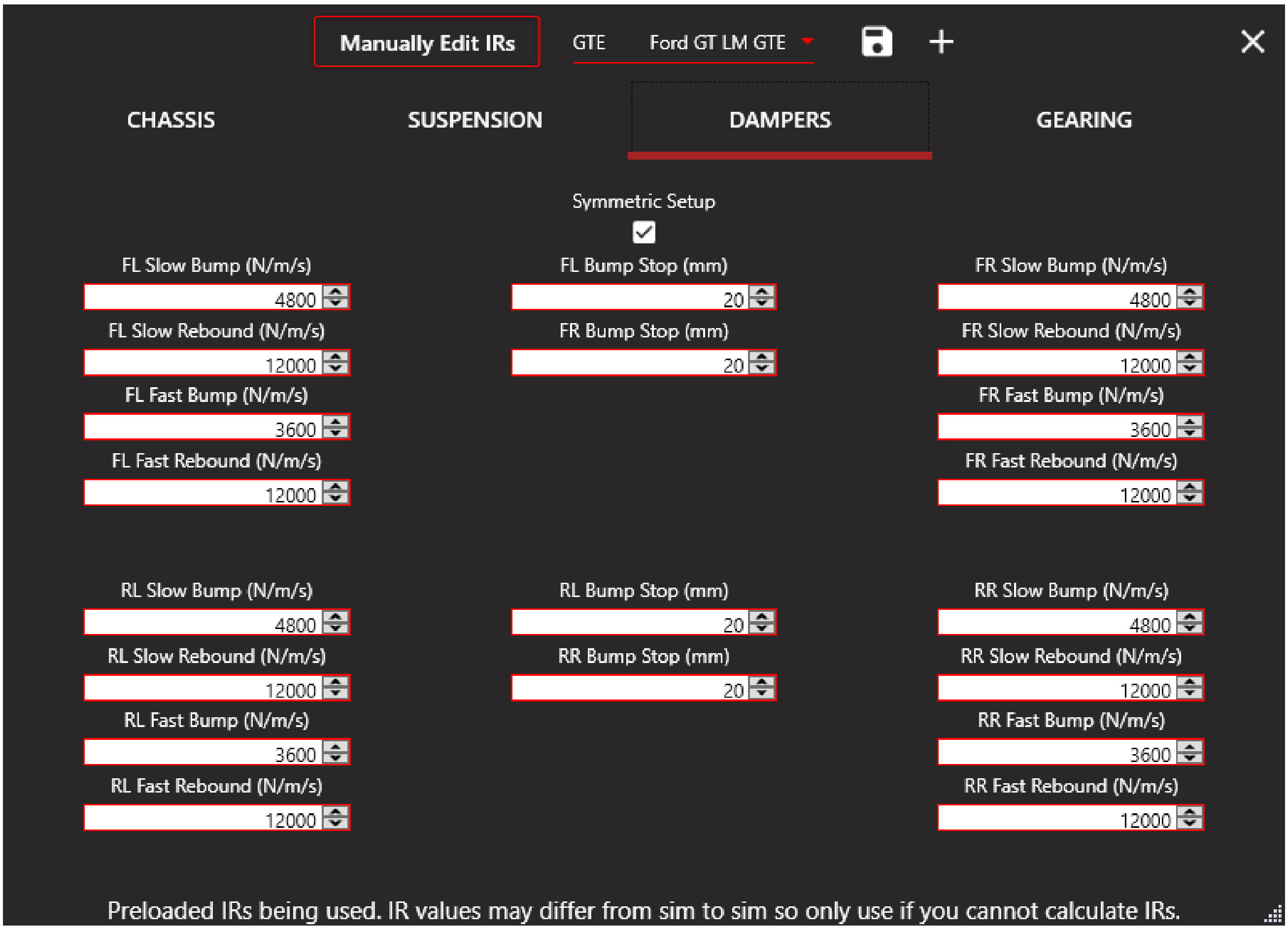

Figure 1.12: Car Parameters: Dampers

Once again, most values can be taken from the in-game setup except for the Damper Installation Ratio.

Like the spring's IR the damper's IR can be defined as

$$IR = \frac{Damper\ Travel}{Wheel\ Travel}$$

In a typical coilover suspension both IRs are identical, so you can use the same value for most race cars.

If you select a car from the dropdown list the IRs will be entered automatically (and hidden), but you can also enter them manually by clicking on the "Manually Edit IRs" button.

Gearing

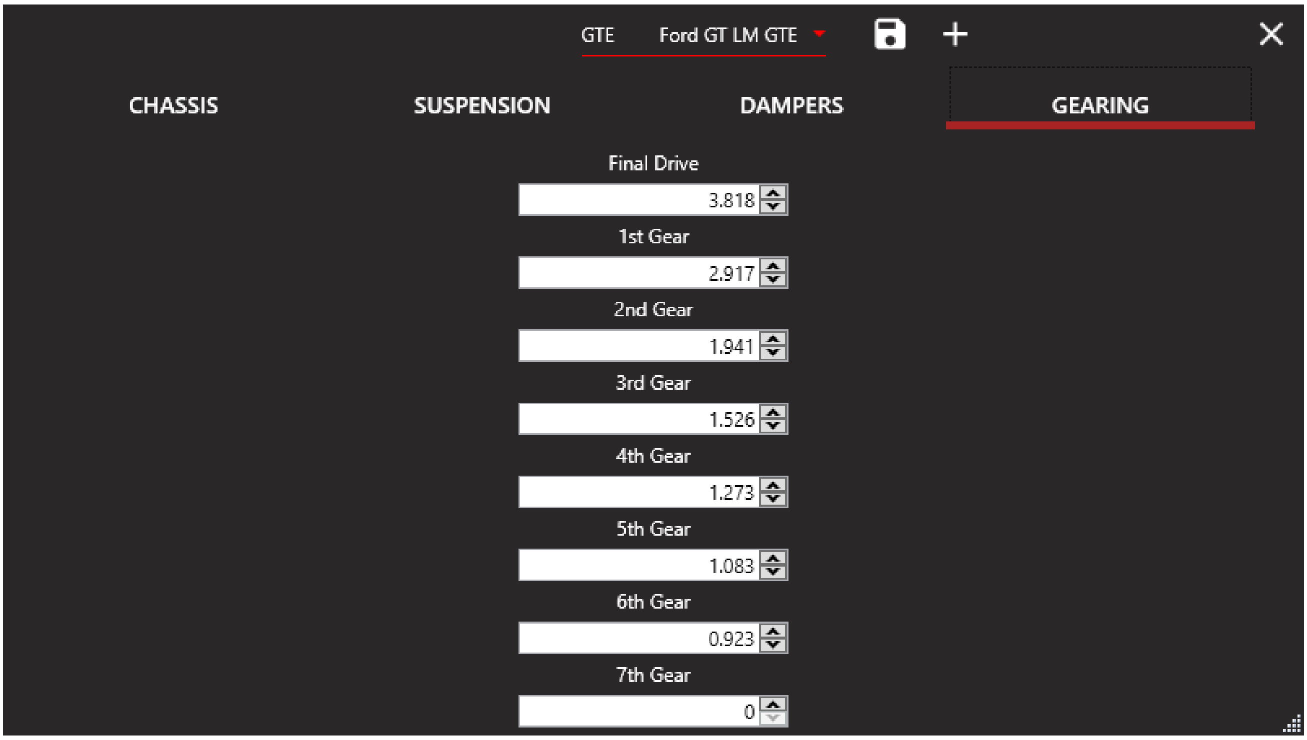

Figure 1.13: Car Parameters: Gearing

Simply enter the gearing ratios from the in-game setup for your car here.

1.3.2. Assetto Corsa (PC)

Chassis

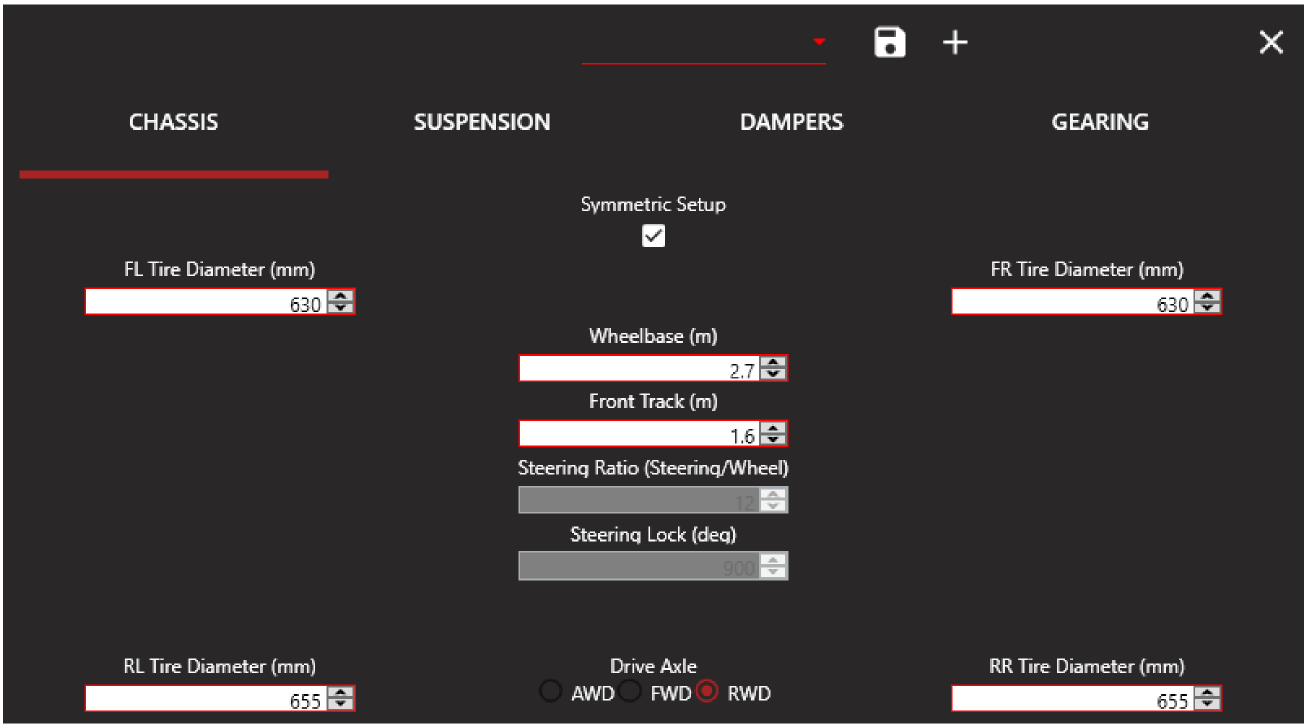

Figure 1.14: Car Parameters: Chassis

Steering ratio and steering lock values aren't needed for AC, that's why they're greyed out.

Front track width is difficult to find for many cars (unlike wheelbase), but a value of **1.6 m** is a close enough approximation for most cars.

We're currently building a car parameter database that'll include all of the above data (and more) for Assetto Corsa which can be found here.

If you want to help collecting data for our database, please fill out our Google Form.

Once the database is complete, we'll implement it in the app, so you won't have to enter said data manually anymore.

Tire Diameters:

To assure that tire diameters are correct, check the Wheel Slip % Charts in the Differential screen.

If the tire diameters are correct, the wheel slip % will be close to zero when driving in a straight line, as shown in the image below:

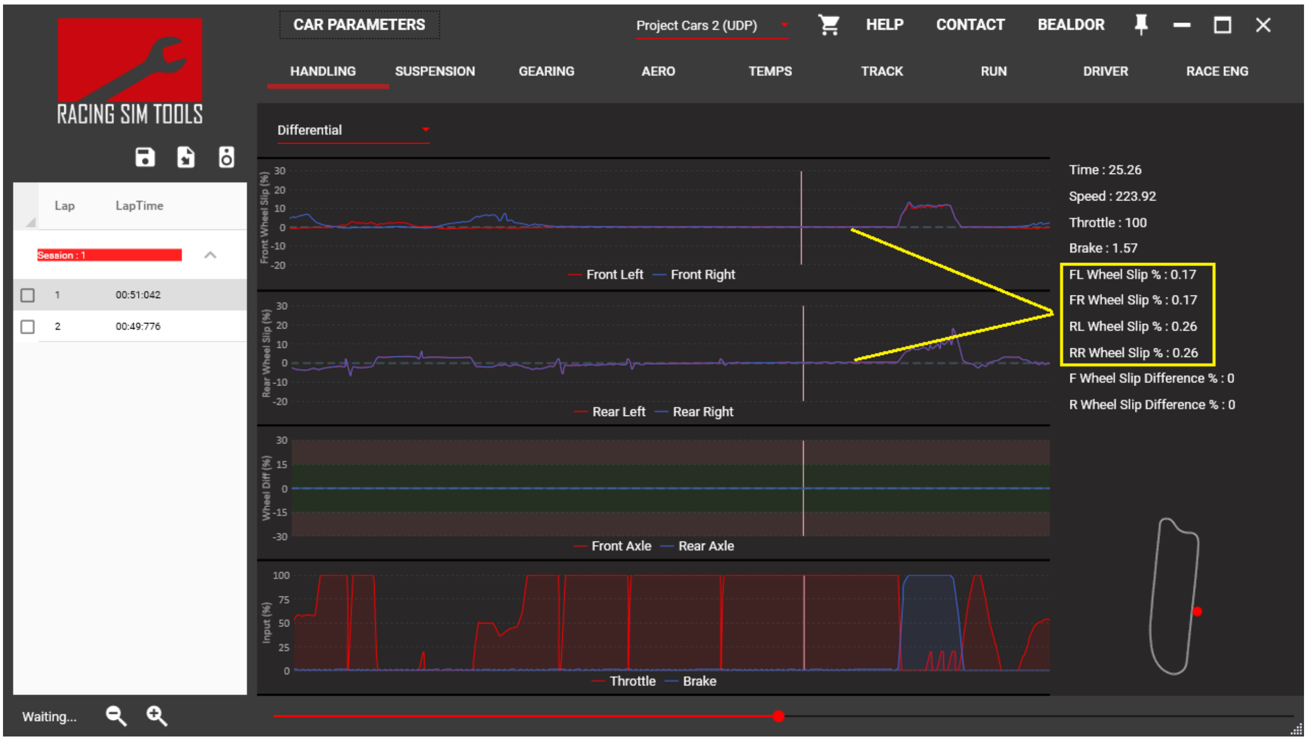

Figure 1.15: Wheel Slip % = 0 with Correct Tire Diameters

Suspension

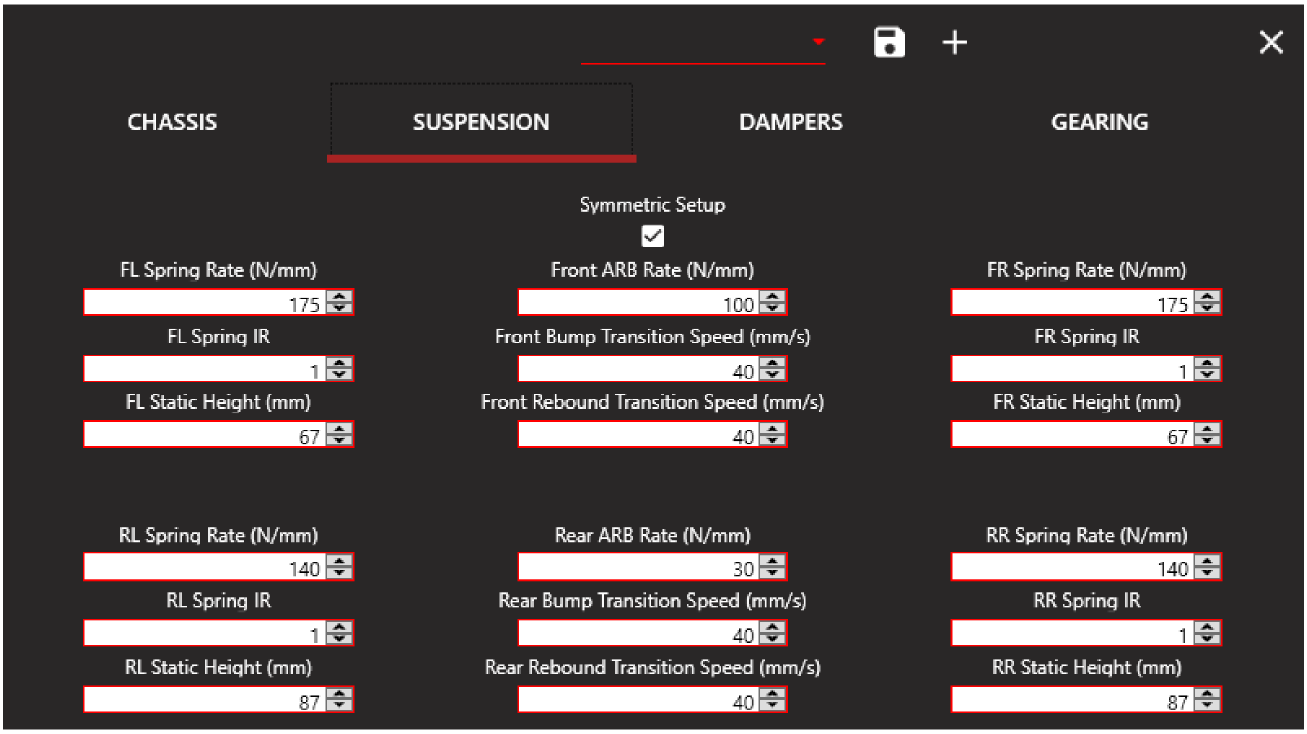

Figure 1.16: Car Parameters: Suspension

Most values can be directly taken from the game's setup except for Installation Ratio (IR).

The IR is the inverse of the Motion Ratio (MR) and is defined as

$$IR = \frac{Spring\ Travel}{Wheel\ Travel}$$

Many sources (falsely) refer to it as MR, so be careful when searching for data on the web. Unfortunately, data for this is hard to find because it's confidential for most (race) cars.

Installation Ratios

For AC you can set the installation ratios for all cars to **IR = 1.0.**

Transition Speeds

Since there's no way to determine (and adjust) the transition speeds in AC, it is recommended to keep those values at the default setting.

ARB Rates

To get actual ARB rates download the Content Manager app, select your car and then click on "Manage Setups". Select your current setup and scroll down to the Suspensions tab:

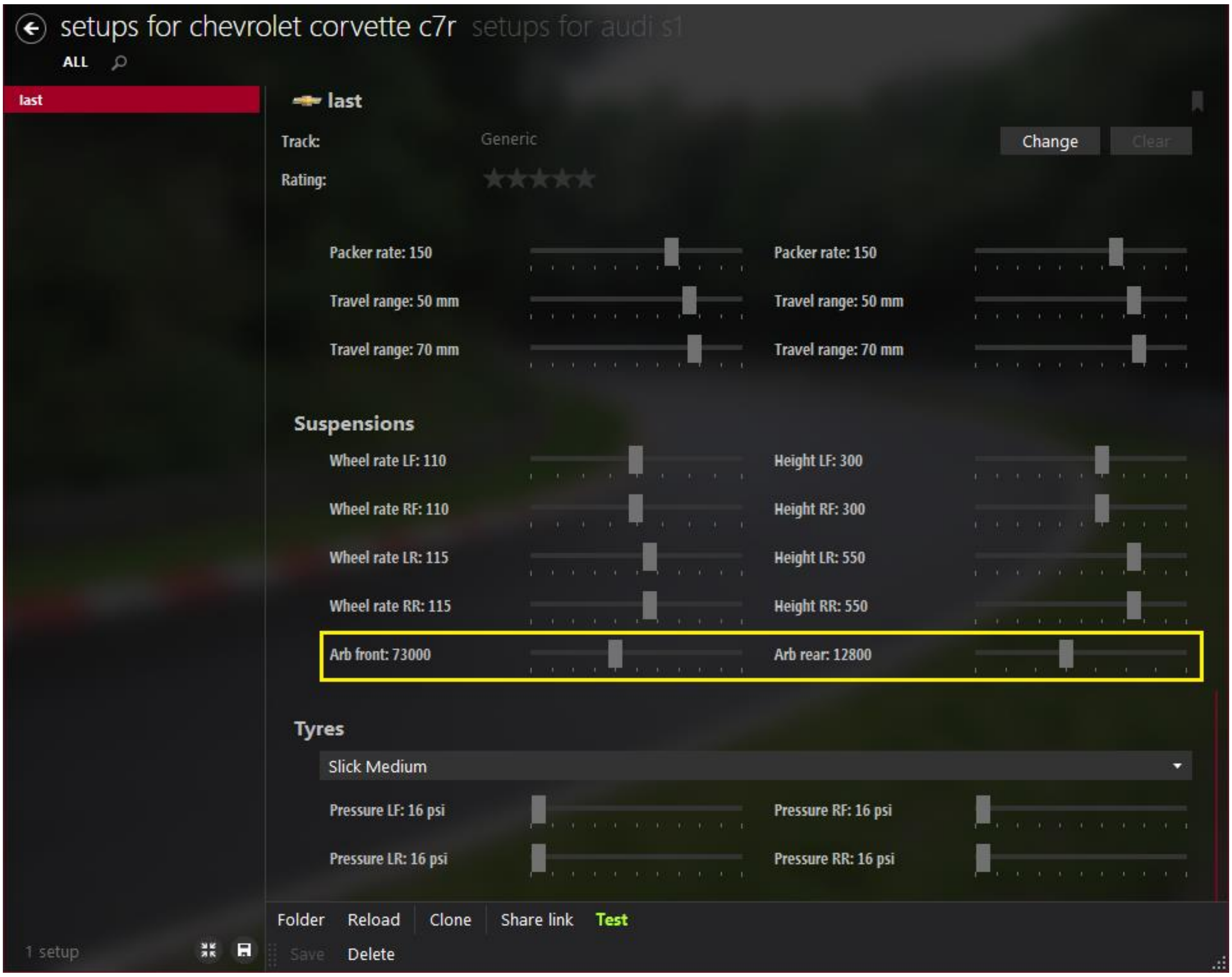

Figure 1.17: Actual ARB Rates from Content Manager App

The ARB rates in Content Manager are displayed in N/m. For RST you need to convert them into N/mm via the following formula:

$$ARB_{RST} = \frac{ARB_{CM}}{1000}$$

Now, simply enter the ARB rates in your Car Parameters screen (73 N/mm and 12.8 N/mm in the example above).

Ride Height:

In AC, you need to “calibrate” the suspension travel to achieve correct wheel and aero loads. This procedure is similar to the sensor calibration done in real race cars.

1) Enter the car parameters like you normally would. The following example is from as base setup from the Lamborghini Huracan GT3 at Catalunya:

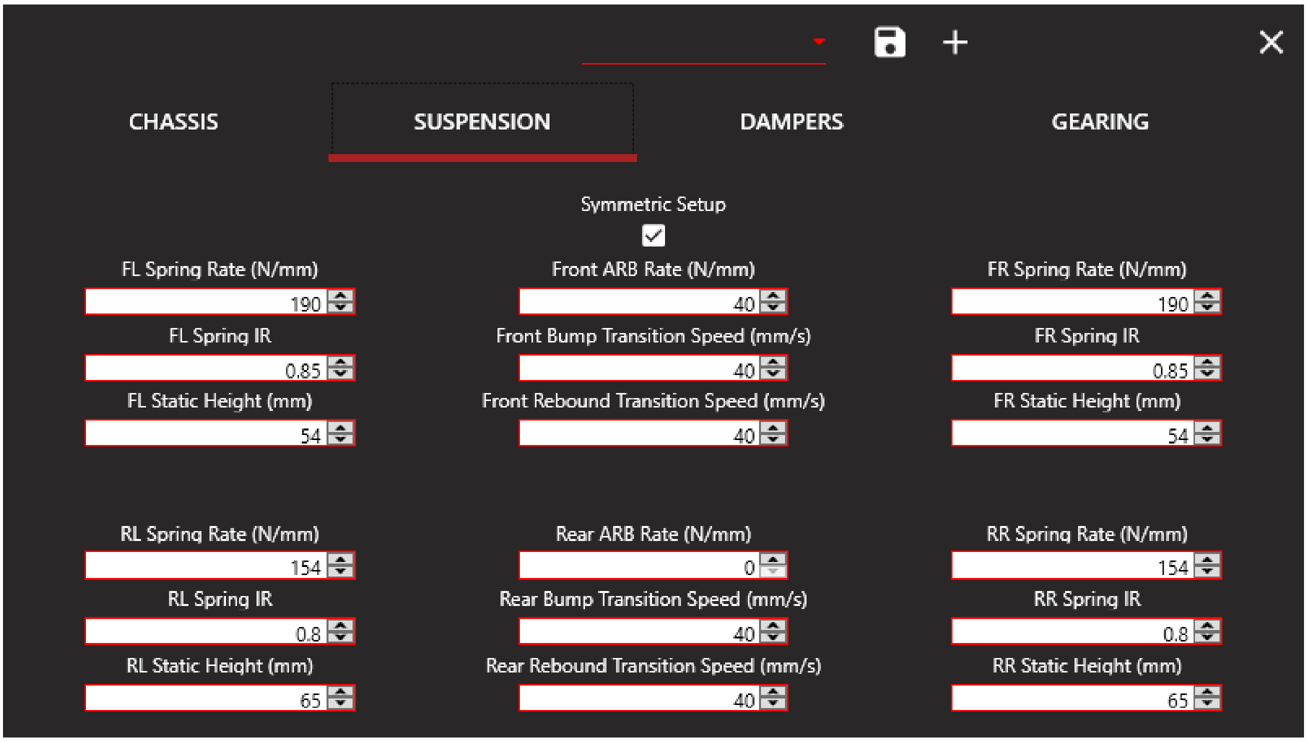

Figure 1.18: Car Parameters Base Setup Lamborghini Huracan GT3

2) Now you need to identify the static spring position. To do this, find a part of the lap where your car is basically static (no downforce skewing the results). There's two ways to achieve this. Either measure when the car is driving out of the pits or (for even more accuracy) sacrifice a lap and stop on a flat section of the lap for a few seconds, like it's done in the example below:

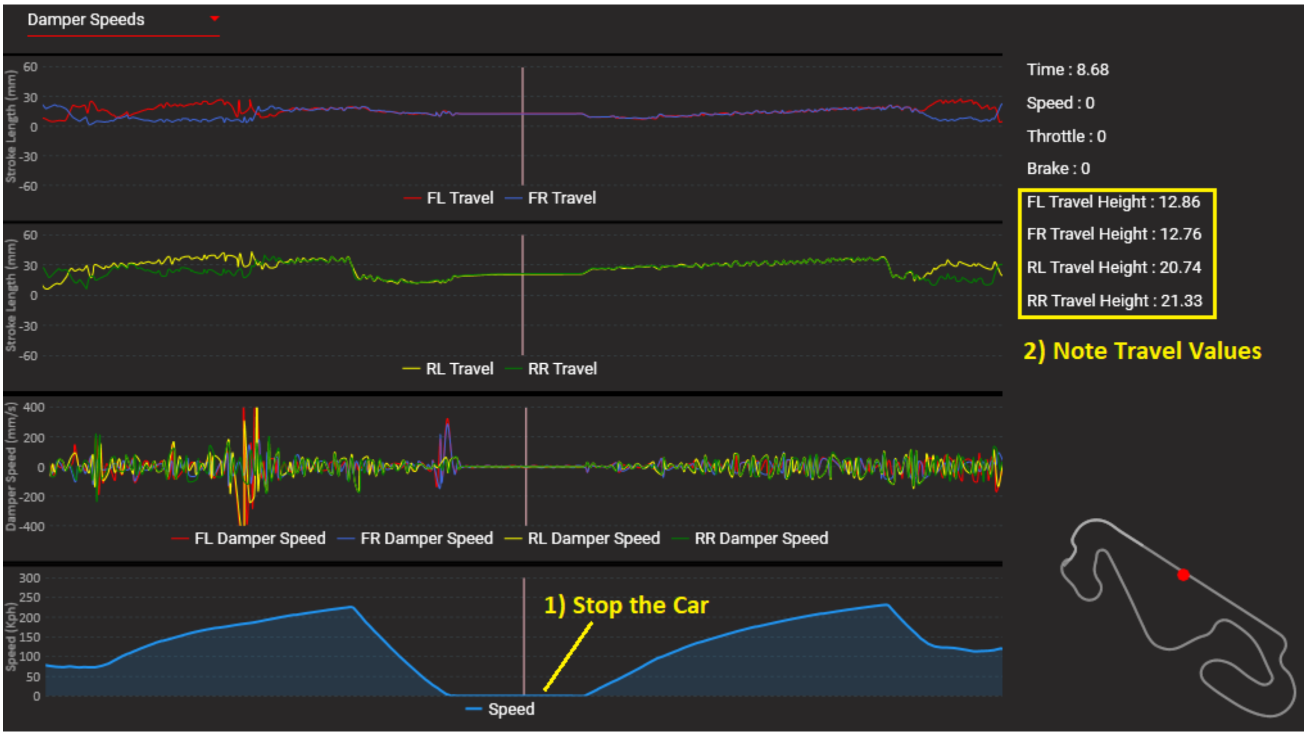

Figure 1.19: Measuring Static Spring Deflection

3) From the data legend on the right, you can see the static spring deflection is ~13 mm on the front and ~21 mm on the back

4) Now go back to the Car Parameters screen and enter the values in the static height cells:

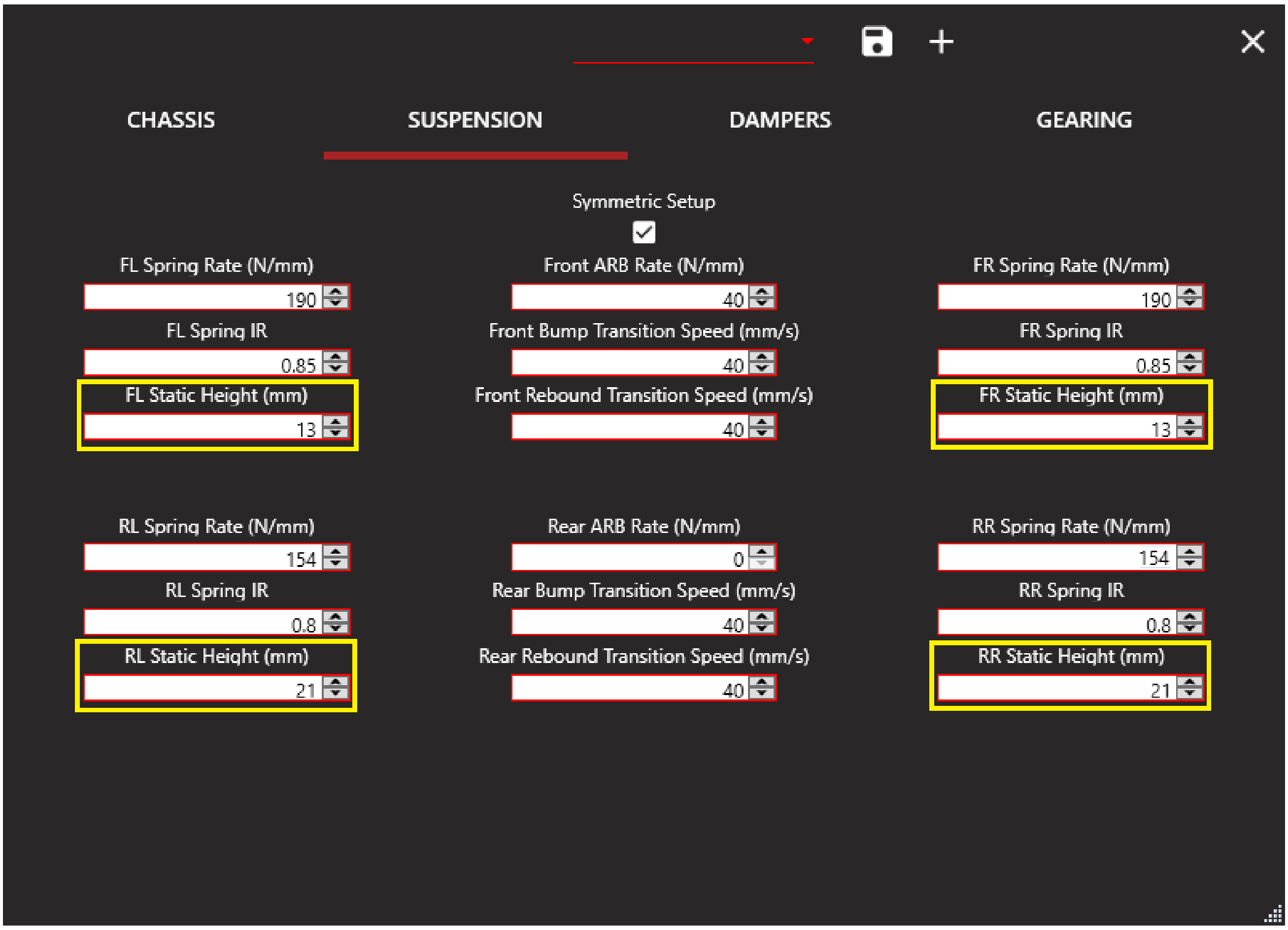

Figure 1.20: Car Parameters with Correct Static Spring Deflection Values

5) Your car parameters are now calibrated correctly, and you can now start analyzing the following charts:

Wheel Loads (chapter 3.3.1)
Lateral Load Transfer Bias (chapter 3.4.6)
Downforce (chapter 3.6.2)

Dampers

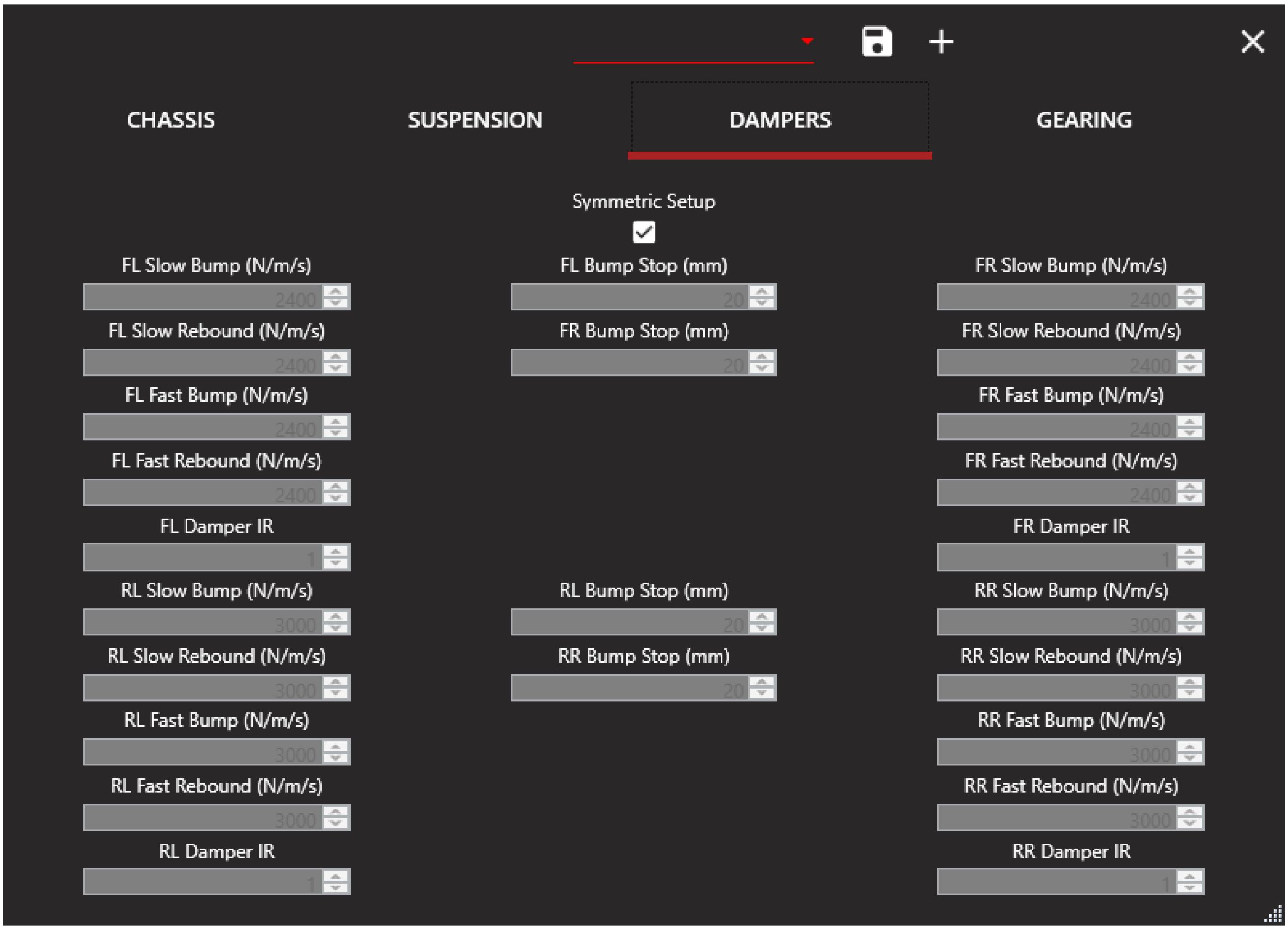

Figure 1.21: Car Parameters: Dampers

Unfortunately, there is no way to determine the actual damping rates from the “clicks” setting in AC. That’s why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

For your gearing setup you need to enter the inverse values from the AC setup screen in decimal numbers, as shown in the image below:

= 41 / 13 = **3.154**

= 41 / 19 = **2.158**

= 34 / 21 = **1.619**

= 34 / 26 = **1.308**

= 34 / 30 = **1.133**

= 33 / 33 = **1.000**

= 48 / 12 = **4.000**

Figure 1.22: Gearing Ratio Setup Example in AC

The above gearing setup will look like this in the app's Car Parameters screen:

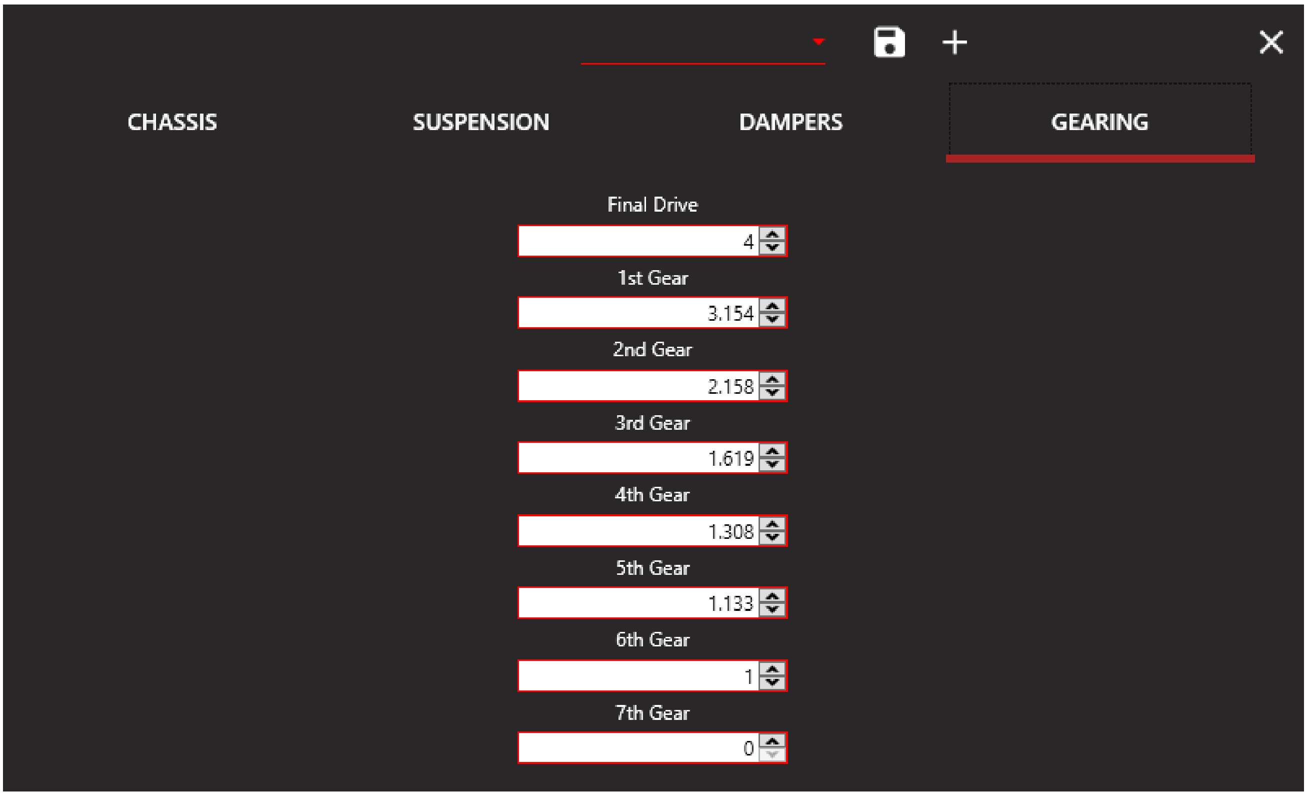

Figure 1.23: Car Parameters: Gearing

1.3.3. Assetto Corsa Competizione

Chassis

Figure 1.24: Car Parameters: Chassis

If you select a car from the dropdown list the yellow cells will be updated automatically, otherwise you have to enter the correct values yourself.

Steering Ratio and steering lock values aren't needed for ACC, that's why they're grayed out.

Suspension

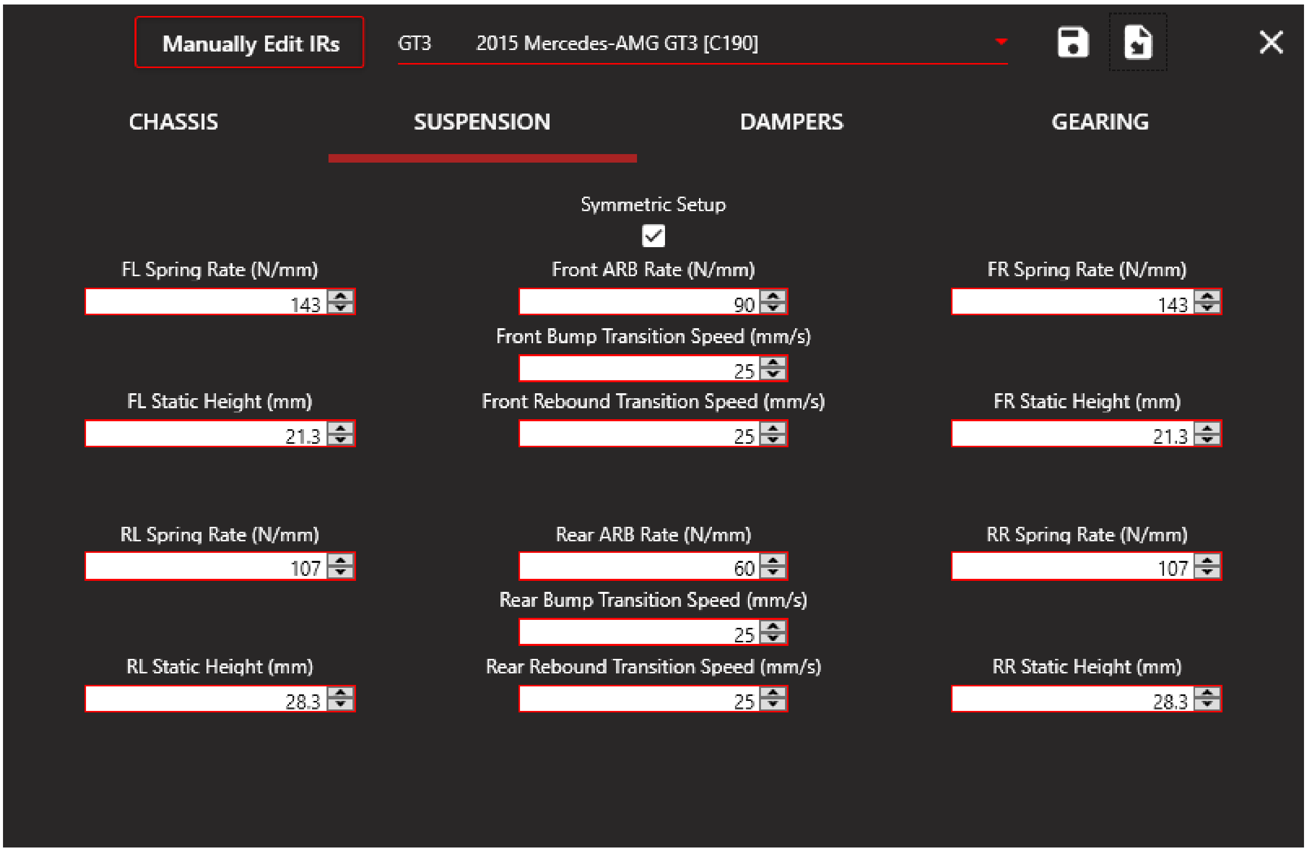

Figure 1.25: Car Parameters: Suspension

Most values can be directly taken from the game's setup except for ARB rates and Installation Ratio (IR).

The IR is the inverse of the Motion Ratio (MR) and is defined as

$$IR = \frac{Spring\ Travel}{Wheel\ Travel}$$

Many sources (falsely) refer to it as MR, so be careful when searching for data on the web. Unfortunately, data for this is hard to find because it's confidential for most (race) cars.

If you select a car from the dropdown list the IRs will be entered automatically (and hidden), but you can also enter them manually by clicking on the "Manually Edit IRs" button.

Transition Speeds

Since there's no way to determine (and adjust) the transition speeds in ACC, it is recommended to keep those values at the default setting.

ARB Rates

Unfortunately, there is no way to determine the actual ARB rates from the “clicks” setting in ACC.

A good estimation is to assume an ARB range of 0 – 120 N/mm front and 0 – 100 N/mm rear and divide those ranges by the total number of available “clicks”. The formulas to calculate the ARB rates you should enter in the car parameters will then be:

$$Front\ ARB\ Rate = \frac{120\ N/mm}{Total\ \#\ of\ Clicks}\ x\ Front\ \text{ARB Setting}$$

$$Rear\ ARB\ Rate = \frac{100\ N/mm}{Total\ \#\ of\ Clicks}\ x\ Rear\ \text{ARB Setting}$$

Ride Height:

In ACC, you need to “calibrate” the suspension travel to achieve correct wheel and aero loads. This procedure is similar to the sensor calibration done in real race cars.

1) Enter the car parameters like you normally would. The following example is from as base setup from the Lamborghini Huracan GT3 at Catalunya:

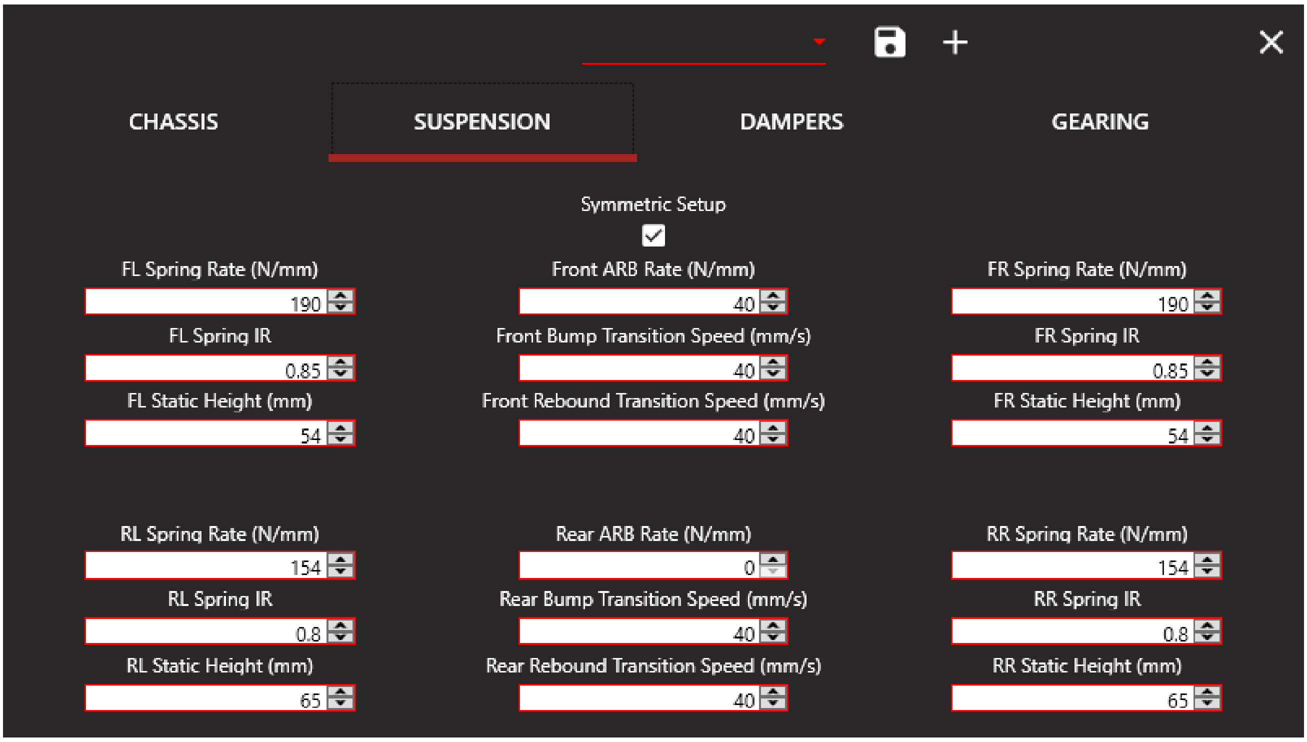

Figure 1.26: Car Parameters Base Setup Lamborghini Huracan GT3

2) Now you need to identify the static spring position. To do this, find a part of the lap where your car is basically static (no downforce skewing the results). There's two ways to achieve this. Either measure when the car is driving out of the pits or (for even more accuracy) sacrifice a lap and stop on a flat section of the lap for a few seconds, like it's done in the example below:

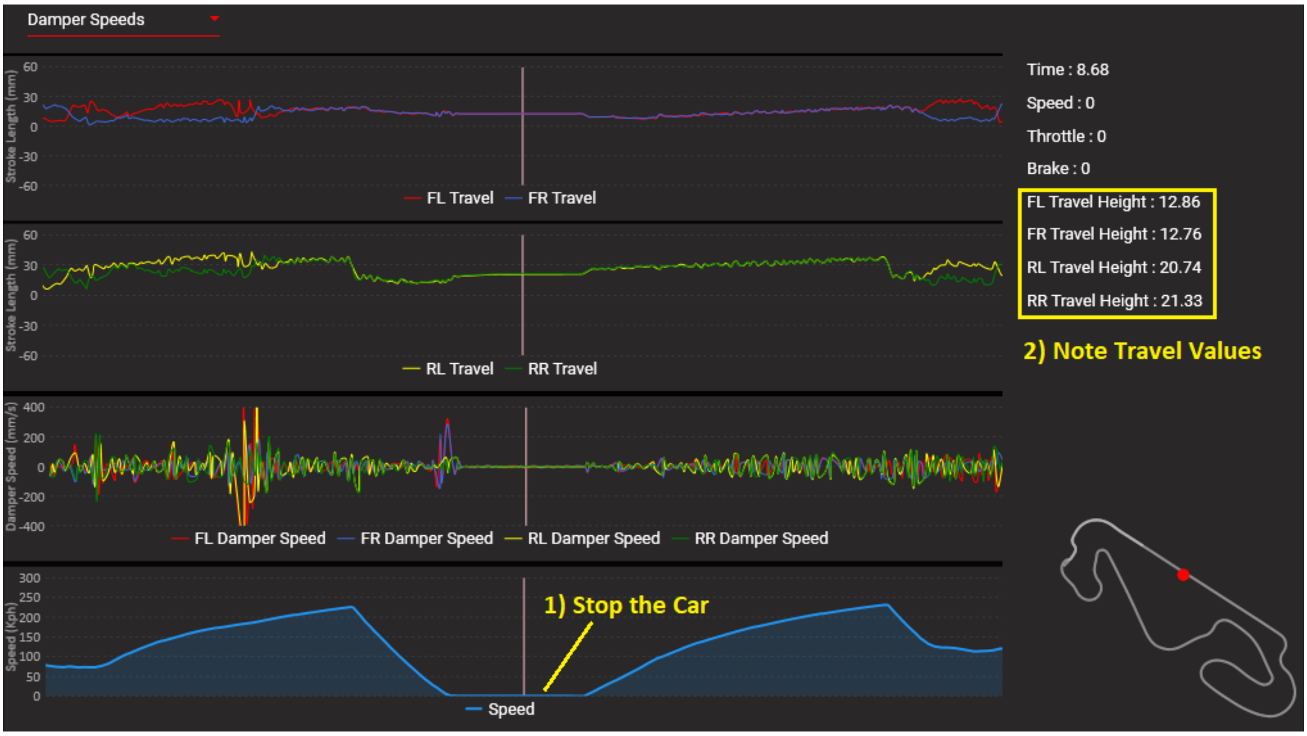

Figure 1.27: Measuring Static Spring Deflection

3) From the data legend on the right, you can see the static spring deflection is ~13 mm on the front and ~21 mm on the back

4) Now go back to the Car Parameters screen and enter the values in the static height cells:

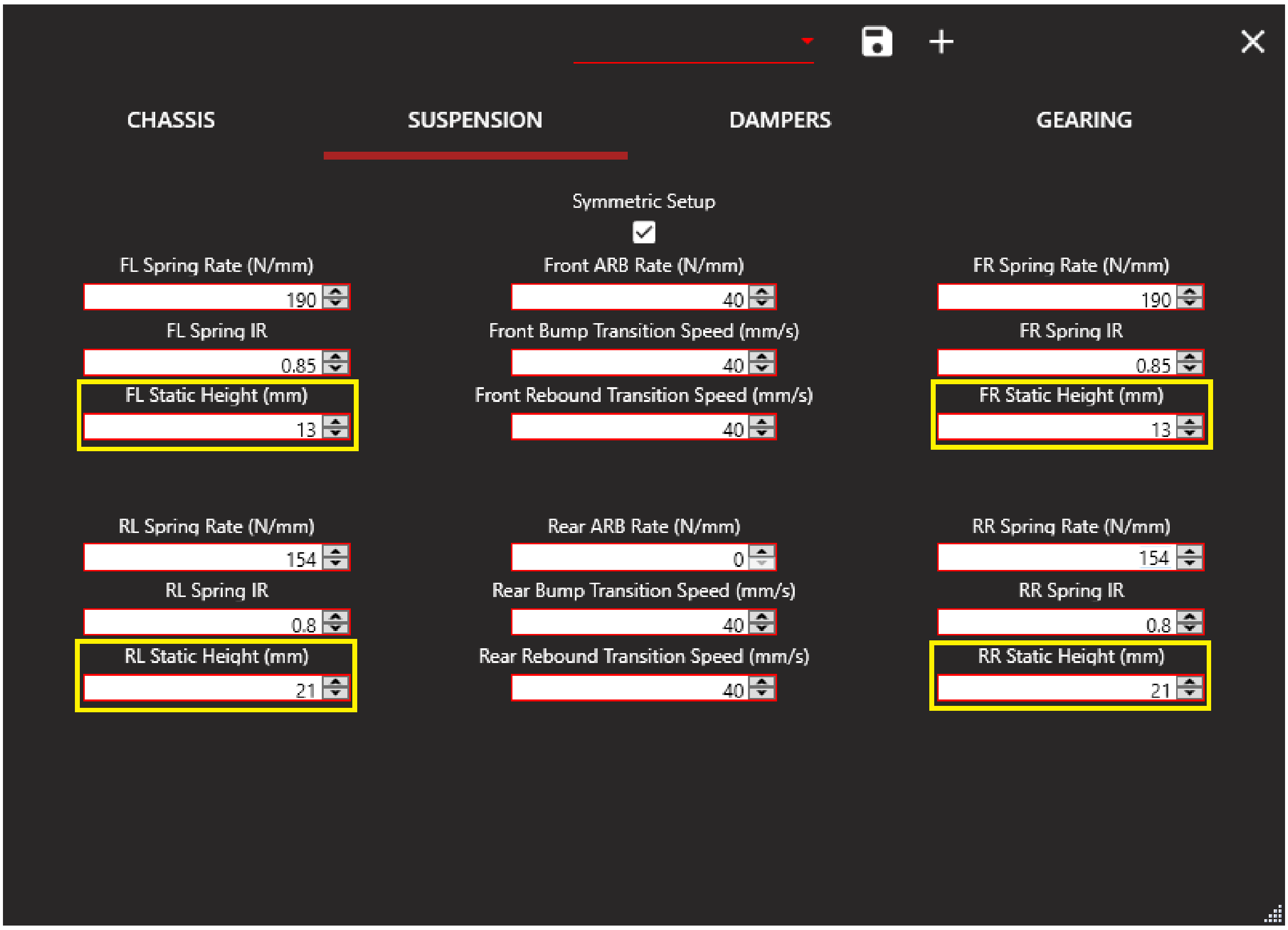

Figure 1.28: Car Parameters with Correct Static Spring Deflection Values

5) Your car parameters are now calibrated correctly, and you can now start analyzing the following charts:

Wheel Loads (chapter 3.3.1)
Lateral Load Transfer Bias (chapter 3.4.6)
Downforce (chapter 3.6.2)

Dampers

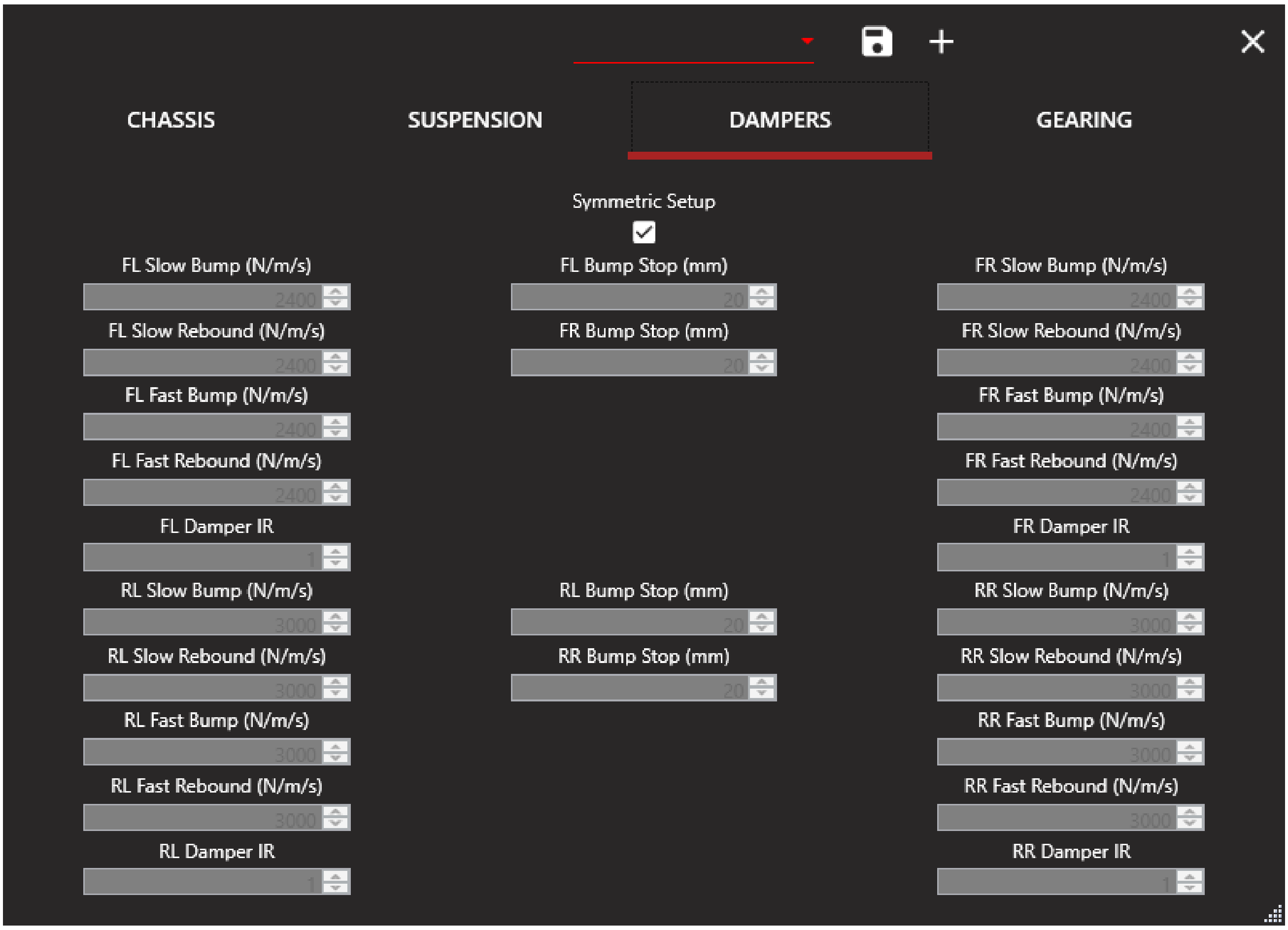

Figure 1.29: Car Parameters: Dampers

Unfortunately, there is no way to determine the actual damping rates from the “clicks” setting in ACC. That’s why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

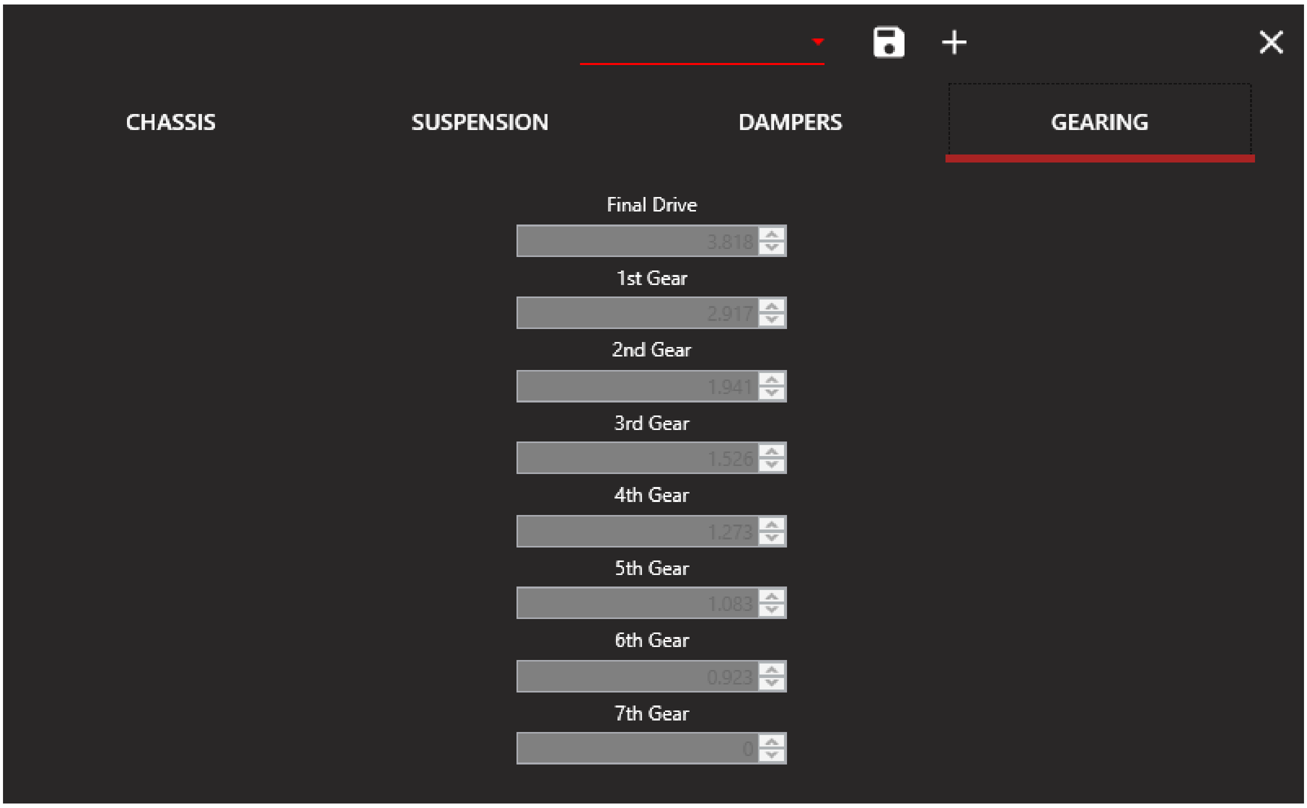

Figure 1.30: Car Parameters: Gearing

Since gear ratios are fixed in ACC, you can safely ignore this screen.

1.3.4. F1 2019

In F1 2019 most car parameters are automatically filled out by the because the game transmits this data via its UDP stream. As a result, you don't need to worry about most settings.

Chassis

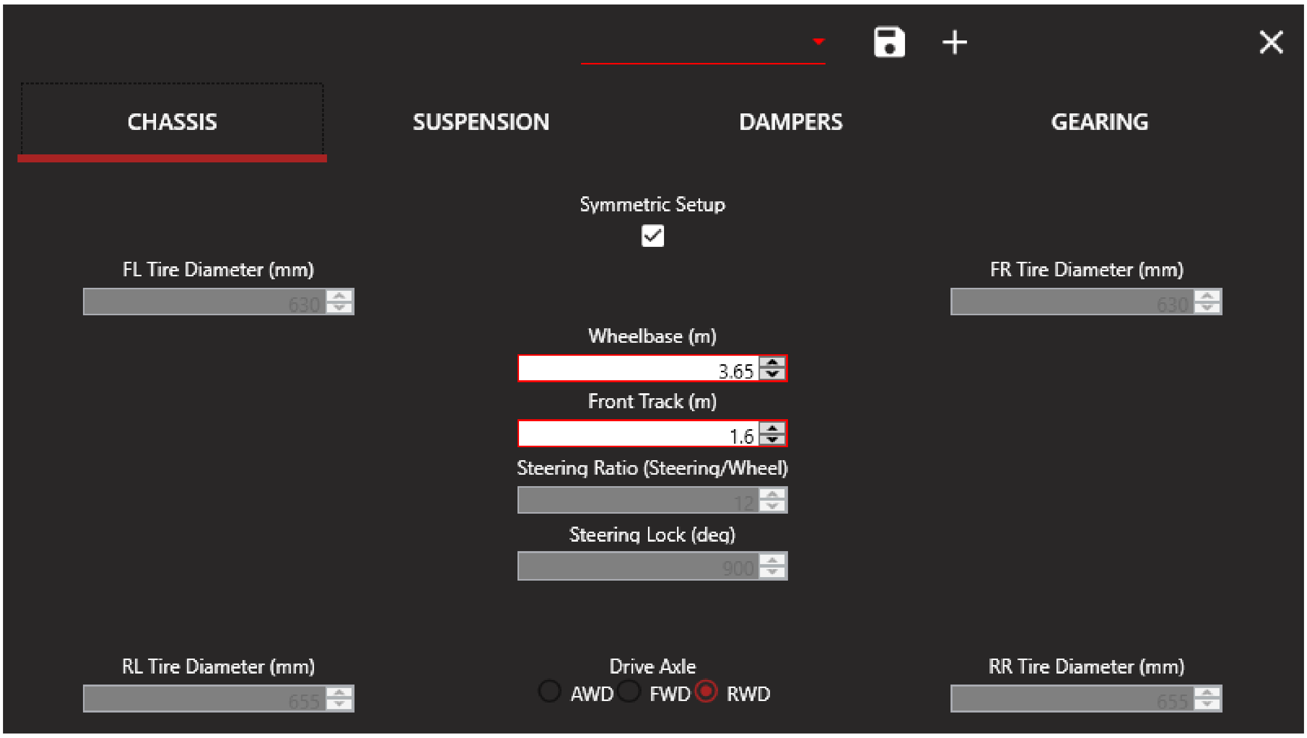

Figure 1.31: Car Parameters: Chassis

Front track width is close to **1.6 m** in all current F1 cars.

The wheelbase for current F1 cars varies between 3.62 m and 3.70 m. So, an average value of **3.65 m** is close enough for all cars.

Exact wheelbase data for every car can be found here.

Suspension

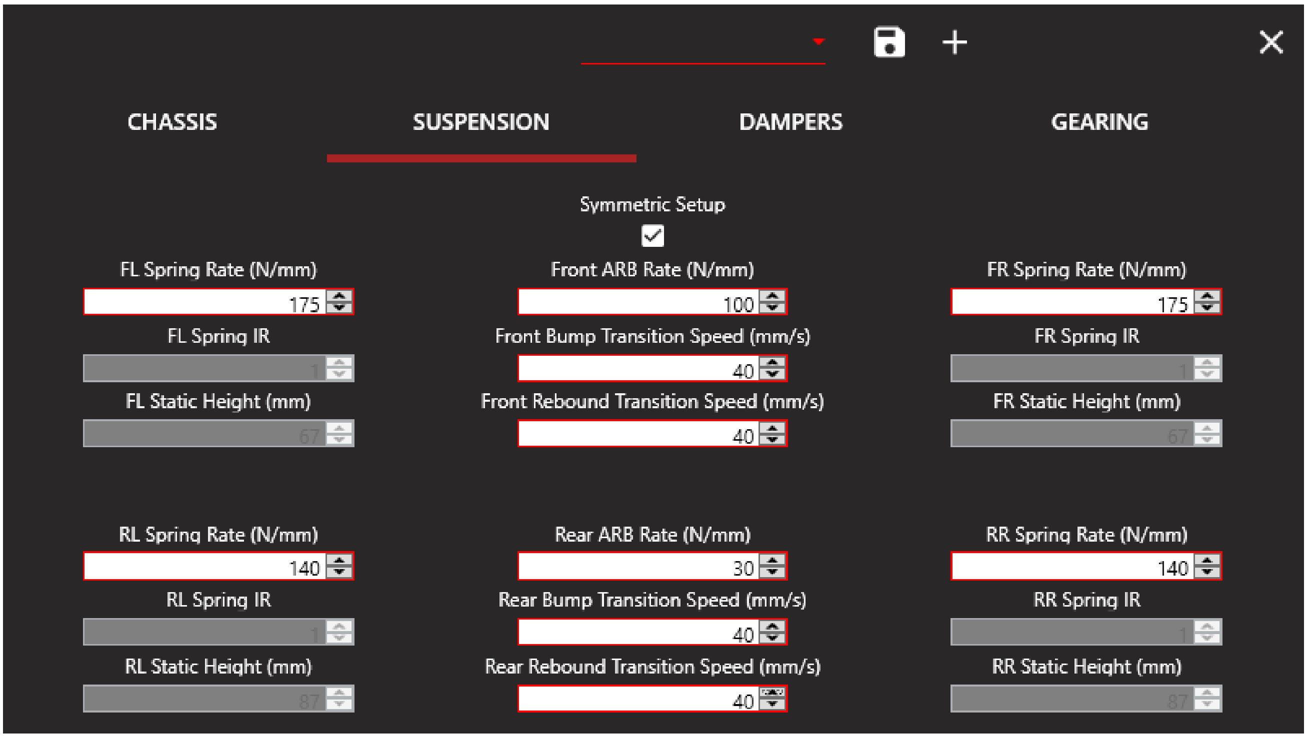

Figure 1.32: Car Parameters: Suspension

Spring and ARB rates are automatically filled out by the app, but you can still edit them if you wish. Those values are estimated because there's no way to find out the true values based on the game's "click" settings.

Transition Speeds

Since there's no way to determine (and adjust) the transition speeds in F1 2019, it is recommended to keep those values at the default setting.

Dampers

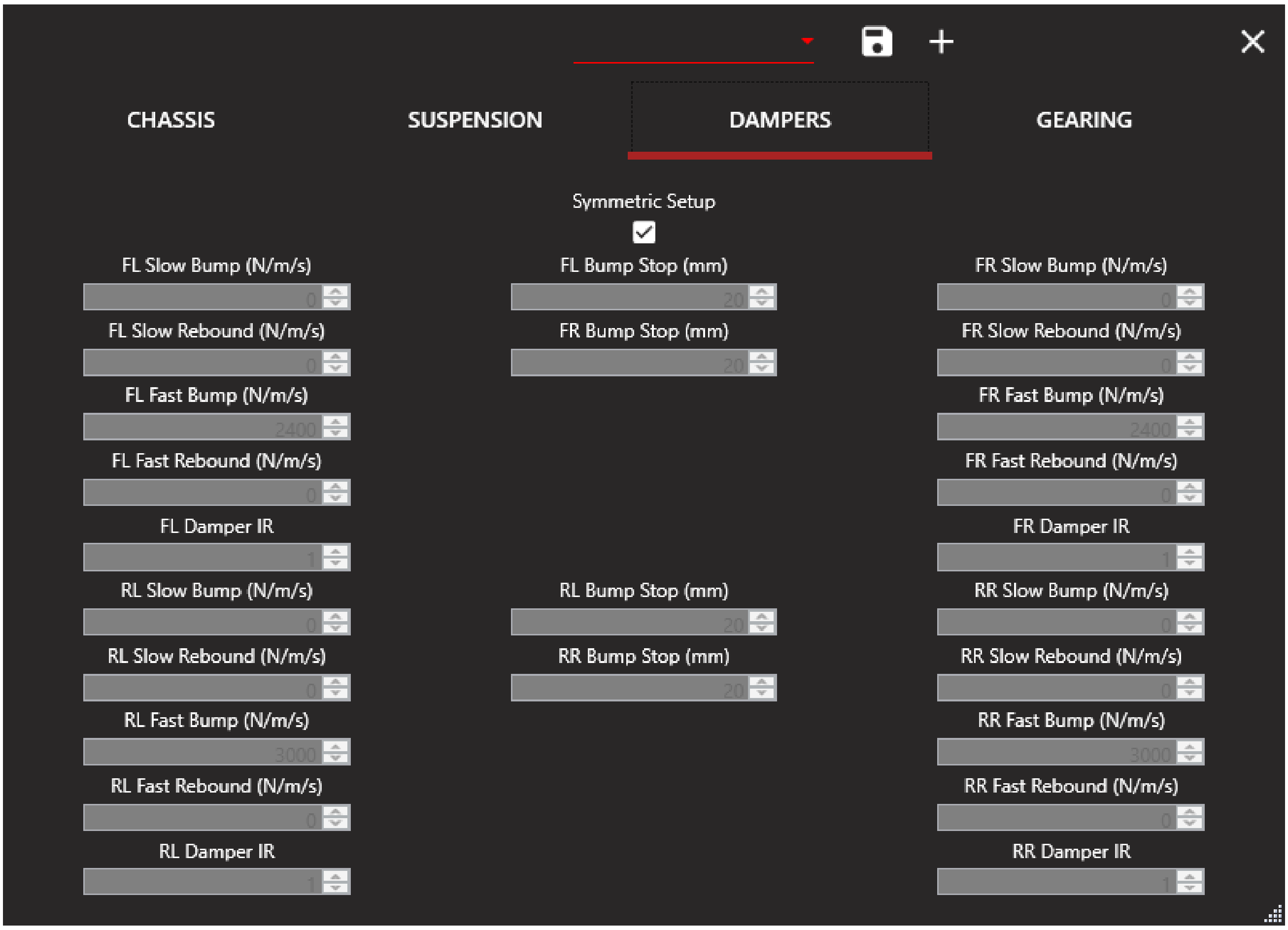

Figure 1.33: Car Parameters: Dampers

Unfortunately, there is no dedicated damper setup in F1 2019. That's why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

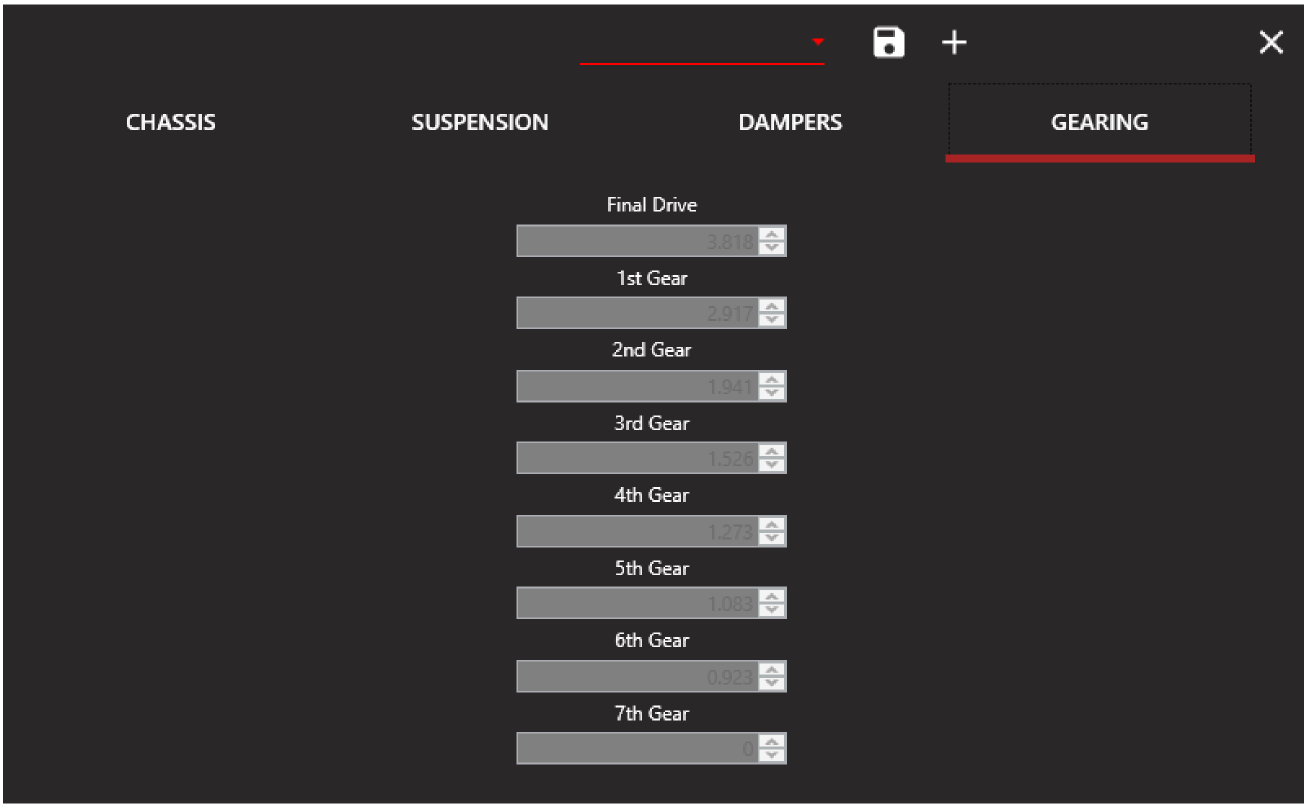

Figure 1.34: Car Parameters: Gearing

Since gear ratios are fixed in F1 2019, you can safely ignore this screen.

1.3.5. iRacing

Chassis

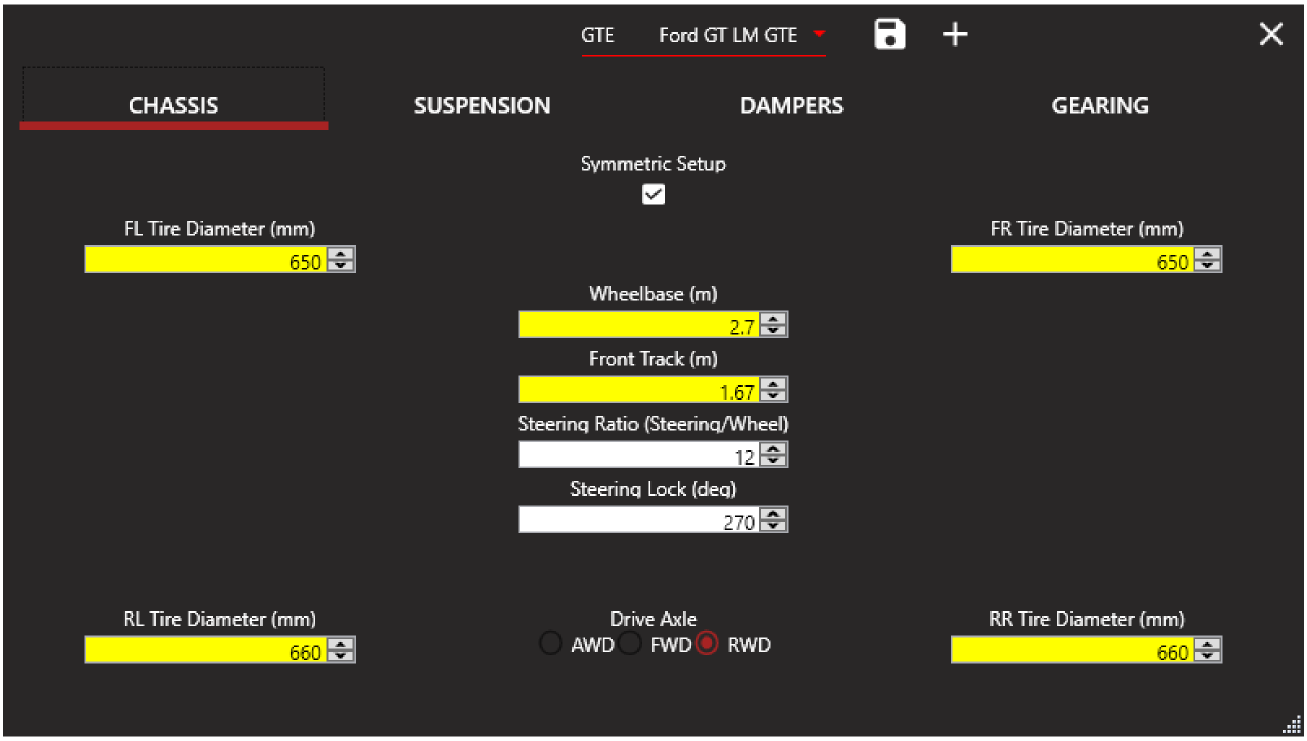

Figure 1.35: Car Parameters: Chassis

Steering ratio is part of the in-game car setup and should be taken from there.

For steering lock, you'll have to enter the actual steering lock from the in-game car. To do this, **turn the car's steering wheel fully to one side while standing still, estimate the steered angle and multiply it by 2**.

Front track width is difficult to find for many cars (unlike wheelbase), but a value of **1.6 m** is a close enough approximation for most cars.

Tire Diameters

To assure that tire diameters are correct, check the Theoretical RPM chart in the Gearing tab.

Adjust the rear tire diameter until the current RPM in the selected gear match the theoretical RPM, as shown in the image below:

Figure 1.36: Actual and Theoretical RPM Matching with Correct Rear Tire Diameter

For best results, check the RPM at the end of a straight where longitudinal acceleration and therefore wheel slip is minimal.

You don't need to match the theoretical and actual RPM perfectly. Keeping the deviation below ±100 RPM is accurate enough since even small amounts of wheel slip will minimally skew the results and tire diameter slightly varies with changing tire pressures anyway.

For this method to work correctly, your gear ratio setup parameters need to match the ones in-game (see page 45).

Since iRacing provides longitudinal wheel speeds directly, entering correct front tire diameters isn't necessary and therefore can be skipped.

Suspension

Figure 1.37: Car Parameters: Suspension

Most values can be directly taken from the game's setup except for Installation Ratio (IR).

The IR is the inverse of the Motion Ratio (MR) and is defined as

$$IR = \frac{Spring\ Travel}{Wheel\ Travel}$$

Many sources (falsely) refer to it as MR, so be careful when searching for data on the web. Unfortunately, data for this is hard to find because it's confidential for most (race) cars.

For iRacing there's a way to estimate IR by adjusting spring perch offset and observing the change in static ride height. The iRacing specific formula is

$$IR = \frac{\Delta Spring\ Perch\ Offset}{\Delta Ride\ Height}$$

Simply adjust spring perch offset by a defined length and note the change in static ride height.

For the formula to work correctly, you need to measure $\Delta Ride\ Height$ at 0 rake (front ride height = rear ride height). Set all four wheels to the same ride height, adjust all four spring perch offsets by the same amount and measure the change in ride height.

If you select a car from the dropdown list the IRs will be entered automatically (and hidden), but you can also enter them manually by clicking on the "Manually Edit IRs" button.

Alternatively you can use this Excel File for IR Calculation.

Transition Speeds

Since there's no way to determine (and adjust) the transition speeds in iRacing, it is recommended to keep those values at the default setting.

Dampers

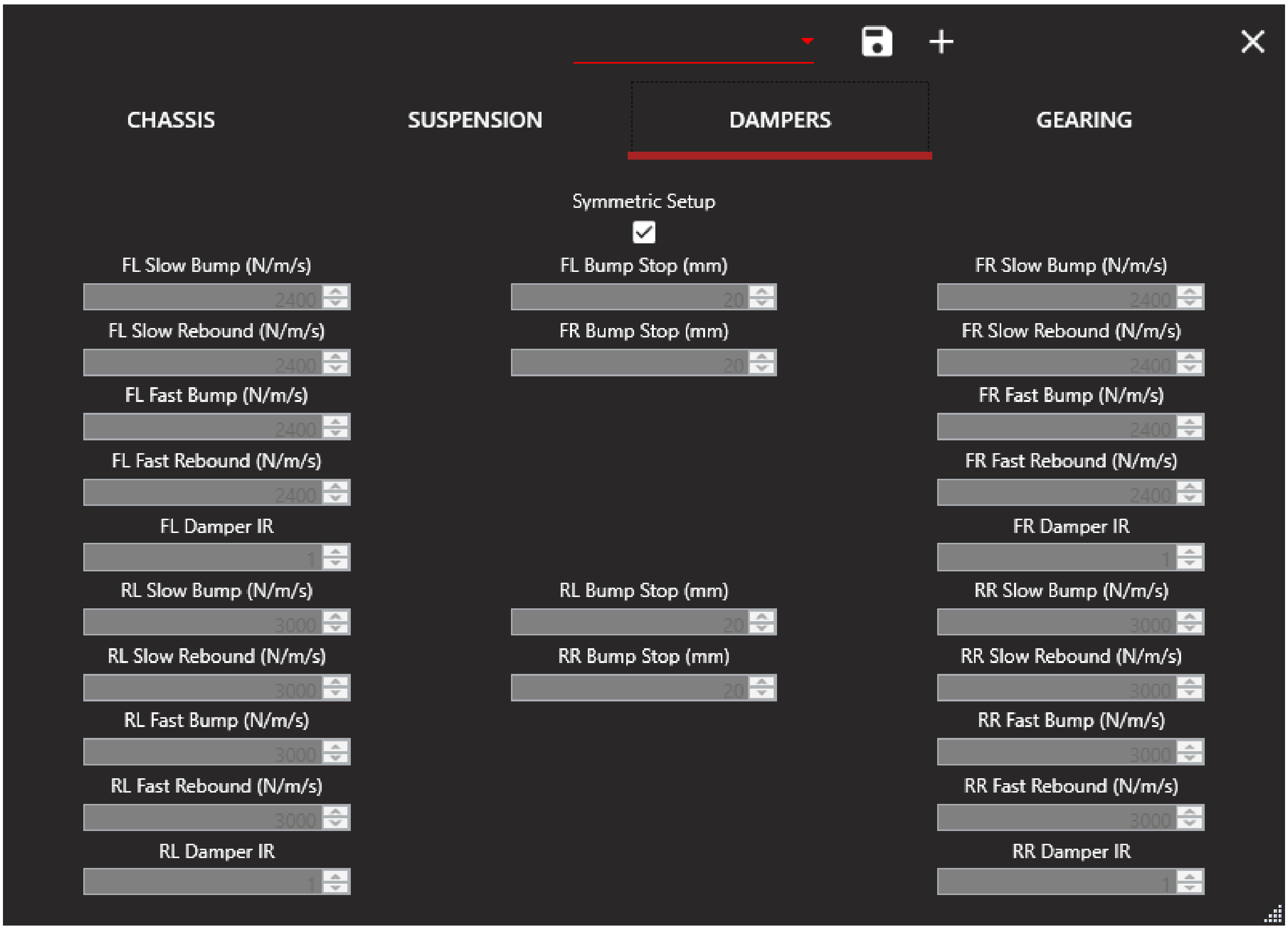

Figure 1.38: Car Parameters: Dampers

Unfortunately, there is no way to determine the actual damping rates from the “clicks” setting in iRacing. That’s why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

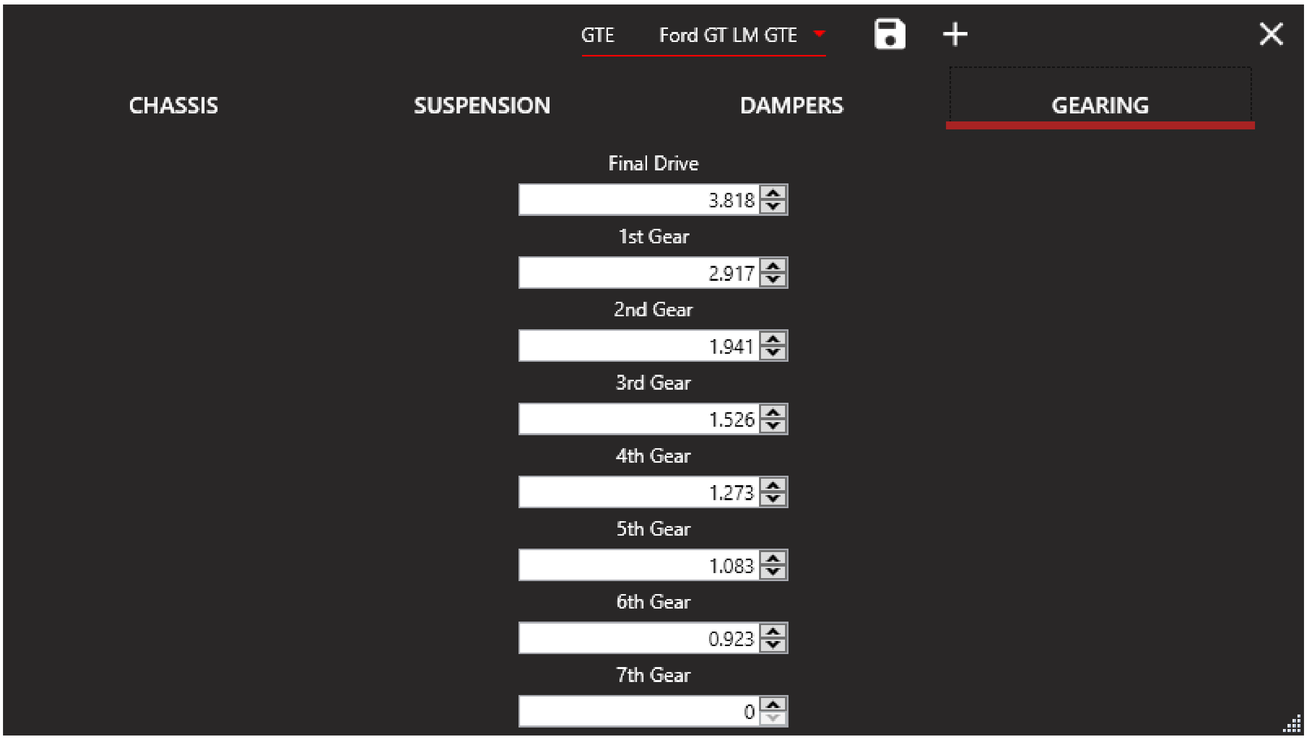

Figure 1.39: Car Parameters: Gearing

Simply enter the gearing ratios from the in-game drivetrain setup for your car here.

1.3.6. RaceRoom Racing Experience

Chassis

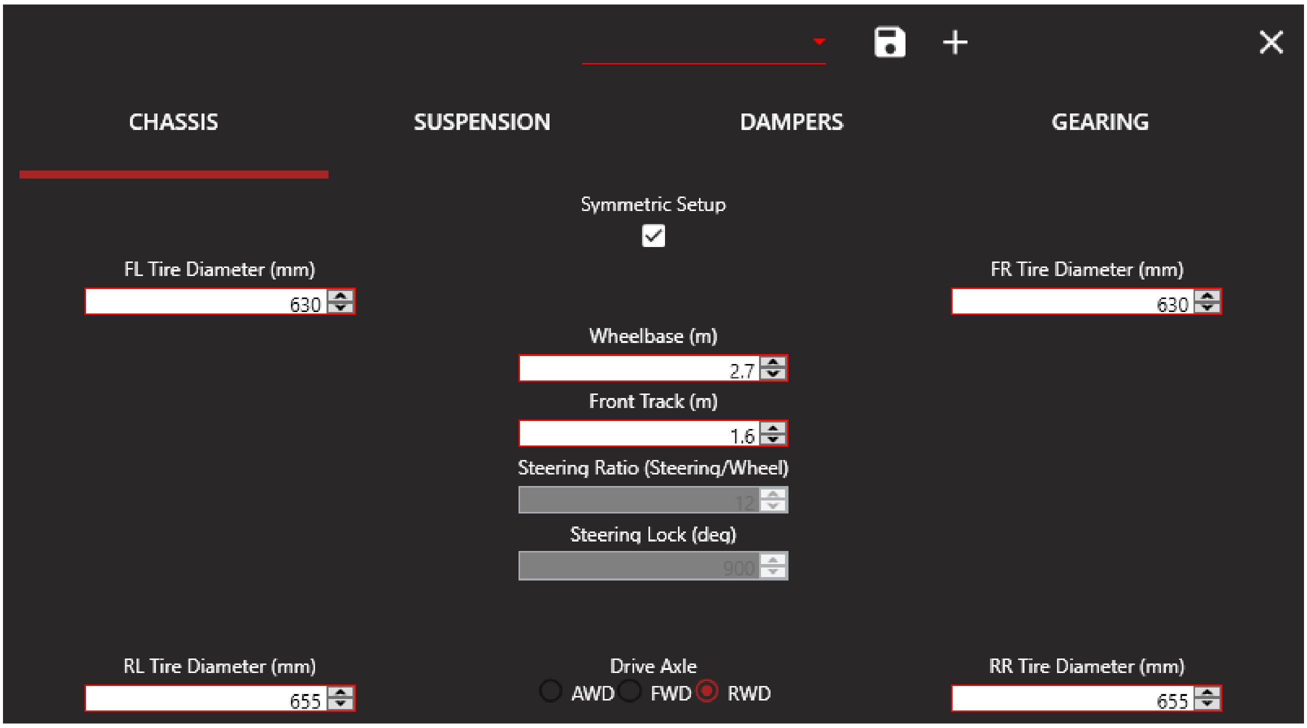

Figure 1.40: Car Parameters: Chassis

Steering ratio and steering lock values aren't needed for R3E, that's why they're grayed out.

Front track width is difficult to find for many cars (unlike wheelbase), but a value of **1.6 m** is a close enough approximation for most cars.

We're currently building a car parameter database that'll include all of the above data (and more) for R3E which can be found here.

If you want to help collecting data for our database, please fill out our Google Form.

Once the database is complete, we'll implement it in the app, so you won't have to enter said data manually anymore.

Tire Diameters

To assure that tire diameters are correct, check the Wheel Slip % Charts in the Differential screen.

If the tire diameters are correct, the wheel slip % will be close to zero when driving in a straight line, as shown in the image below:

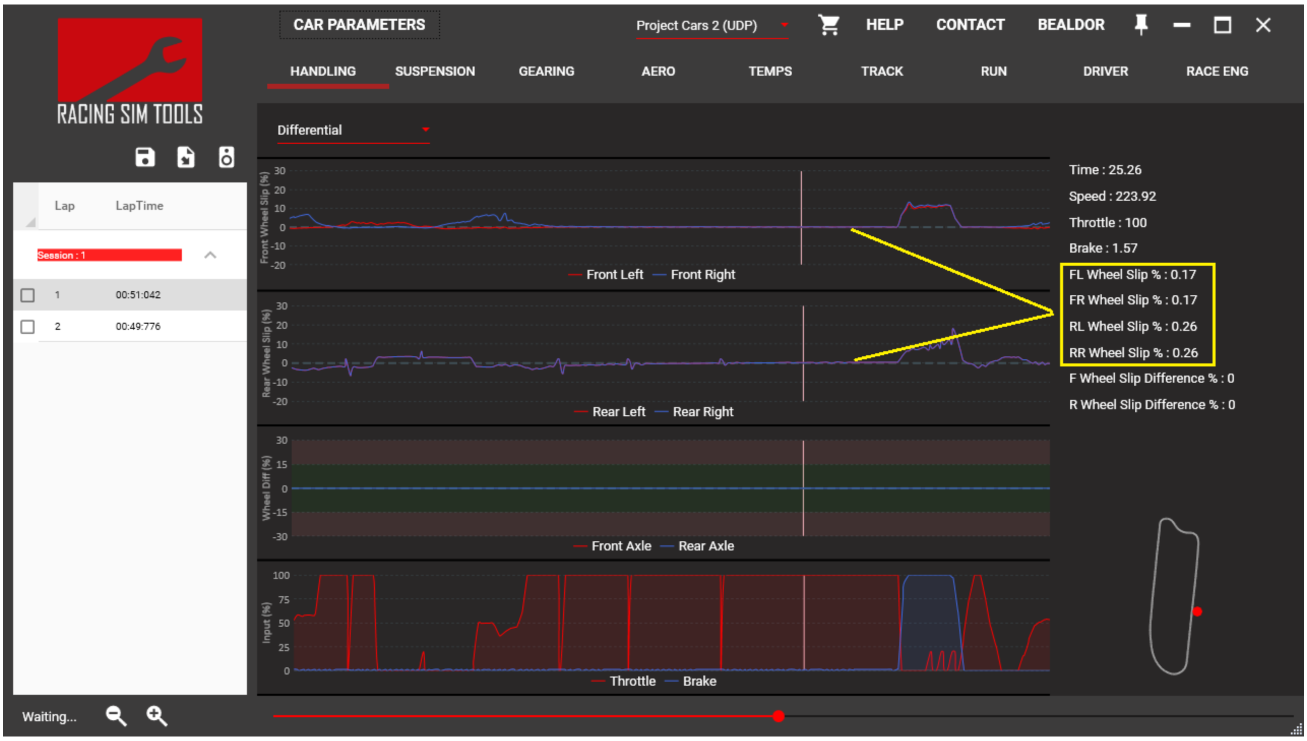

Figure 1.41: Wheel Slip % = 0 with Correct Tire Diameters

Suspension

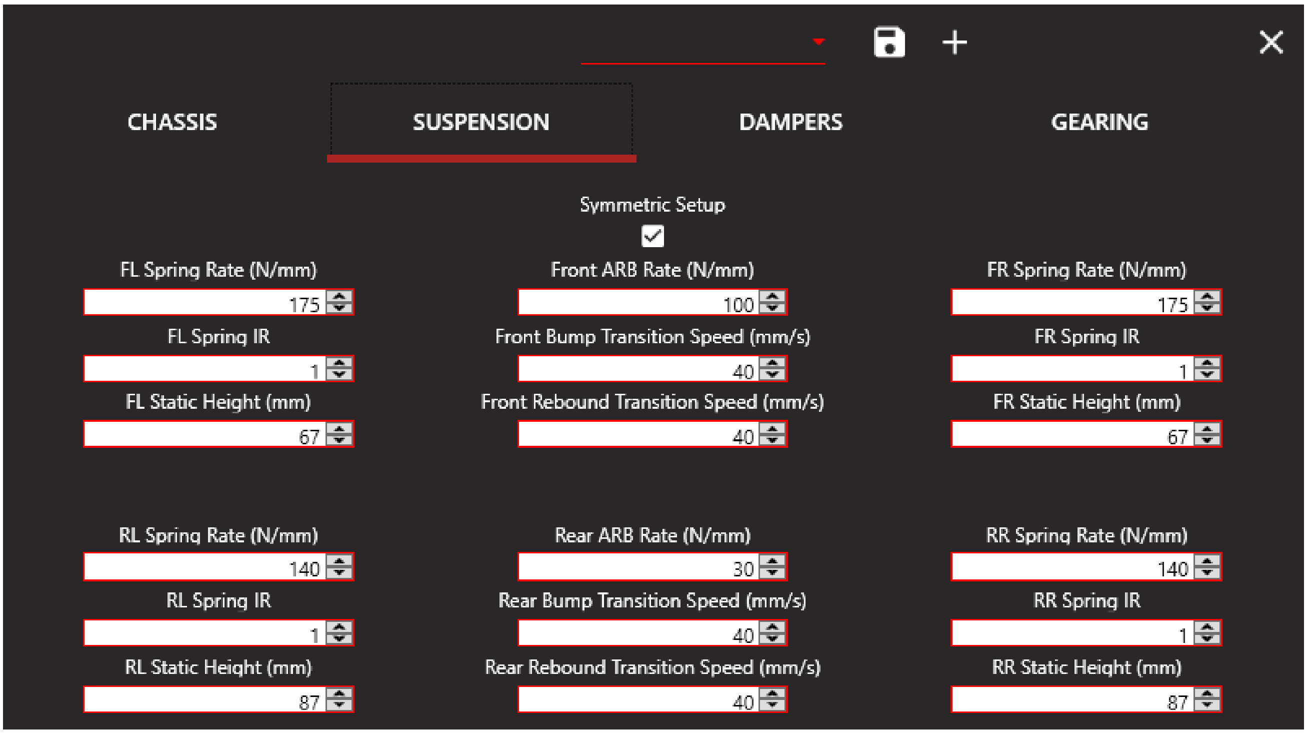

Figure 1.42: Car Parameters: Suspension

Most values can be directly taken from the game's setup except for Installation Ratio (IR).

The IR is the inverse of the Motion Ratio (MR) and is defined as

$$IR = \frac{Spring\ Travel}{Wheel\ Travel}$$

Many sources (falsely) refer to it as MR, so be careful when searching for data on the web. Unfortunately, data for this is hard to find because it's confidential for most (race) cars.

Estimating Installation Ratios

To estimate installation ratios for the cars in R3E please closely follow the instructions of our RST IR Calculation Sheet.

We're currently building a car parameter database that'll include installation ratios (and more) for R3E which can be found here.

If you want to help collecting data for our database, please fill out our Google Form.

Once the database is complete, we'll implement it in the app, so you won't have to enter said data manually anymore.

Transition Speeds

Since there's no way to determine (and adjust) the transition speeds in R3E, it is recommended to keep those values at the default setting.

Ride Height:

In R3E, you need to "calibrate" the suspension travel to achieve correct wheel and aero loads. This procedure is similar to the sensor calibration done in real race cars.

1) Enter the car parameters like you normally would. The following example is from as base setup from the Lamborghini Huracan GT3 at Catalunya:

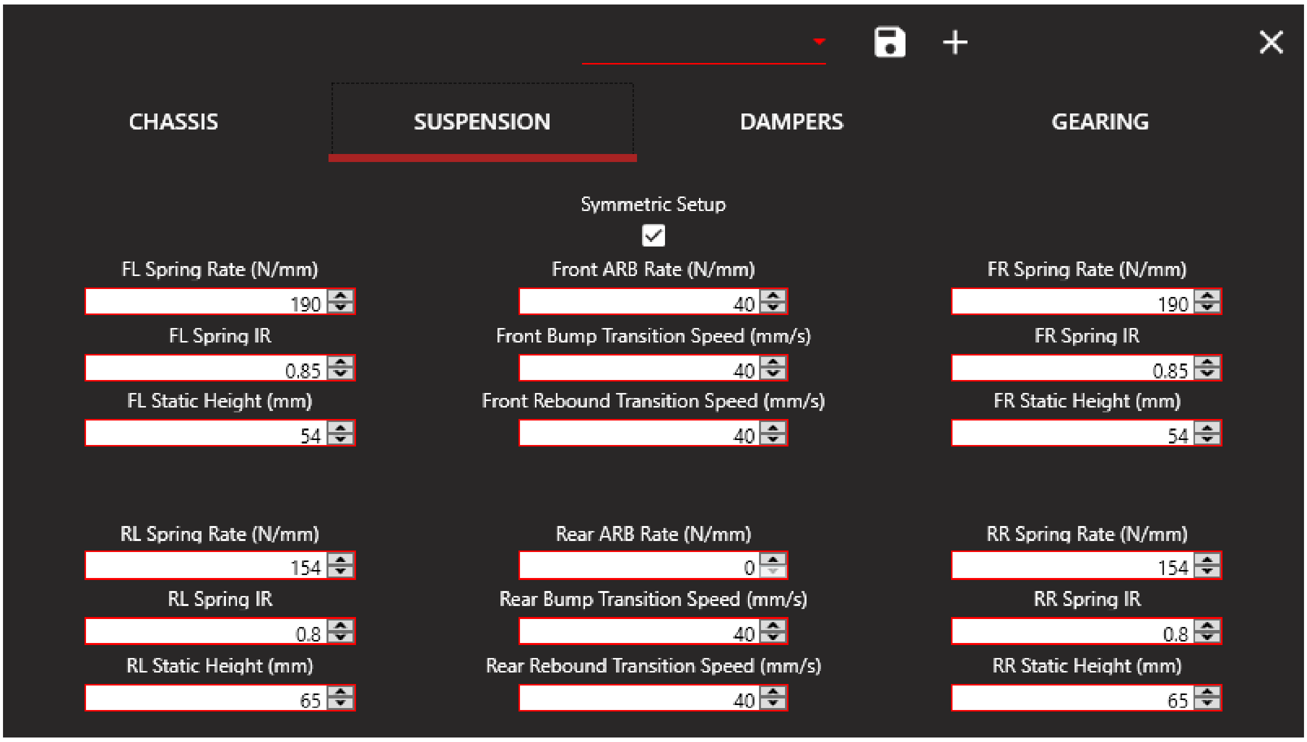

Figure 1.43: Car Parameters Base Setup Lamborghini Huracan GT3

2) Now you need to identify the static spring position. To do this, find a part of the lap where your car is basically static (no downforce skewing the results). There's two ways to achieve this. Either measure when the car is driving out of the pits or (for even more accuracy) sacrifice a lap and stop on a flat section of the lap for a few seconds, like it's done in the example below:

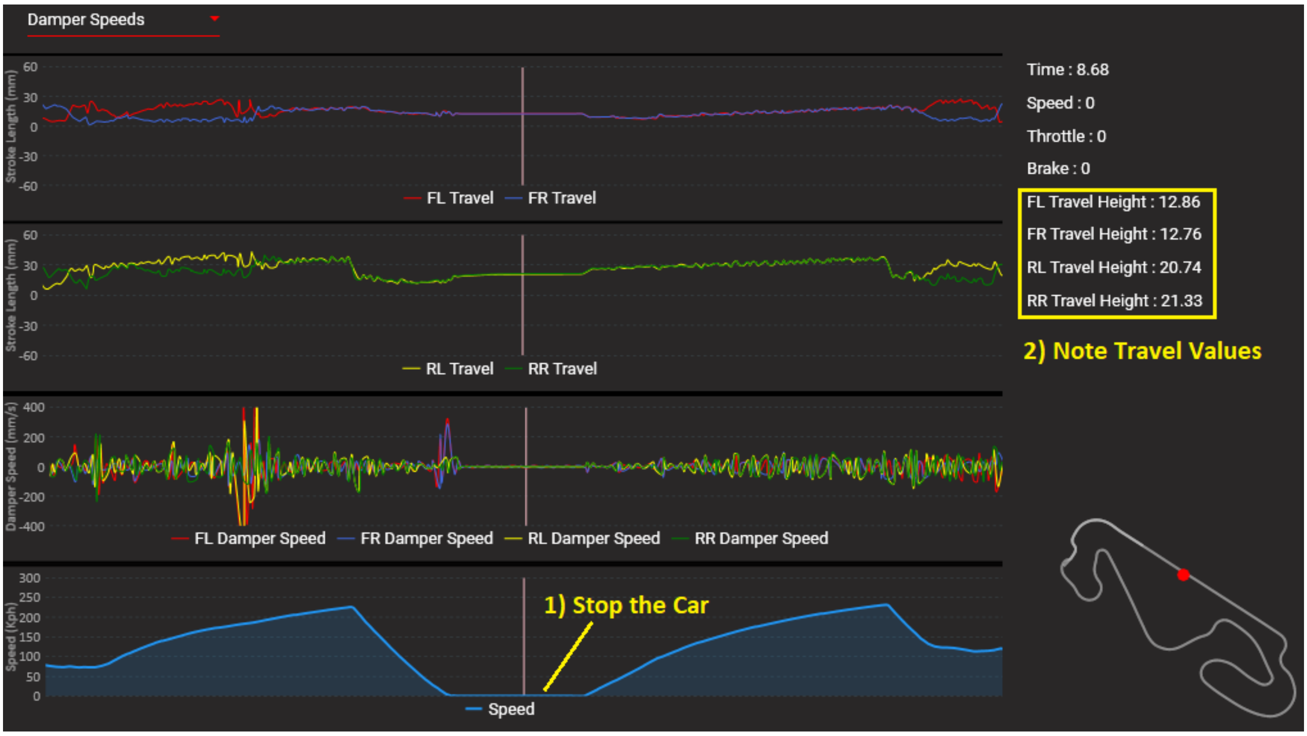

Figure 1.44: Measuring Static Spring Deflection

3) From the data legend on the right, you can see the static spring deflection is ~13 mm on the front and ~21 mm on the back

4) Now go back to the Car Parameters screen and enter the values in the static height cells:

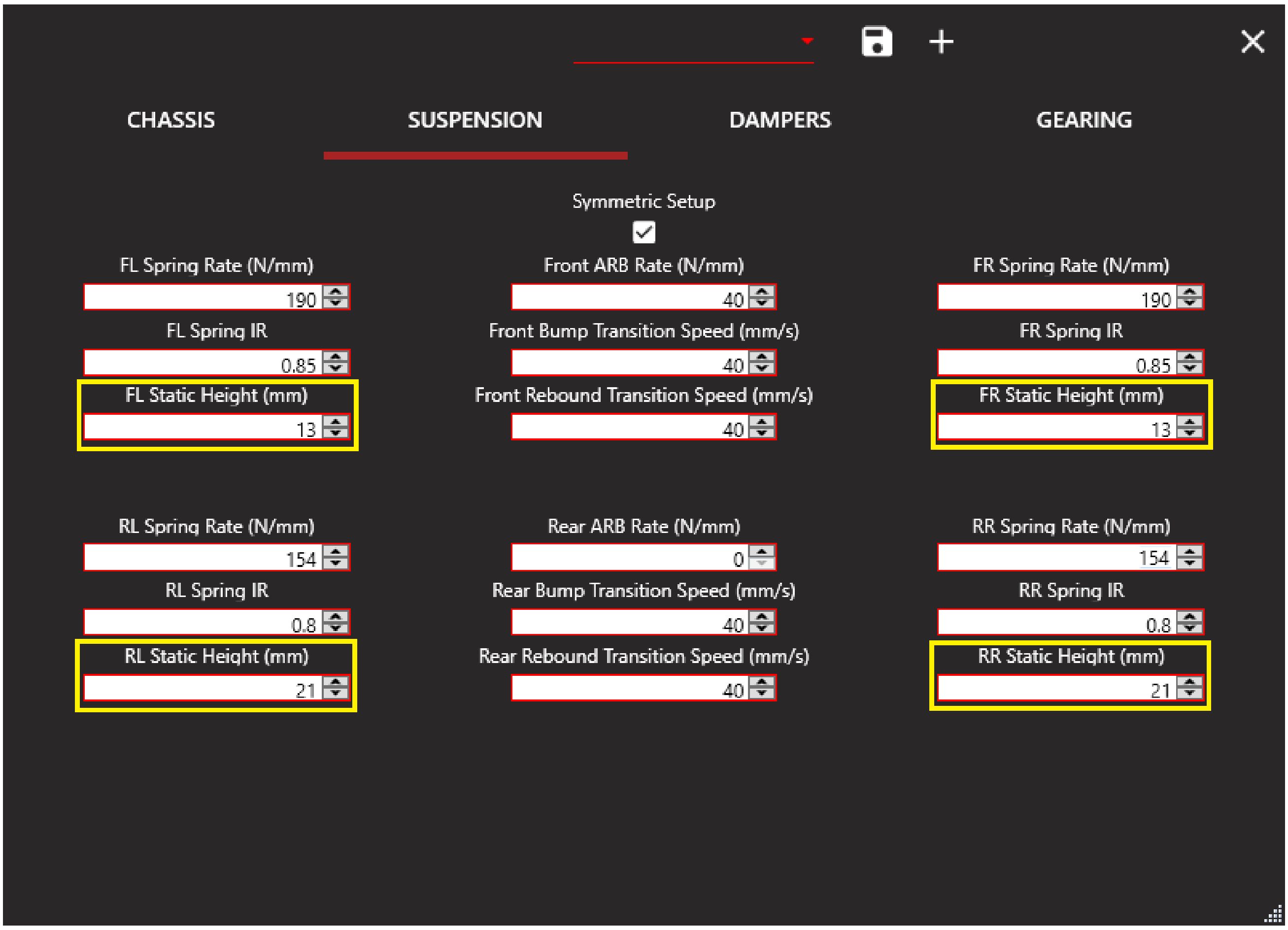

Figure 1.45: Car Parameters with Correct Static Spring Deflection Values

5) Your car parameters are now calibrated correctly, and you can now start analyzing the following charts:

Wheel Loads (chapter 3.3.1)
Lateral Load Transfer Bias (chapter 3.4.6)
Downforce (chapter 3.6.2)

Dampers

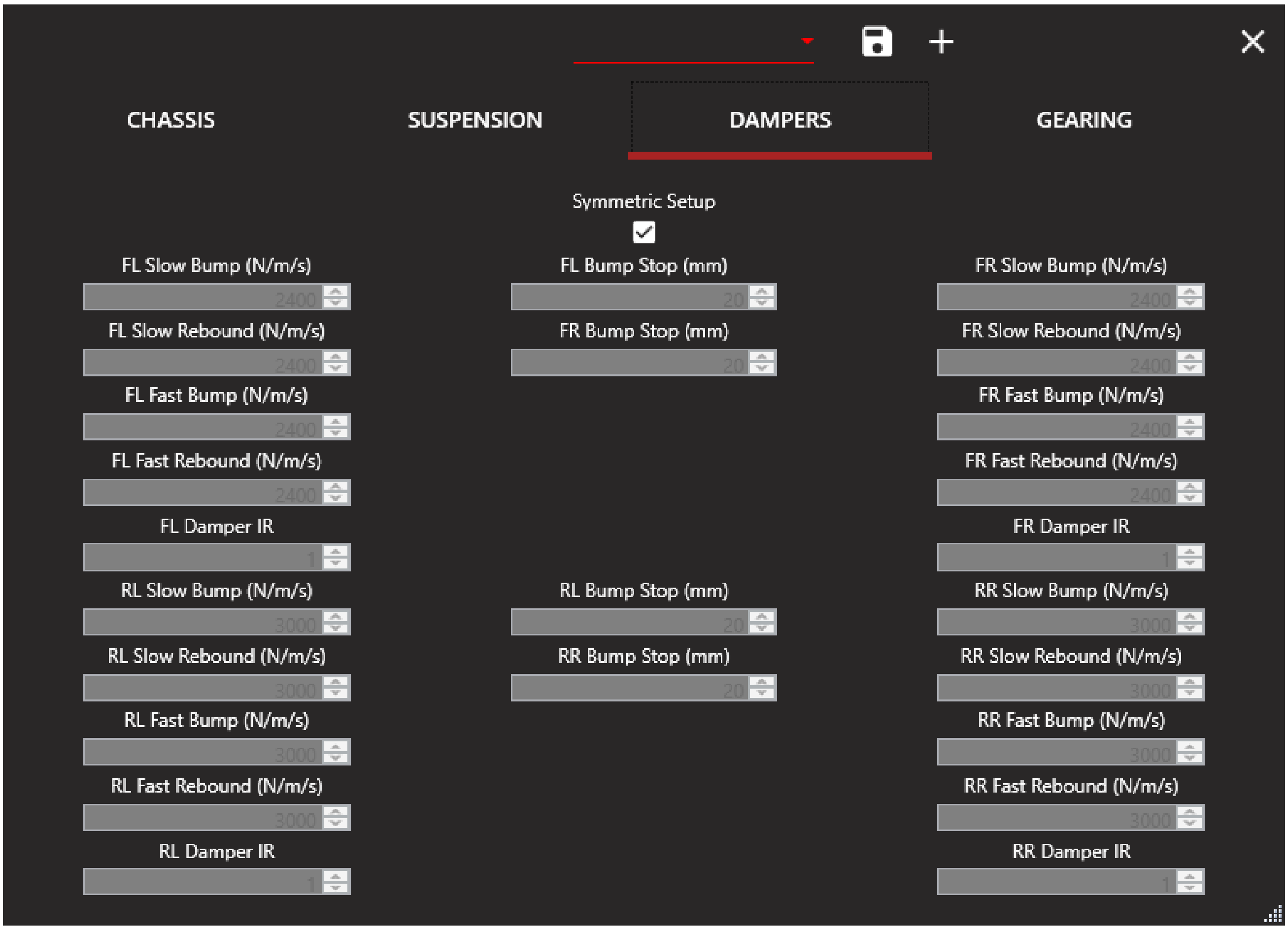

Figure 1.46: Car Parameters: Dampers

Unfortunately, there is no way to determine the actual damping rates from the "clicks" setting in R3E. That's why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

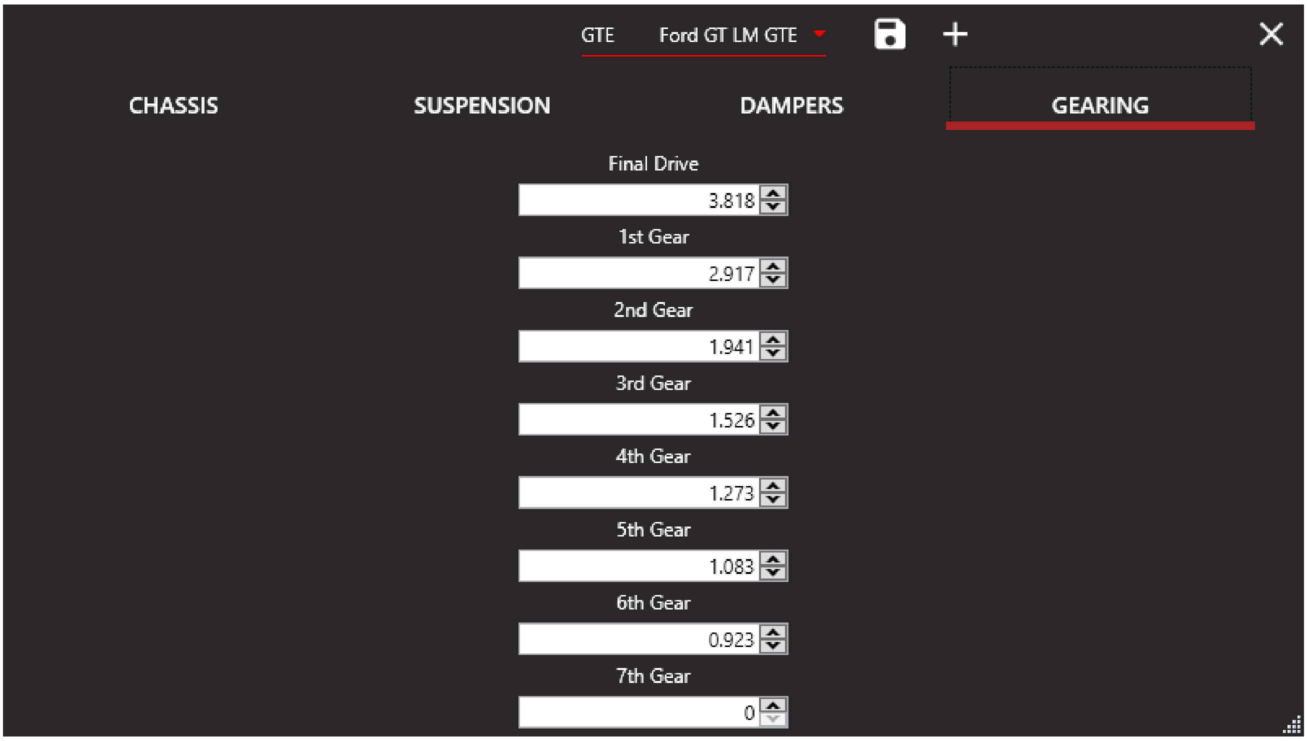

Figure 1.47: Car Parameters: Gearing

Simply enter the gearing ratios from the in-game driveline setup for your car here.

1.3.7. Dirt Rally 2.0 (PC)

Chassis

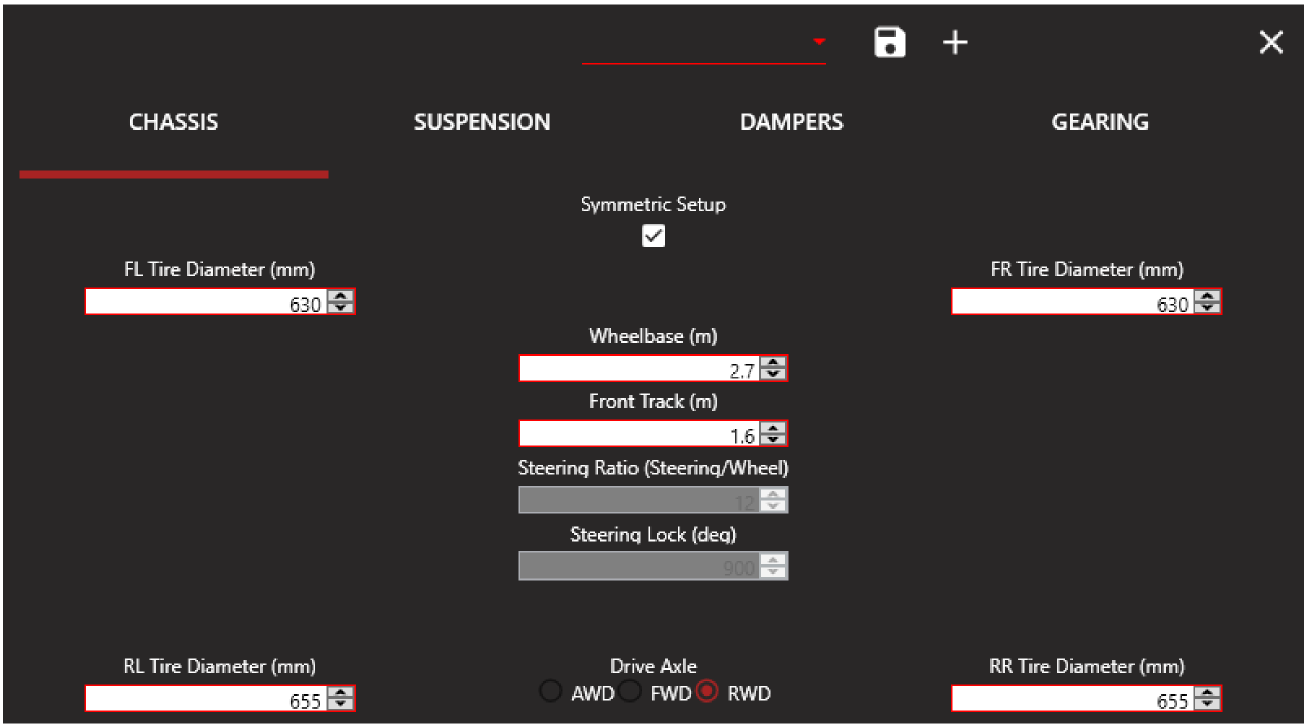

Figure 1.48: Car Parameters: Chassis

Steering ratio and steering lock values aren't needed for DR2.0, that's why they're greyed out.

Wheelbase and front track of most rally cars can be found on the Racing Cars Technology website.

For Group B cars specifically, check out the Rally Group B Shrine website.

We're currently building a car parameter database that'll include wheelbase and track width values for all DR 2.0 cars. Once the database is complete, we'll implement it in the app, so you won't have to enter said data manually anymore.

Tire Diameters:

Since DR 2.0 provides longitudinal wheel speeds directly, entering correct tire diameters isn't necessary and therefore can be skipped.

Suspension

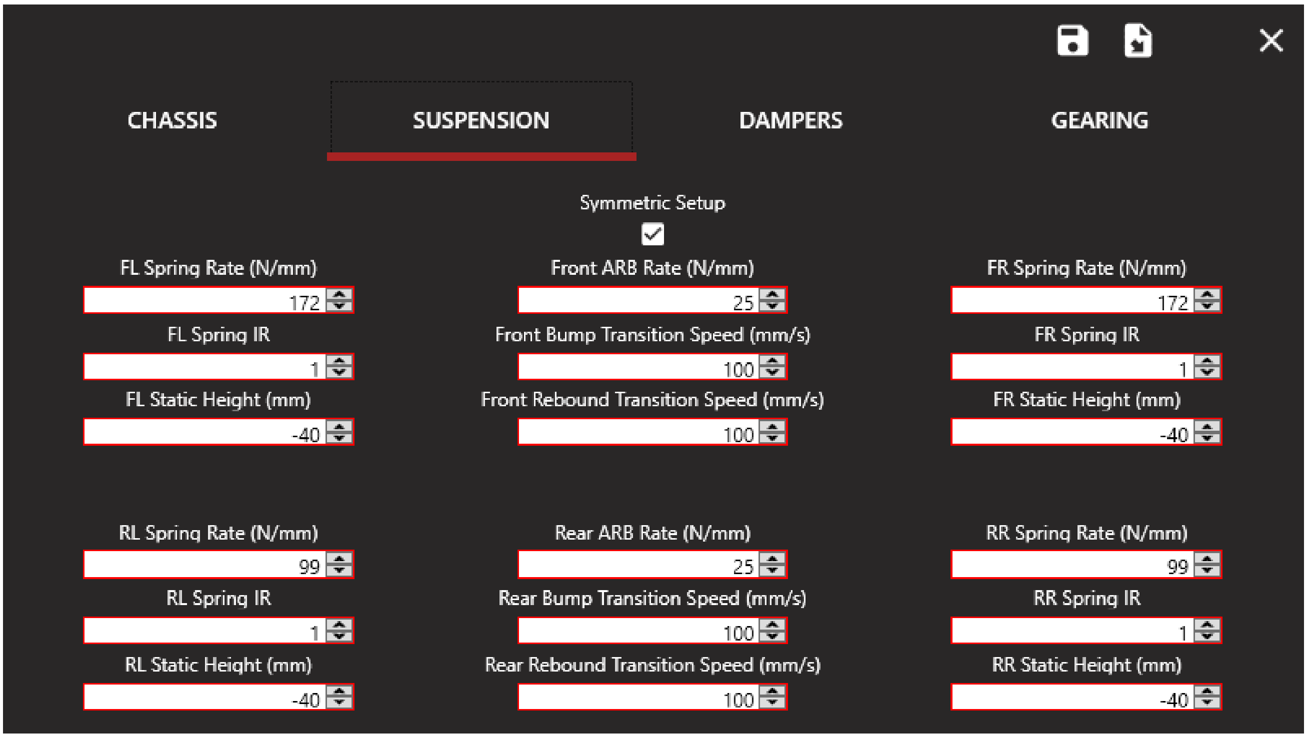

Figure 1.49: Car Parameters: Suspension

Spring & ARB Rates and Ride Heights

Simply enter the spring & ARB rates and ride heights from the in-game setup spring, like shown in the image below:

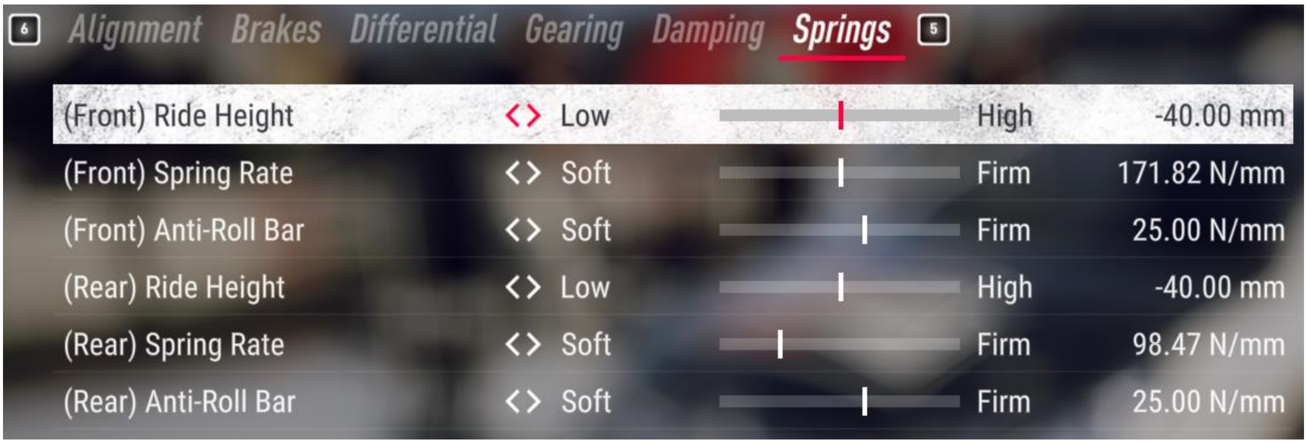

Figure 1.50: DR 2.0 Spring & ARB Rates and Ride Heights

Installation Ratios

In Dirt Rally 2.0 installation ratios are **IR = 1.0 for all cars**.

Transition Speeds

The transition speeds in DR 2.0 can be found and adjusted in the Damping setup screen, as shown below. They're called "Bump Zone Division" in-game and are provided in meters per second [mps]:

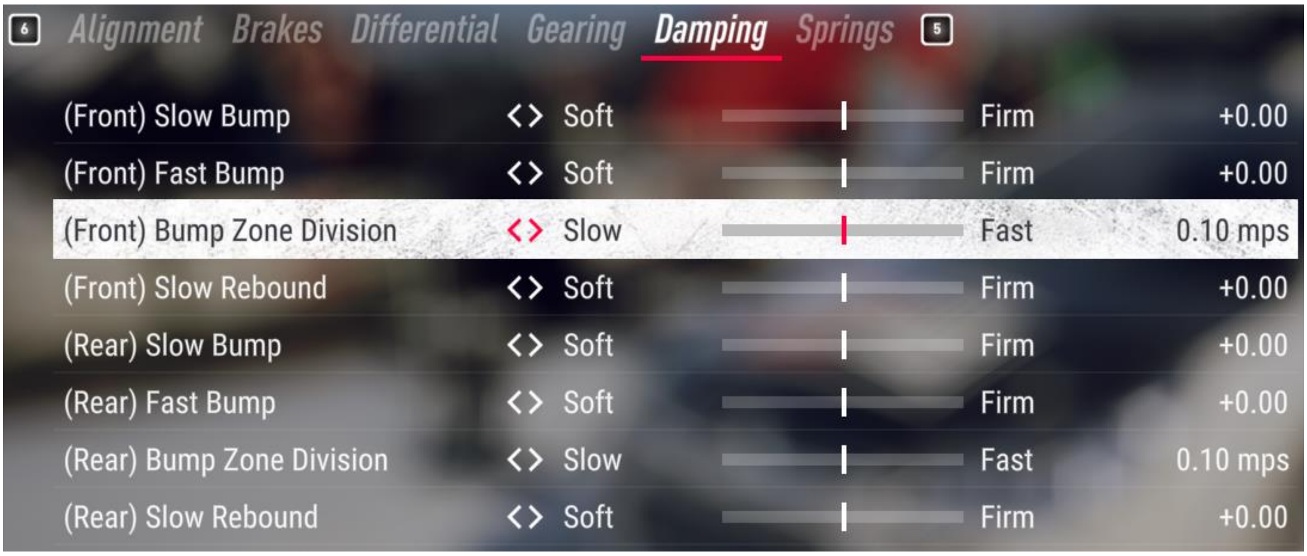

Figure 1.51: DR 2.0 Damper Transition Speeds

Now you just need to convert the transition speeds from m/s to mm/s via the following formula:

$$v_{trans,RST} = v_{trans,DR\ 2.0} \cdot 1000$$

The above transition speeds can now be entered into the car parameters screen:

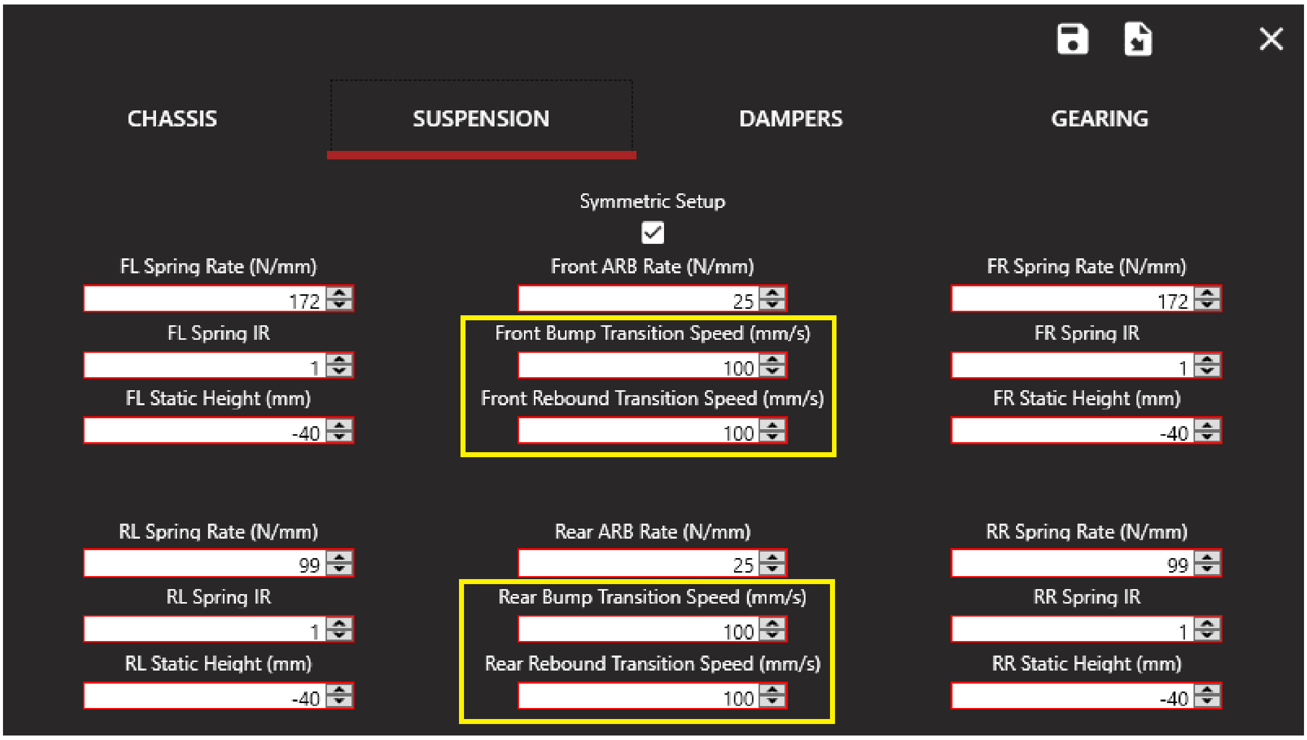

Figure 1.52: DR 2.0 Damper Transition Speeds in RST Car Parameters

Dampers

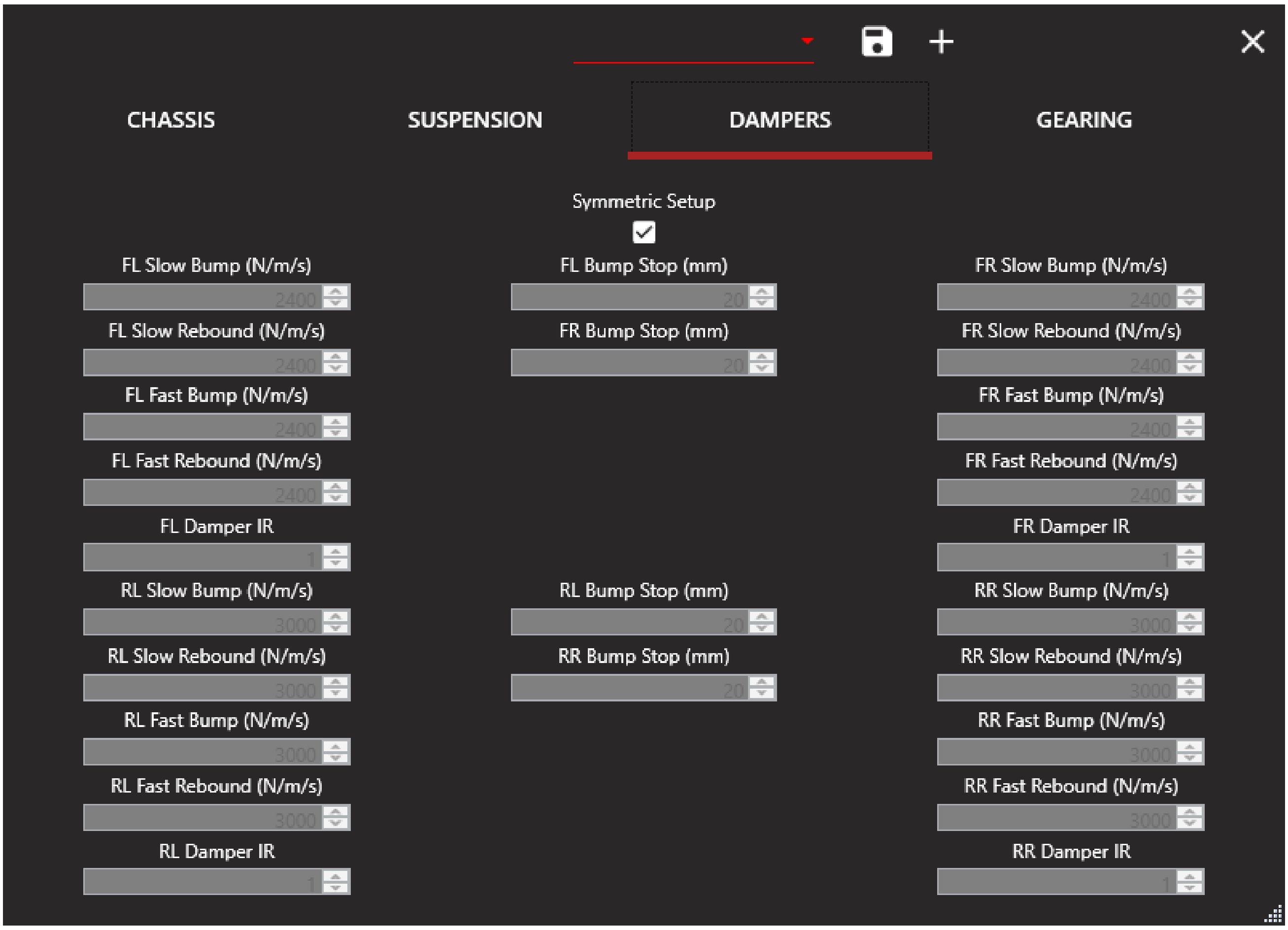

Figure 1.53: Car Parameters: Dampers

Unfortunately, there is no way to determine the actual damping rates from the "±" setting in DR 2.0. That's why this screen can be ignored.

Damper Histograms (chapter 3.4.1) and FFT Analysis (chapter 3.4.2) will still work as intended though.

Gearing

For your gearing setup you need to enter the inverse values from the DR 2.0 setup screen in decimal numbers, as shown in the image below:

Figure 1.54: Gearing Ratio Setup Example in DR 2.0

Converted Gear Ratios

1st Gear	= 1 / 0.338	= **2.959**
2nd Gear	= 1 / 0.438	= **2.283**
3rd Gear	= 1 / 0.555	= **1.802**
4th Gear	= 1 / 0.689	= **1.451**
5th Gear	= 1 / 0.839	= **1.192**
6th Gear	= 1 / 1.000	= **1.000**
Final Drive	= 1 / 0.230	= **4.348**

The above gearing setup will look like this in the app's Car Parameters screen:

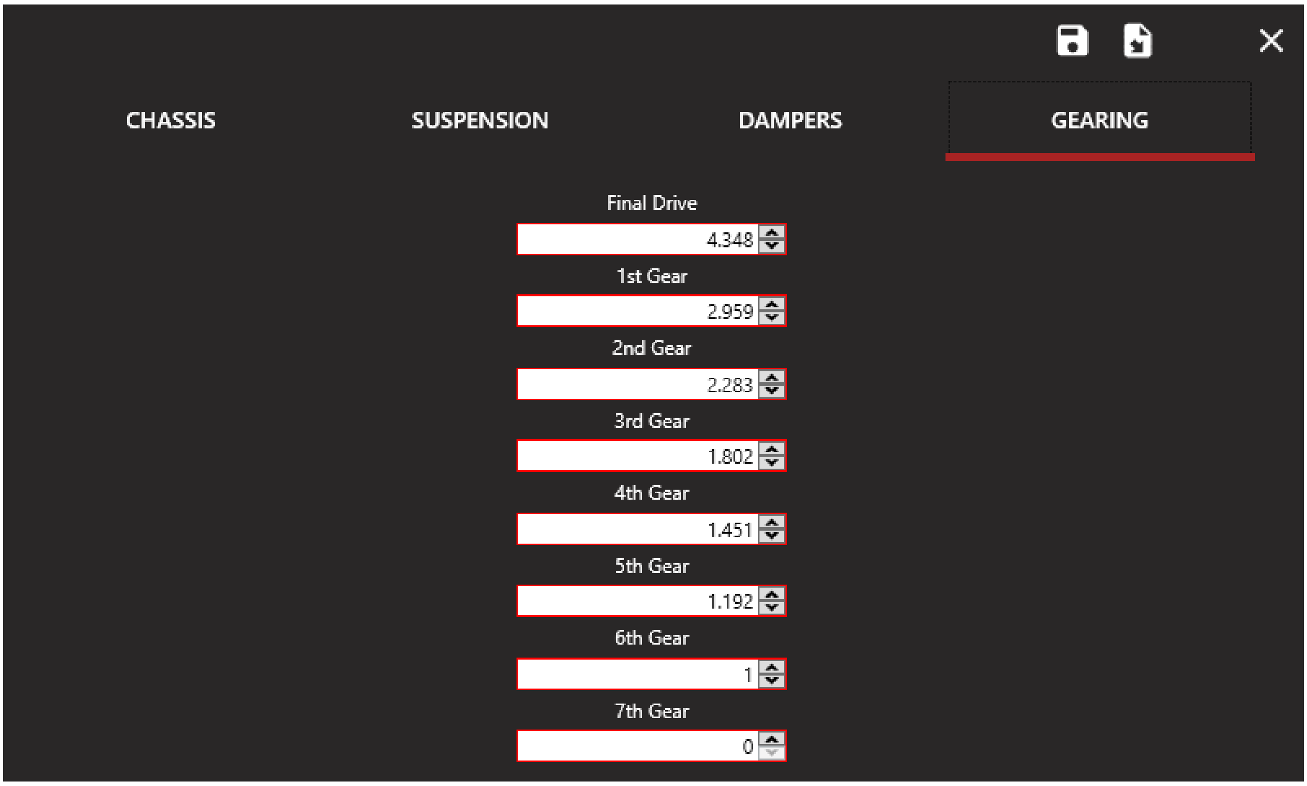

Figure 1.55: Car Parameters: Gearing

2. The 80/20 Rule (Tuning Essentials)

According to the Pareto Principle you can achieve 80% of your goals with 20% effort. The same is true for car setup tuning.

There are a few key components that have by far the most effect on car behavior and once you got those Tuning Essentials right, anything else is just fine tuning.

For this quick guide we will tune the Ford GT LMGTE car and start with a very soft base setup.

2.1. Basic Workflow

1) Start off with a baseline tune that you're familiar with and/or feels stable to you. If you're new to setup tuning you might want to start with the game's default setups, drive at least 5 laps on all of them and choose the one you prefer.

2) Adjust your springs and ARBs to get the car balanced and responsive enough by choosing desired roll and pitch gradients (Suspension tab) and analyzing lateral load bias percentage (Suspension tab), see chapter 2.2.

3) Work on an initial damper setup with the help of the damper histograms (Suspension tab) and set your transition speeds accordingly, see chapter 2.3.

4) Analyze ride height and rake (Aero tab) to improve aero efficiency and ensure sufficient suspension travel, see chapter 2.4.

5) Adjust tire pressures and camber angles (Temps tab) to optimize tire performance, see chapter 2.5.

6) Finally, if you feel the need to adjust your downforce levels it's crucial to take another look at the "Aero" tab and re-adjust ride height and rake.

Notes: When you check these charts and histograms, it's always better to analyze at least three or four relevant laps.

One lap is not enough to make valued judgments. Perform about five to six test laps and then check a few of them.

Reason being, in that one lap you might have followed a different line or hit a bump that you avoided in the other laps.

2.2. Initial Suspension Setup (Roll and Pitch Gradients, Mechanical Balance)

The first thing you'll want to adjust is your spring rate. This is the main dial to get your car balanced.

The lower your roll and pitch gradient the stiffer your suspension will be and the more responsive to load changes your car will get. On top of that, a stiff suspension will also give you a stable aero platform. This is particularly important for high downforce cars like LMPs and open wheelers.

The downside of a stiff suspension is that you'll sacrifice a part of your mechanical grip for it, which is needed to quickly get through slower corners. You'll have to find the right balance between mechanical grip and enough responsiveness.
That's why your goal should be to go **as stiff as necessary and as soft as possible**.

For reference, here are some typical roll gradients for various sports and race cars:

Typical Roll Gradients [B-3]	
High performance sports cars	3.0–4.0°/G
Low downforce sedans	1.0–1.8°/G
Stiff high – downforce race cars	0.2–0.7°/G

Typical Roll Gradients for Various Types of Race Cars [B-1]	
2002 Formula One car	0.03 – 0.10°/G
2001 IndyCar	0.10 – 0.20°/G
2010 Superleague Formula single – seater	0.08 – 0.15°/G
2004 Dodge Viper GTS-R race car	0.44 – 0.55°/G
2004 Corvette C5R GT1 race car	0.20 – 0.40°/G
2006 Corvette C6R GT1 race car	0.25 – 0.35°/G
2011 Audi LMS GT3 race car	0.30 – 0.50°/G

Since GT3 and GTE cars are performing similarly, our goal will be to tune the Ford GT LMGTE to a roll gradient between 0.30 – 0.50°/G.

It's harder to give guidelines on pitch gradients because they can vary quite significantly between cars (even of the same class) because of different suspension designs (especially anti-dive or anti-squat geometry). But overall, they should be lower than the respective roll gradients, mainly because of the much higher wheelbase compared to the car's track width.

The first session with our purposely soft sprung Ford GT LMGTE reveals the following RG and PG:

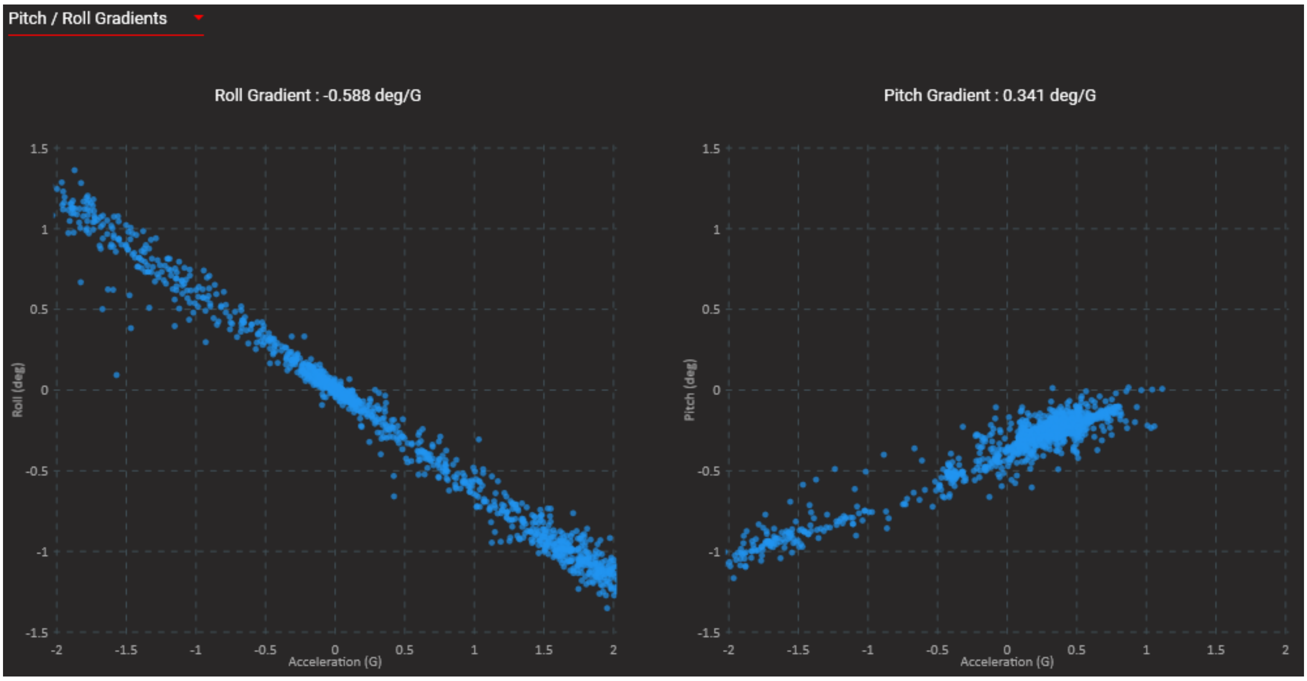

Figure 2.1: Roll and Pitch Gradients, Initial Setup

While the PG is already lower than the RG (as desired), an RG of 0.59°/G is quite high and should be reduced for this type of car. As a result, the car feels unresponsive to quick steering input.

Depending on general US or OS tendency we need to stiffen up the front or rear suspension respectively to get our RG into the desired range:

Roll Gradient	Understeering	Neutral Steer	Oversteering
RG too high	+Rear ARB (& Spring)	+F&R ARB (& Spring)	+Front ARB (& Spring)
RG within range	-F & +R ARB (& Spring)	-	+F & -R ARB (& Spring)
RG too low	-Front ARB (& Spring)	-F&R ARB (& Spring)	-Rear ARB (& Spring)

ARBs should be your main tool to adjust the RG because unlike springs, they won't affect the car's straight-line performance and since they're acting as parallel springs, they're much more effective at it.

In this case the car tended to oversteer quite heavily, so we will need to stiffen the front suspension. We can confirm this through the Lateral Load Bias chart which can be found under Suspension → Lat. Stiffness Distribution:

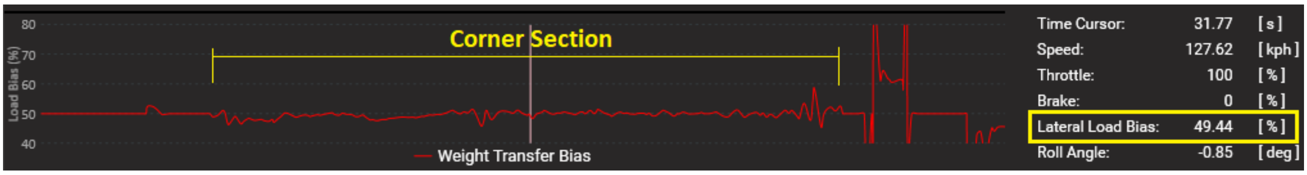

Figure 2.2: Lateral Load Bias, Initial Setup

Let's zoom into a corner we want to analyze (when not zooming in enough, you won't be able to analyze the data reliably) and check the average lateral load bias percentage displayed.

The Lateral Load Bias chart is explained in detail in chapter 3.4.6 but for now all you need to know is that you should aim for a value of ~55% to achieve a balanced suspension setup. Depending on the weight distribution of your car (and to a degree your driving style) this value may vary but 55% is a solid initial target for many cars.

As you can see, the lateral load bias barely reaches the 50% mark, indicating an oversteer tendency of the car.

Now let's increase the front suspension stiffness to lower the RG and neutralize the car's steering behavior.

With increased front stiffness the RG is successfully lowered to the desired target range:

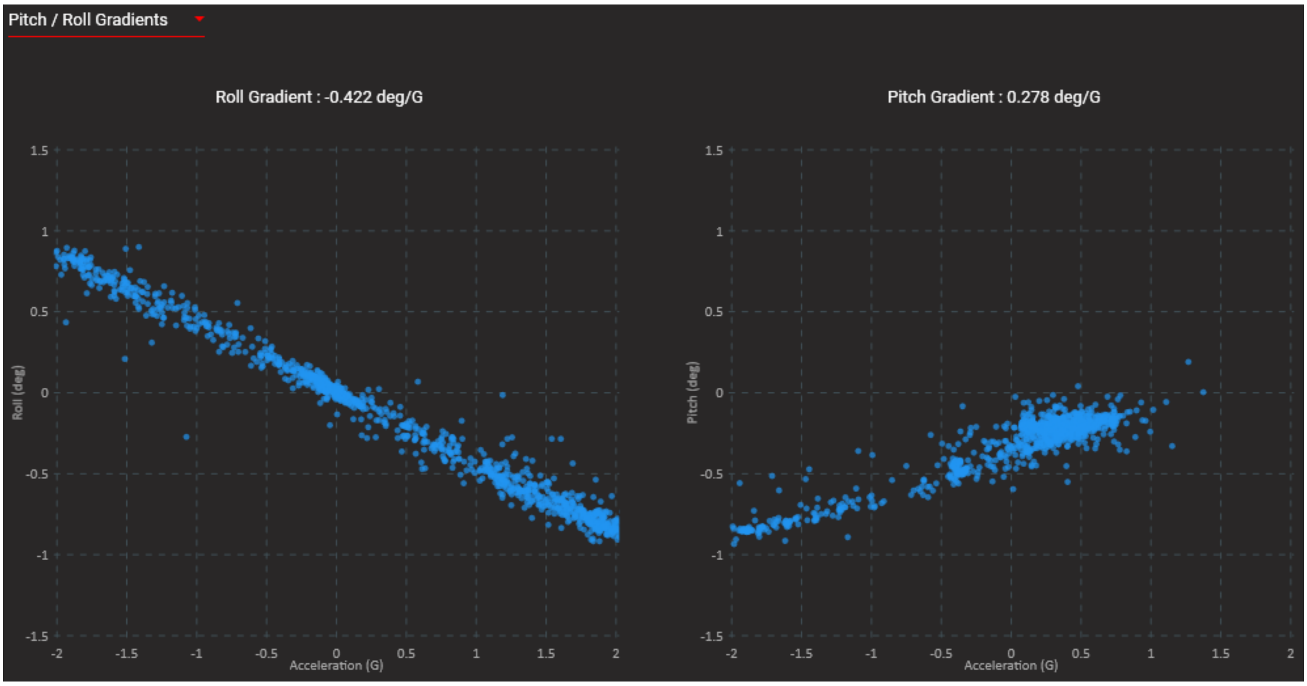

Figure 2.3: Roll and Pitch gradients, Neutral Setup

The car also feels much more balanced, which can also be confirmed by the lateral load bias percentage:

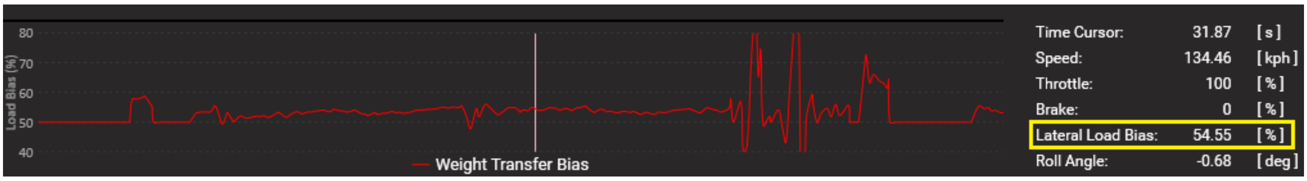

Figure 2.4: Lateral Load Bias, Neutral Setup

Now the average lateral load bias percentage almost perfectly hits the targeted 55% mark, which confirms the car's neutral balance.

Increasing front stiffness even more will further lower the RG and improve steering responsiveness:

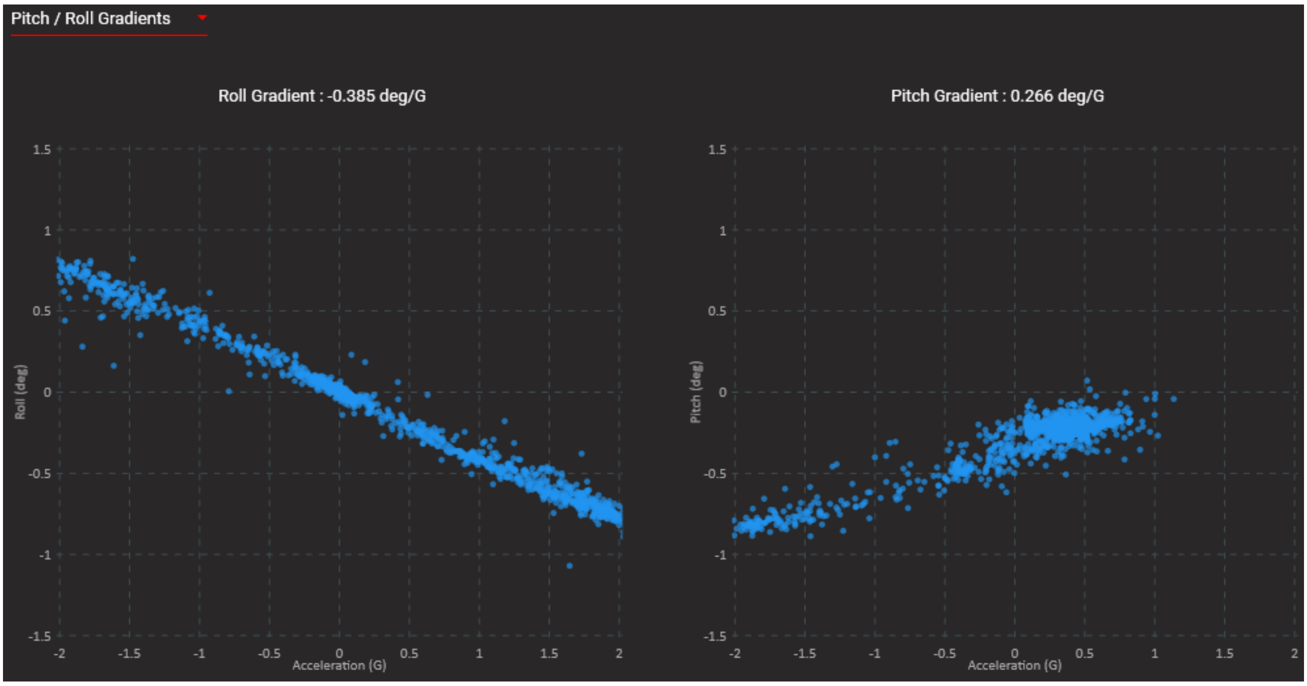

Figure 2.5: Roll and Pitch Gradients, Understeering Setup

Unfortunately, this comes at the cost of understeer, which can again be confirmed with the help of the Lateral Load Bias chart:

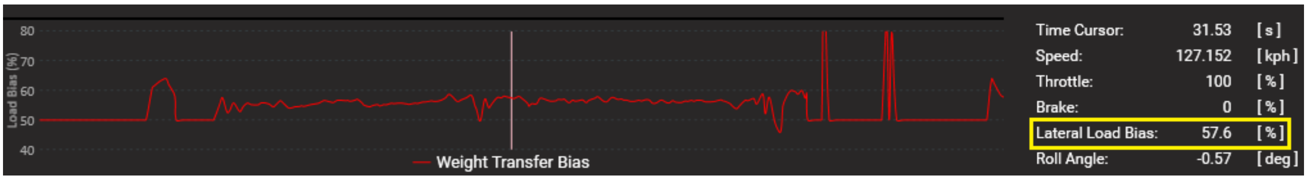

Figure 2.6: Wheel Loads, Understeering Setup

The lateral load bias percentage has now increased to ~57.2% and as a result of that understeer, the turning capacity will be reduced.

2.3. Damper Setup

Now that our springs are balanced, we can start adjusting our dampers with the help of the damper histograms to balance the car during transient maneuvers (turn in + corner exit). For initial damper setup we will solely focus on low-speed damping only because that's where your suspension will spend most of the time over a lap.

Under the premise that our stiffness distribution (springs + ARBs) is balanced, our damper histograms should look roughly the same for all four corners.

For the unoptimized dampers of our balanced setup the histograms show multiple issues that we need to fix:

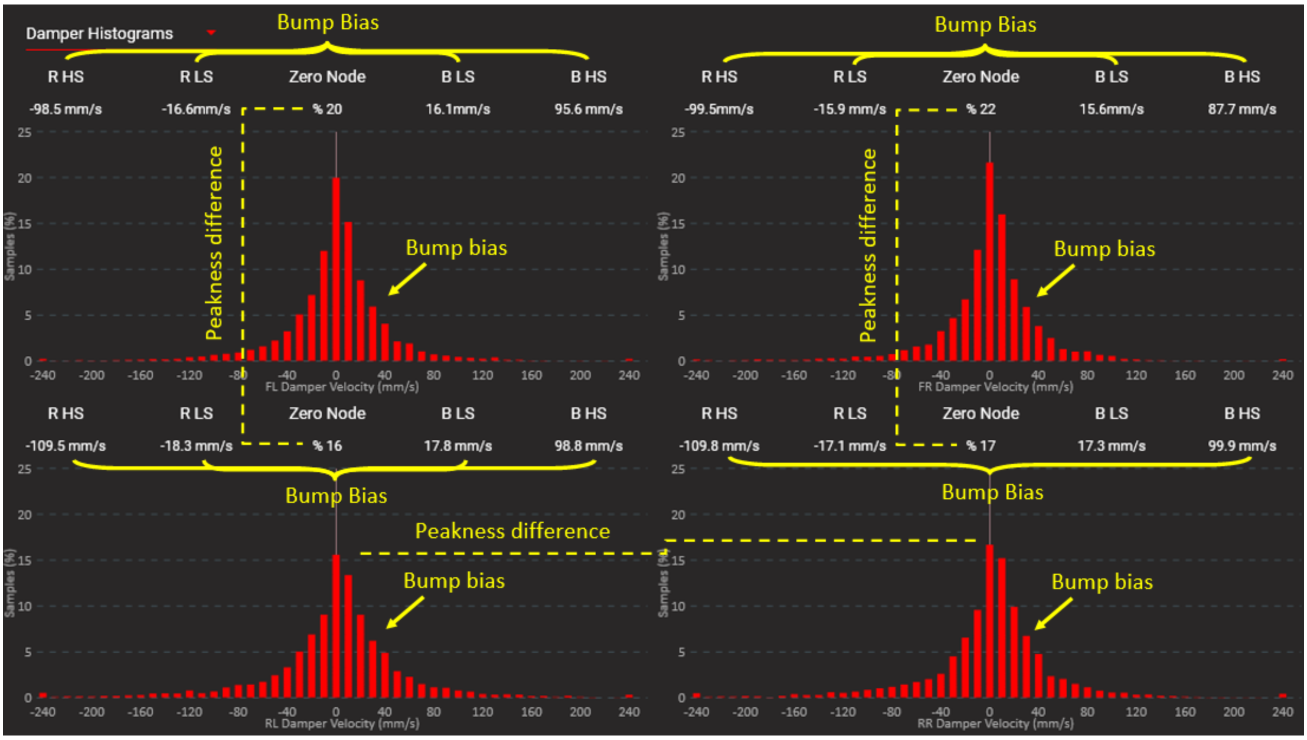

Figure 2.7: Bump Bias, Lower Rear Damping

1) The rear axis is underdamped compared to the front (0 node is significantly lower), so we need to increase overall damping at the rear.

2) All dampers are bump biased (histogram is skewed to the positive velocity values and the average velocity is lower on the bump side). To fix that, we must either increase rebound or lower bump damping.

3) There's also an imbalance between left and right side but that's mostly caused by the track layout. We could even out this too but that's not a critical issue, so we'll ignore that for initial damper setup.

Since the rear dampers display both critical issues (underdamped + bump bias), we will increase rebound damping by a few clicks and bump damping only by one click.

The overall damping rate at the front is already high enough, so we will increase rebound and lower bump damping equally.

On top of that, we'll increase rear spring stiffness a bit.

With our improved damper setup now looks like this:

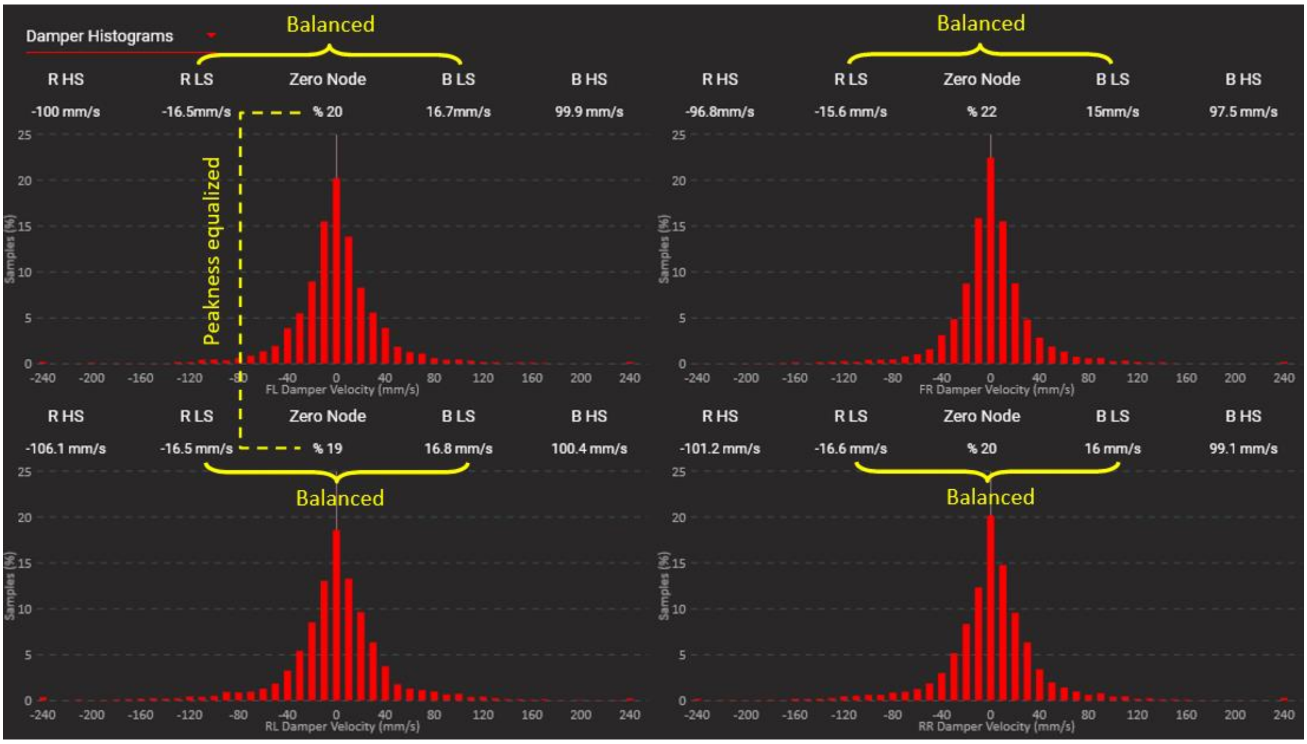

Figure 2.8: Bump and Rebound Balanced, Overall Damping Rate Balanced

The overall damping is now roughly equal on both axles (0 nodes within 2% or each other) and the bump bias has been tuned out (histograms are more symmetrical about the 0 node).

If we'd increase the rebound damping rate even further, the histograms would look like this:

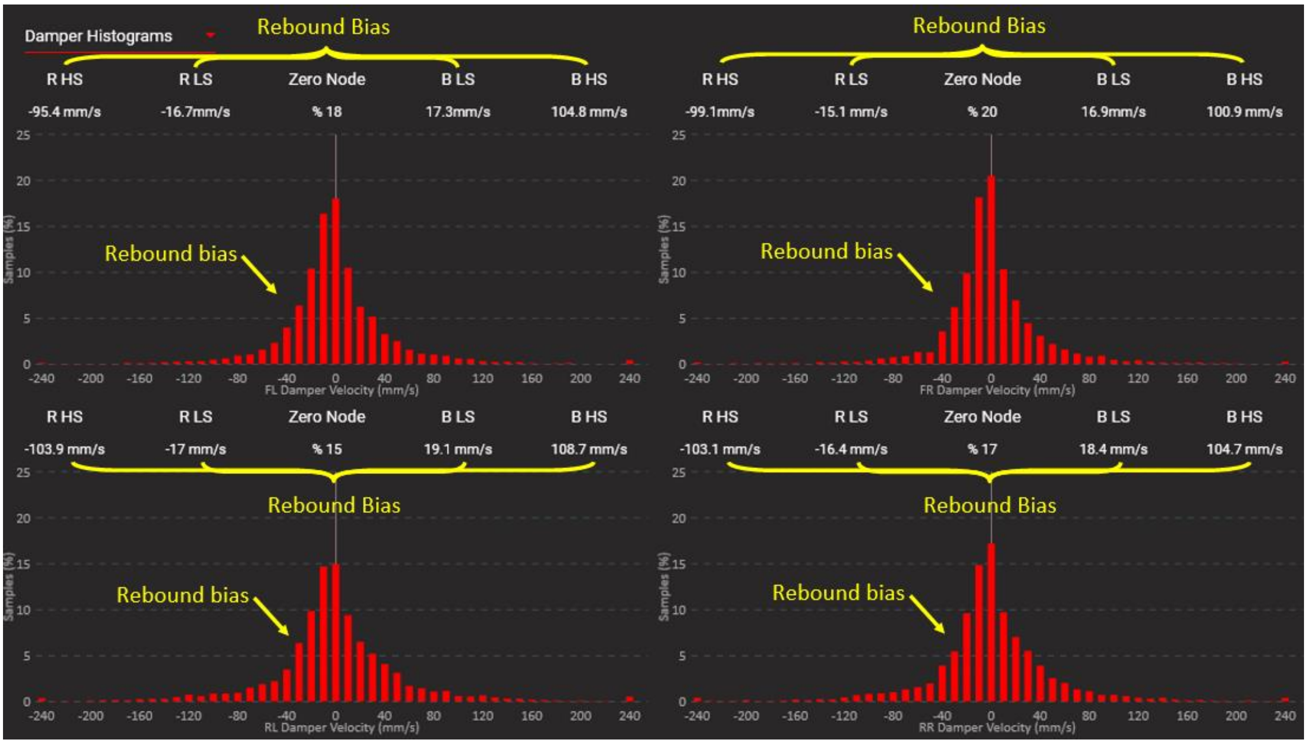

Figure 2.9: Rebound Bias, Too Much Front Damping

The histograms are now skewed to the negative velocity values (rebound bias).

While it's generally recommended to aim for symmetrical damper histograms, a slight bump or rebound bias can positively affect the vehicle's performance in transient. This is mostly based on driver preference, so don't hesitate to experiment with purposely unbalanced dampers.

2.4. Aero Setup (Ride Height, Rake, Downforce)

Since we achieved a balanced suspension setup, we can now start improving our aero balance and efficiency.

The optimal location to analyze aero data is right at the end of the fastest straight of the track where max top speed is reached (normally the start-finish straight).

There are basically three goals we want to achieve with our aero setup:

1) **Maximize downforce**, preferably without increasing drag by more aggressive wing settings

2) **Minimize drag** by reducing the frontal area (lowest possible ride height and 0 rake at high speed)

3) Move the **center of pressure (CoP)** into the right place (balanced aero).

Priority should be to achieve balanced aero loads first. As a rule of thumb, the CoP should be located **5 – 10% further to the rear than the car's longitudinal weight distribution**. Since our car has 55% rear weight distribution, the CoP should be at 60 – 65% to the rear.

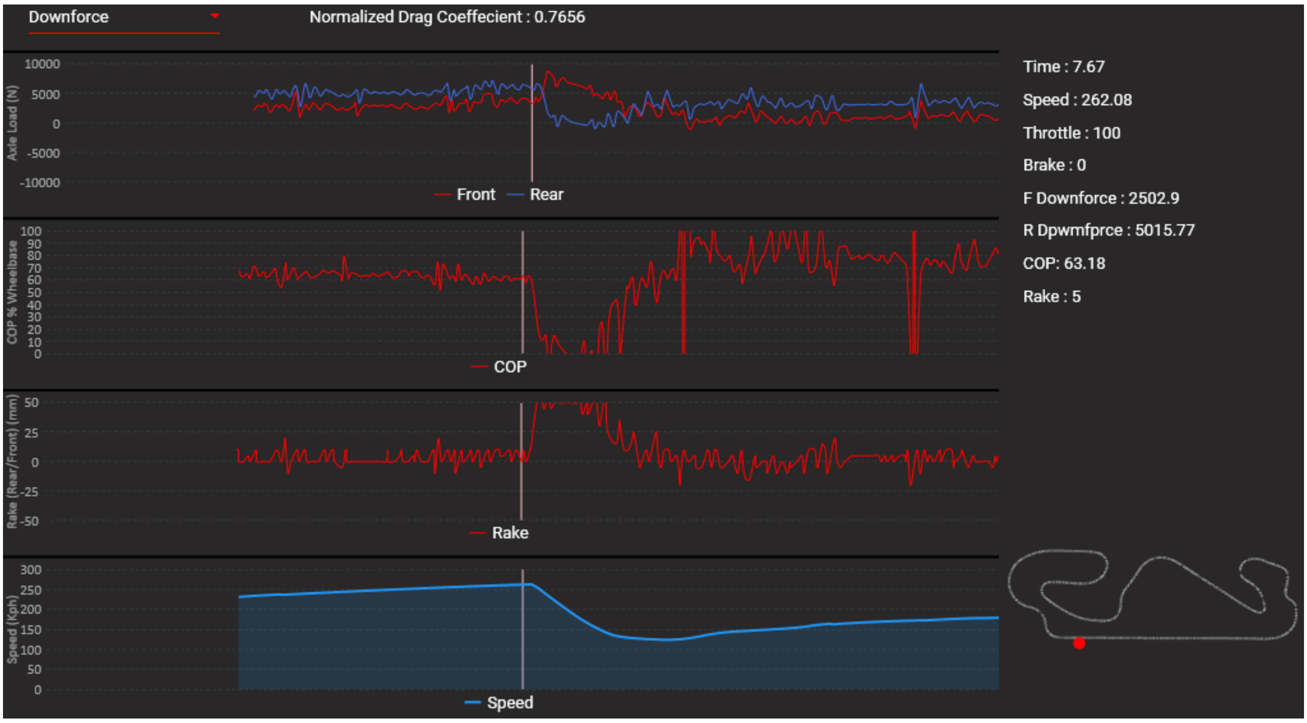

Figure 2.10: Aero Data for Initial Setup (RH 67/87, DF 2-4)

Our car feels pretty neutral already, so it's not a surprise that the CoP is within the desired range.

Now let's see if we can increase overall downforce a bit and increase top speed by removing some drag.

We'll start by lowering front ride height as much as possible without bottoming out:

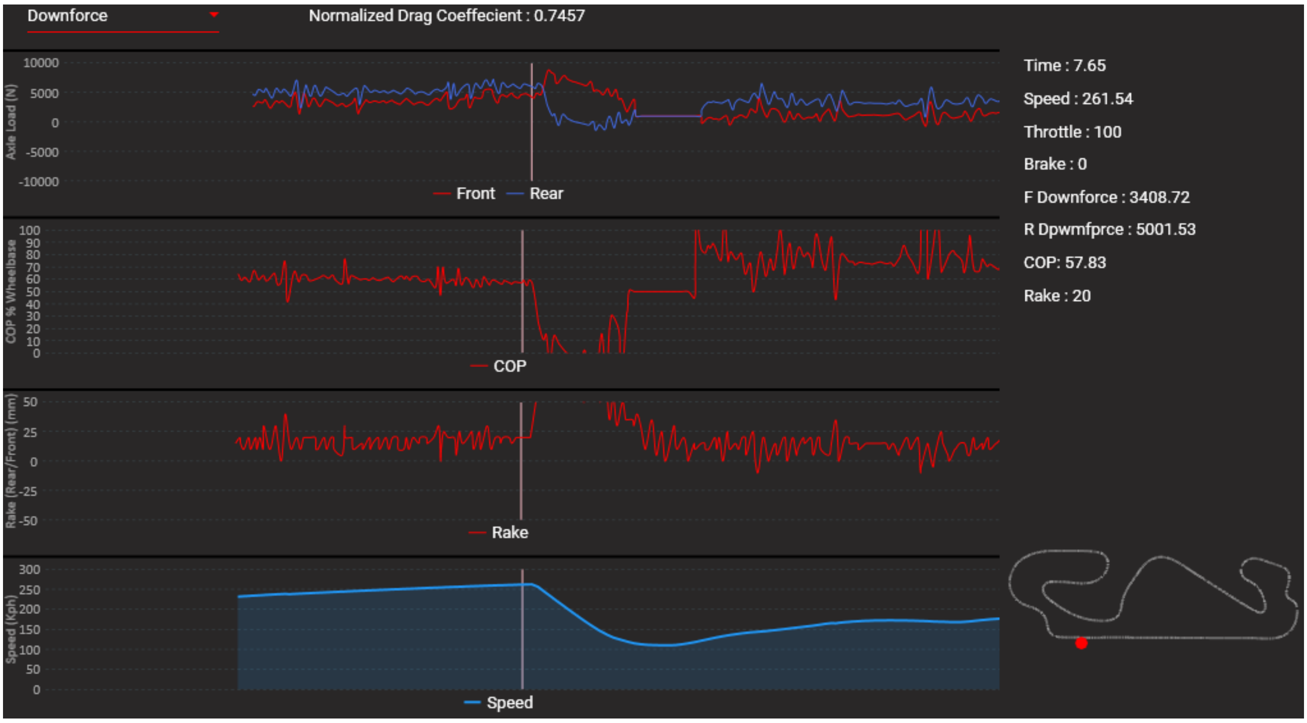

Figure 2.11: Aero Data for High Rake (RH 58/87, DF 2-4)

The good news is that we could increase front downforce, but unfortunately the CoP shifted forward (57.8%) which is causing oversteer in fast corners.

On top of that, drag hasn't been reduced either. We can see that through the lack of increased top speed.

The next logical step seems to be lowering rear ride height move minimize the frontal area and shift the CoP back into the desired range.

Reducing the rear ride height to 75 mm results in the following aero data:

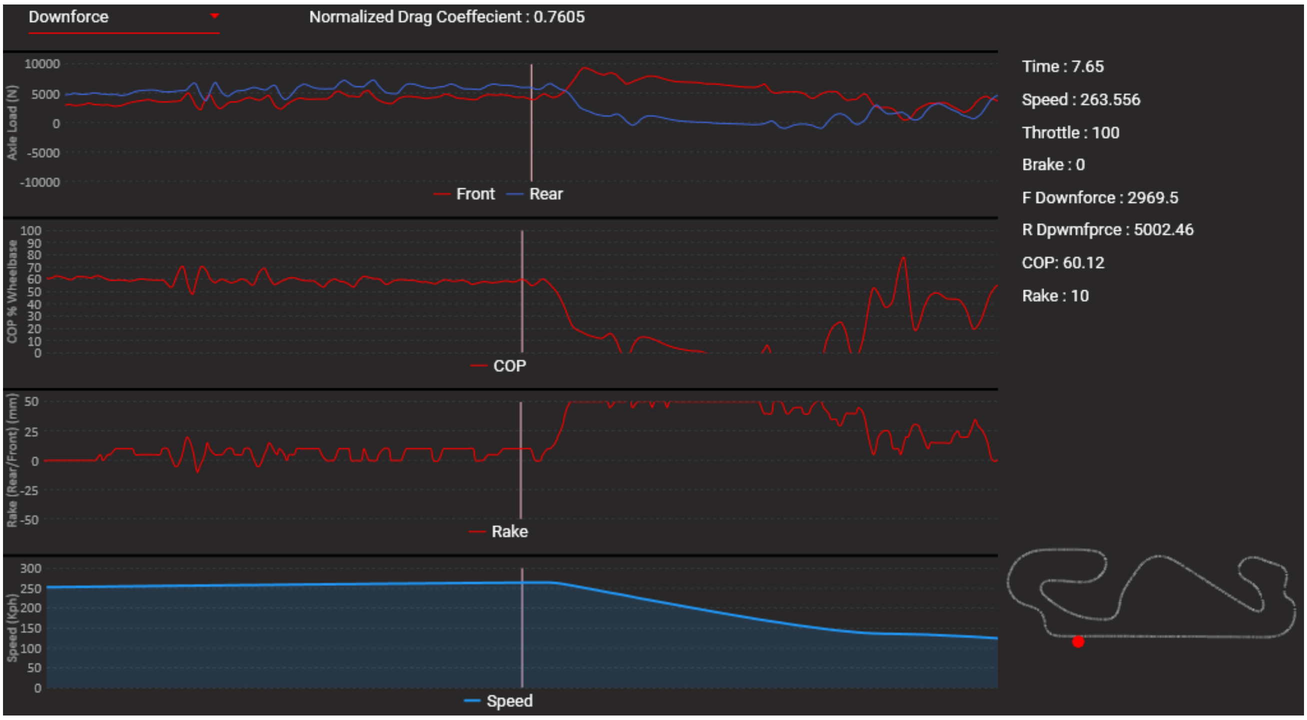

Figure 2.12: Aero Data for Low Ride Height (RH 58/75, DF 2-4)

As we can see, we were quite successful in reducing drag (increased top speed) and moving the CoP backwards. Rake could be reduced a little bit but it's close enough, so we'll leave it at that for now.

The car still feels a bit loose though. Since front downforce is still higher than on our initial setup, we'll reduce front aero for the next test run.

Let’s check out the telemetry data for our reduced downforce setup (in-game setting 1-4).

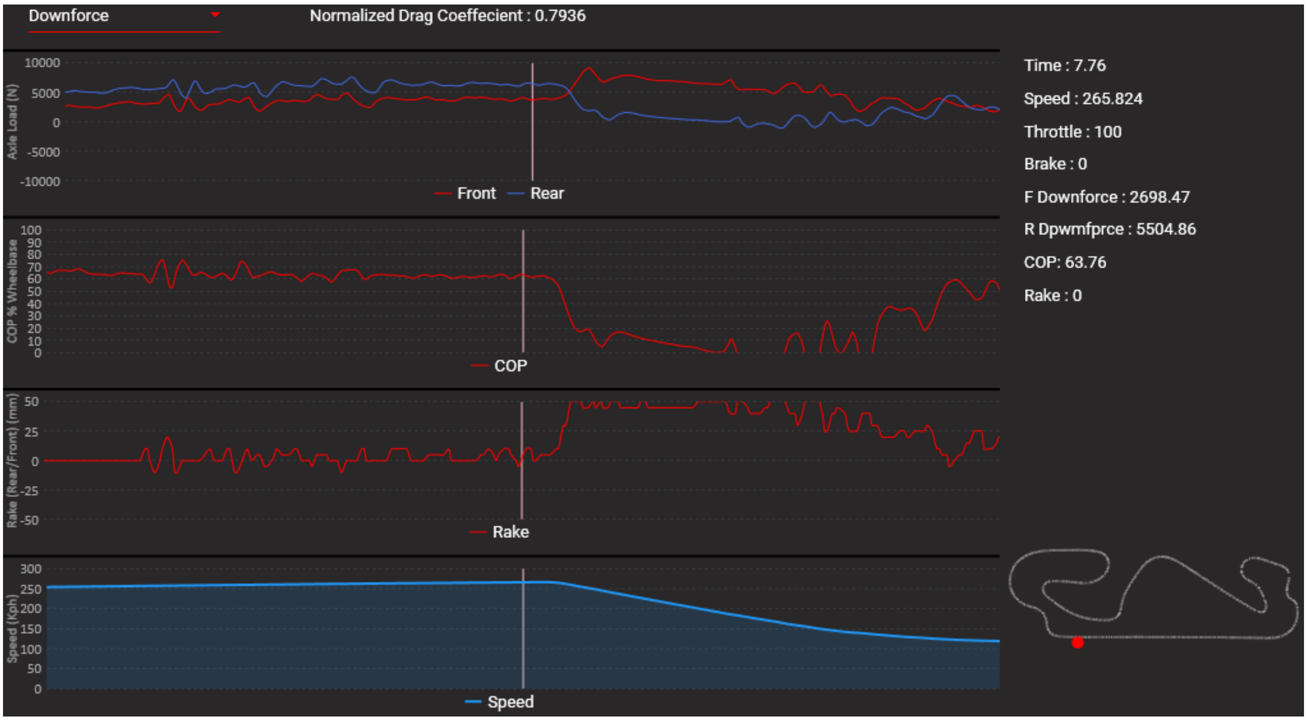

Figure 2.13: Aero Data for Low Ride Height and Reduced Front Aero (RH 58/75, DF 1-4)

It looks like we were quite successful with lowering front aero.

CoP is back to ~63% rear and as a result the car feels balanced again.

Overall downforce values are even a bit higher than with our initial setup although we’re running less aero.

As a side effect of the lower front aero, the ride height has been raised a bit which results in 0 rake and therefore reduced drag (increased top speed to ~266 kph).

Although our aero setup seems to be as good as it can get, let’s analyze the effect of a too high overall ride height on downforce, for educational purposes...

Let’s analyze our aero with ride height set to 77/87 mm:

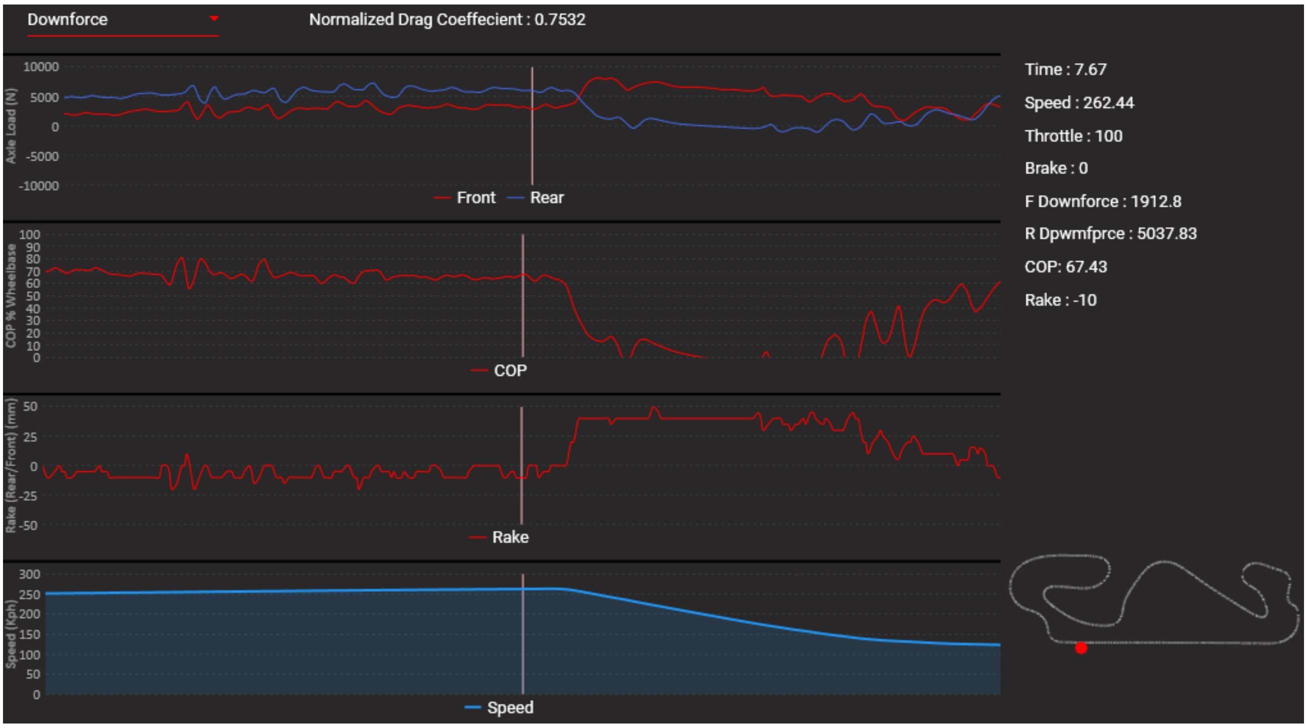

Figure 2.14: Aero Data for High Ride Height and Negative Rake (RH 77/87, DF 2-4)

Even though we’re again using the high downforce setup (DF 2-4), aero load on the front tires is significantly reduced. As a result, the CoP shifts to the rear, causing significant understeer in fast corners.

On top of that, drag has increased because of our high downforce setup and the larger frontal area.

The table below gives an overview of all the aero test runs we did:

Static RH [mm] Aero Setting [-]	Rake (R – F) [mm]	Front DF [N]	Rear DF [N]	CoP [Rear %]	Top Speed [kph]	Tendency US / N / OS
68 / 87 **2 – 4**	~5	~2500	~5000	**63.2**	262.1	**N**
58 / 87 **2 – 4**	~20	**~3400**	~5000	57.8	261.5	++OS
58 / 75 **2 – 4**	~10	~3000	~5000	**60.1**	263.6	OS
58 / 75 **1 – 4**	**~0**	~2700	**~5500**	**63.8**	**265.8**	**N**
77 / 87 **2 – 4**	~-10	~1900	~5000	67.4	262.4	US

We can clearly see that our low ride height + low drag setup provides the most efficient aero for this car / track combo.

Important note: Ride height is measured at different locations in the various supported games and not necessarily at the lowest point of the chassis. So please be aware that this data isn't always comparable between games but more importantly, that **you can get chassis/aero damage from bottoming out although the data shows sufficient ground clearance.** In that case, increase your ride height to avoid damage from too low ride height.

2.5. Tires (Camber, Pressures)

As the final tuning essential we'll adjust our tire pressures and camber angles to maximize the contact patch area in corners. We will do that with the help of the Camber Temp and Pressure Temp graphs which can be found in the Temps tab.

Correct camber angles will show a temperature gradient of ~5 – 10°C between the inside and the outside of the tire. If the camber temp graph is below the optimum range, you'll need to increase the negative camber angle and vice versa.

When tire pressures are set up properly, the middle temperature will be right between the inside and outside temperatures. The Pressure Temp graph will display values close to 0°C in this case. If the value is negative, increase the pressure of this specific tire and if it's positive, lower the pressure.

The image below shows that there's a lot of potential left to improve our tire setup:

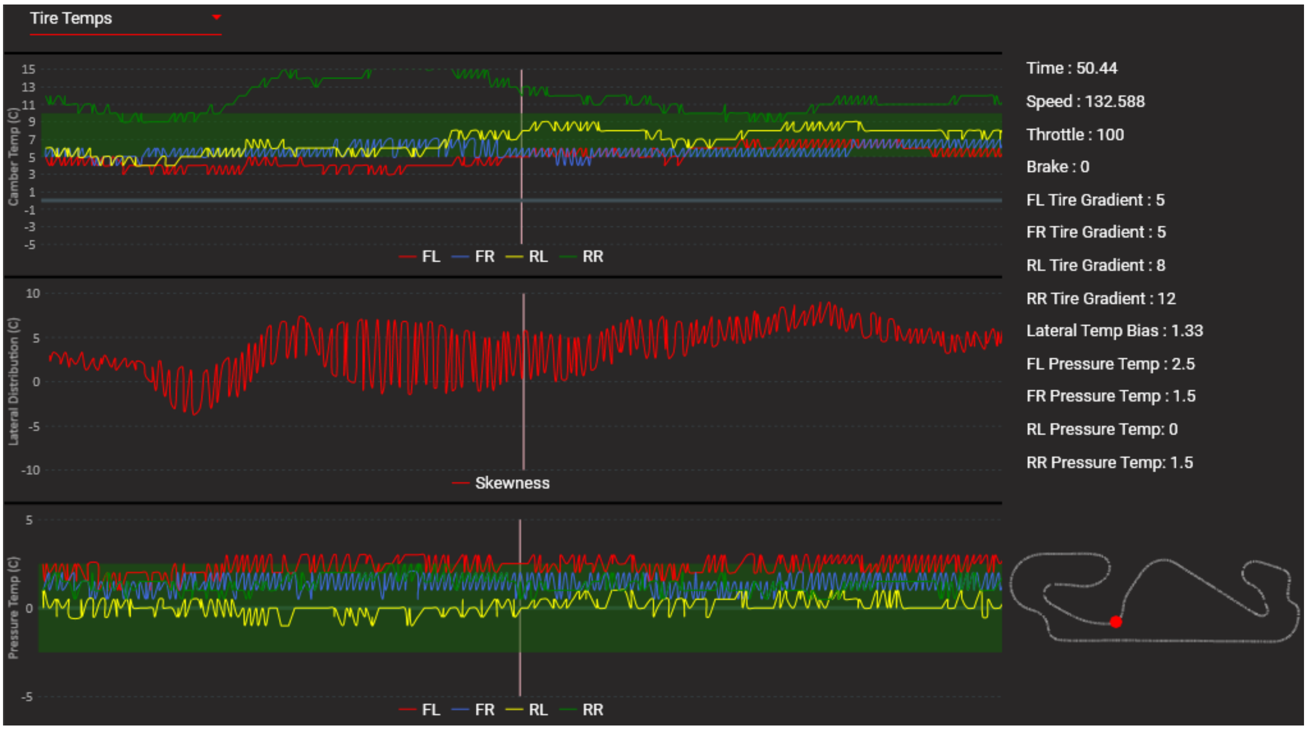

Figure 2.15: Unoptimized Camber Angles, Too High Tire Pressures

1) The rear right temperature gradient is way too high, so we'll need to decrease its camber angle.
2) The temperature gradients of both front tires are a little bit low. Negative camber for both tires should be increased slightly to improve cornering performance.
3) Pressure temperatures of the rear right and both front tires are a bit high, so let's lower the pressures on those.

With the required adjustments being done, our tire temperature graphs are showing a well-balanced tire setup:

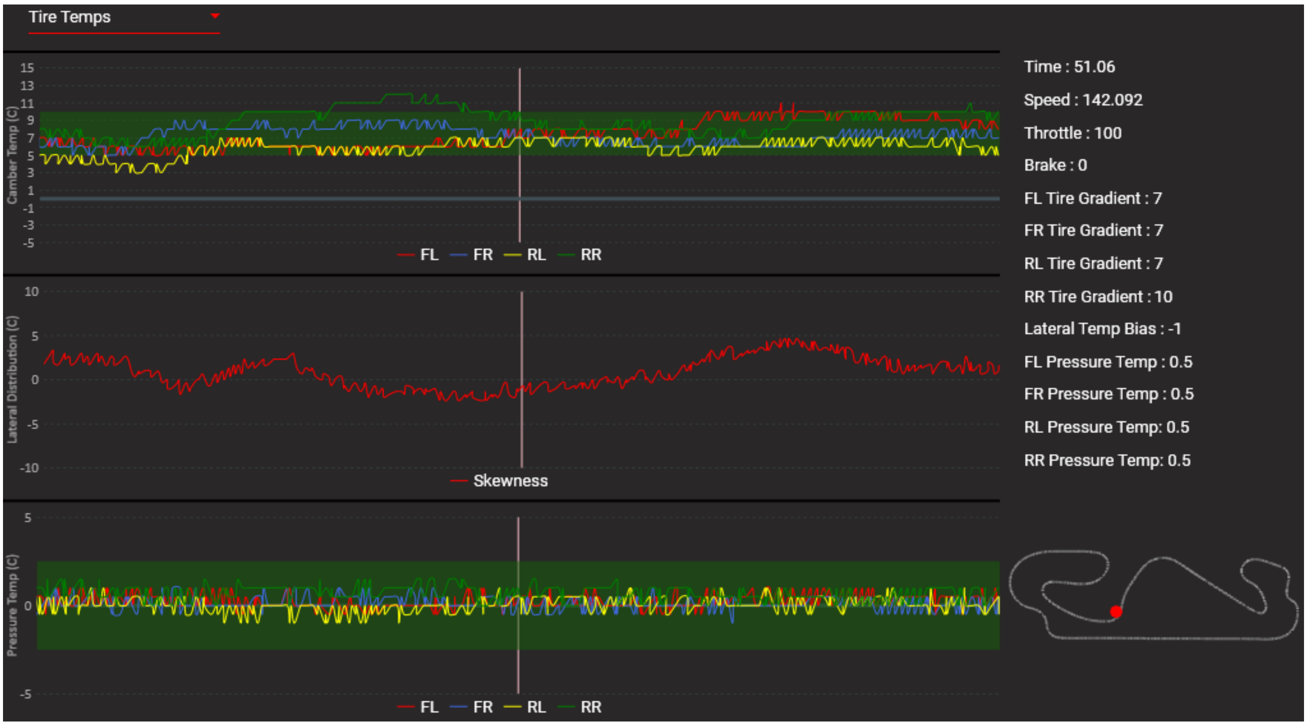

Figure 2.16: Optimized Camber Angles and Tire Pressures

Since there's no rule without exceptions, uneven temperature gradients or too high / low tire pressures can be of advantage in various situations:

Depending on track layout you should use asymmetric camber angles to achieve similar temperature gradients, but this is not always advisable:

Example 1: Autódromo do Algarve has multiple medium fast to fast right hand turns and basically only slow left-hand turns. You should set a higher negative camber on the left wheels to increase cornering ability in those fast corners and a low negative camber on the right wheels for more mechanical grip in the slower corners.

Example 2: Spa Francorchamps has multiple fast and slow, left and right corners. Since you'd want to have similar cornering performance through all those turns you should stick to a more symmetrical camber setup at this track.

Another possibility to tweak your camber setup is to **lower rear camber angles**. This can **improve your acceleration** on corner exit because of the increased contact patch area.

Depending on the track you're driving on it might be beneficial to over- or under inflate your tires.

On **fast tracks** like Le Mans or Monza you should **increase your pressures** to profit from the **reduced rolling resistance, which will increase your top speed**.

On **slower tracks** like Long Beach you should **lower your pressures** to get **more mechanical grip in slow corners**.

The tire temperature graphs will look quite different in iRacing:

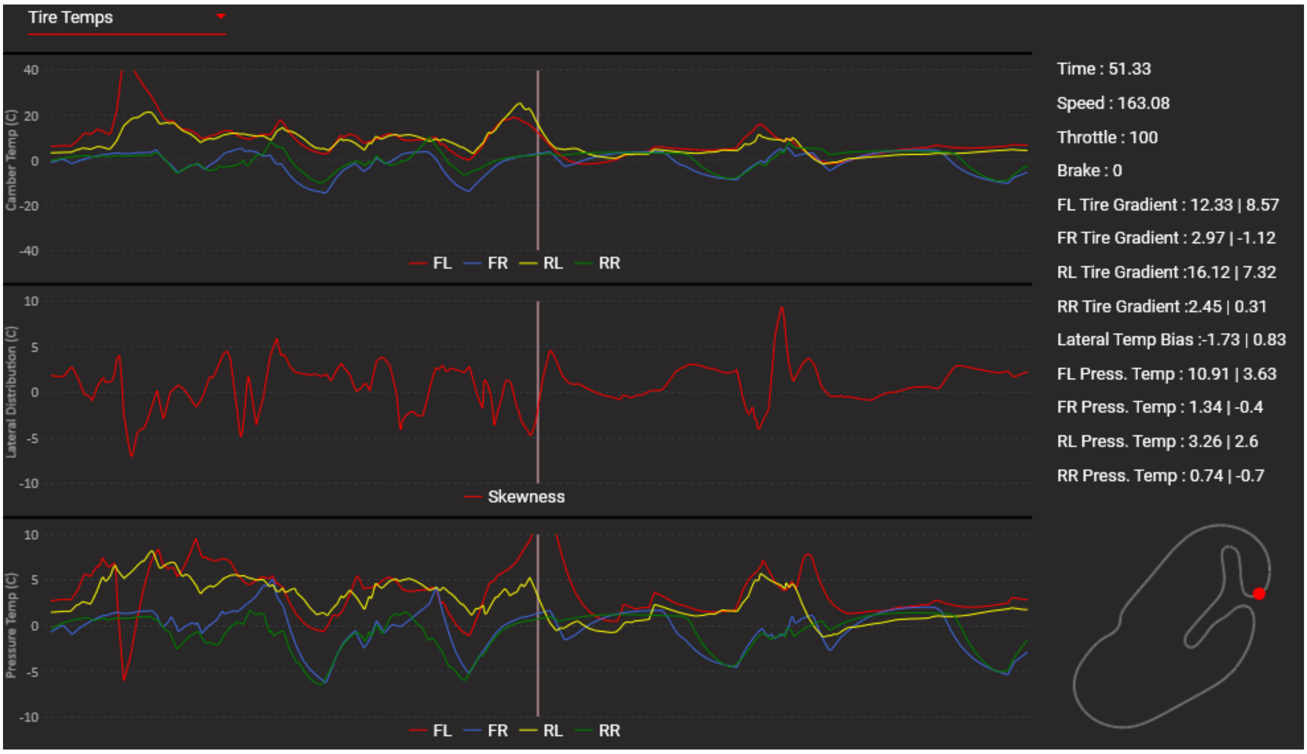

Figure 2.17: Tire (Surface) Temperature Graphs in iRacing

The temperature variance is much higher in iRacing's telemetry data because, unlike Project CARS 2, it's representing surface temperatures.

Tuning camber angles and tire pressures should preferable be done with the lap average values. They're displayed as the second number in the telemetry data table on the right side.

3. An Overview

This section will give a detailed overview on all the available tuning graphs and tools and how to interpret them.

3.1. Time vs. Distance Charts

For most graphs available in the RST Software you can choose to plot them either against distance or time. Most of the time you'll want them to be drawn in Distance Mode because the driven distance will be reasonably constant over all laps even if lap times vary significantly. This way it's easier to compare specific sections between laps to analyze braking points or driving lines for example.

Distance Mode generally expands high-speed sections and compresses low-speed sections while Time Mode is doing the opposite (see image below).

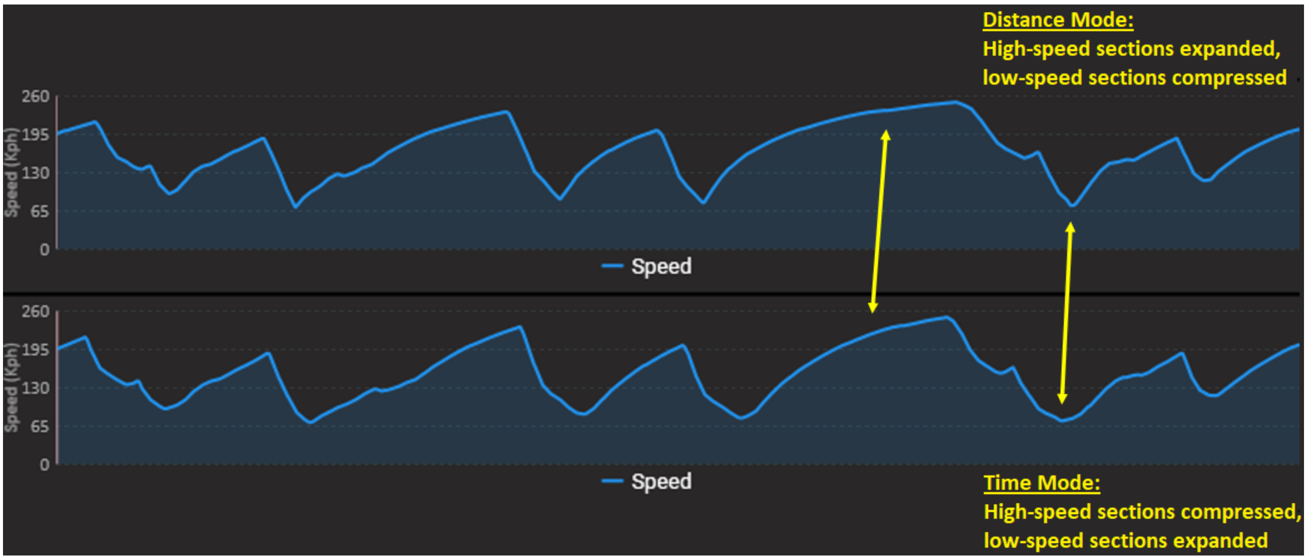

Figure 3.1: Speed Trace in Distance Mode (top) and Time Mode (bottom)

Time Mode is mainly used to judge the duration of specific events like coasting times or throttle and brake application speeds.

Note: When overlaying telemetry data of two laps in the Driver tab, you need to select **Distance Mode**. Using Time Mode will create an offset in the charts, caused by the lap time delta, making it impossible to compare the data in a meaningful way.

3.2. The Speed Trace

When making yourself familiar with the app, you'll notice that the Speed Trace appears multiple times, as shown in the image below:

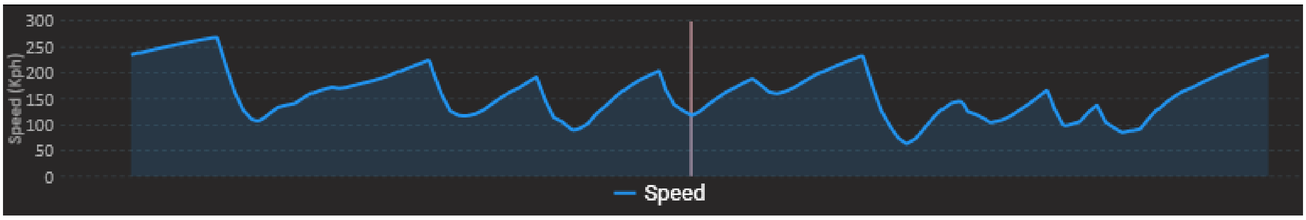

Figure 3.2: Speed Trace; The Most Important Reference Graph

The reason for this is that it serves as a reference graph most of the time to evaluate vehicle performance and to validate that your setup adjustments actually improved it.

The Speed Trace is the easiest chart to navigate on the track because it directly reflects the track profile. Once you're familiar with it, you'll find that finding a specific track location in this graph will be just as easy as looking at a track map:

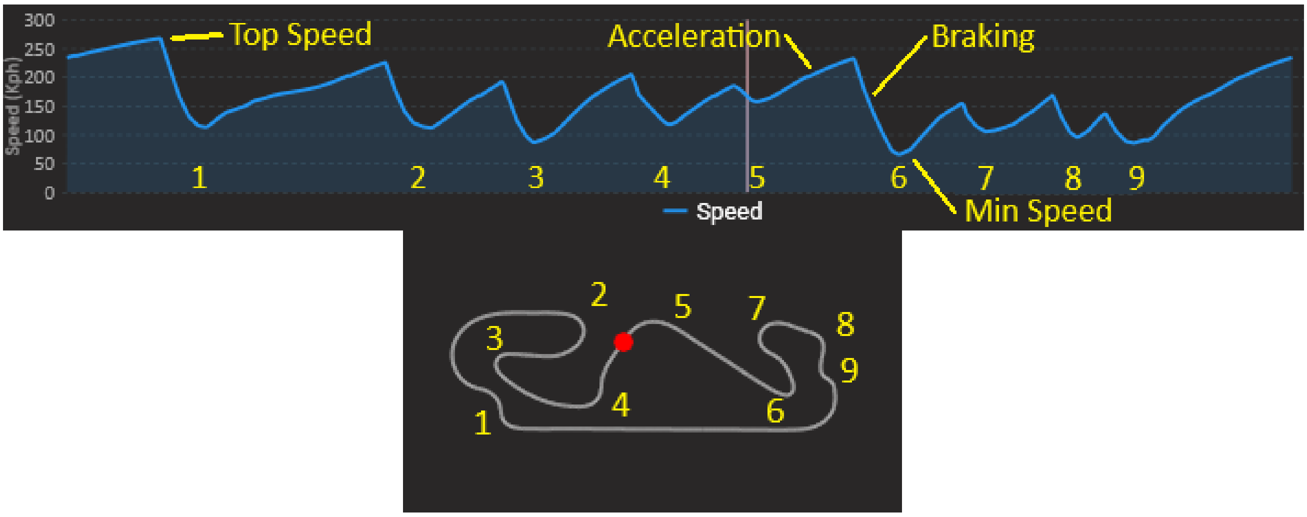

Figure 3.3: Speed Trace Reflecting Track Profile

The Speed Trace is by far the most important chart to analyze, because no matter how much effort you put into tuning and how many components you optimize, in the end it's all about maximizing vehicle speed to improve your lap times.

3.3. Handling

The Handling tab should be your first place to visit during telemetry analysis. It'll tell you everything regarding your car's general driving behavior (wheel slip, brake balance, differential behavior, basic car balance through wheel loads, etc.). Use it to confirm your "feel" of the car on track and to analyze basic handling affecting parameters.

3.3.1. Component Wheel Loads

The Component Wheel Loads screen displays the vertical load on your tires and every suspension element's (springs, ARBs and dampers) contribution to it. The car's weight is already subtracted in the wheel load calculation, so what you'll see in this screen are exclusively dynamic load components:

Figure 3.4: Component Wheel Loads

The wheel loads are defined as: Positive → Bump / Compression

Negative → Rebound / Extension

Component wheel loads are extremely useful to analyze multiple conditions:

1) Longitudinal weight transfer
2) Lateral weight transfer
3) Aerodynamic forces
4) Bumps and road surface irregularities
5) Banking effects

Longitudinal and Lateral Weight Transfer

With the wheels loads the effects of longitudinal and lateral weight transfer can be quantified easily. Let's analyze a cornering sequence for example (Turn 1 + 2 at Circuit de Catalunya):

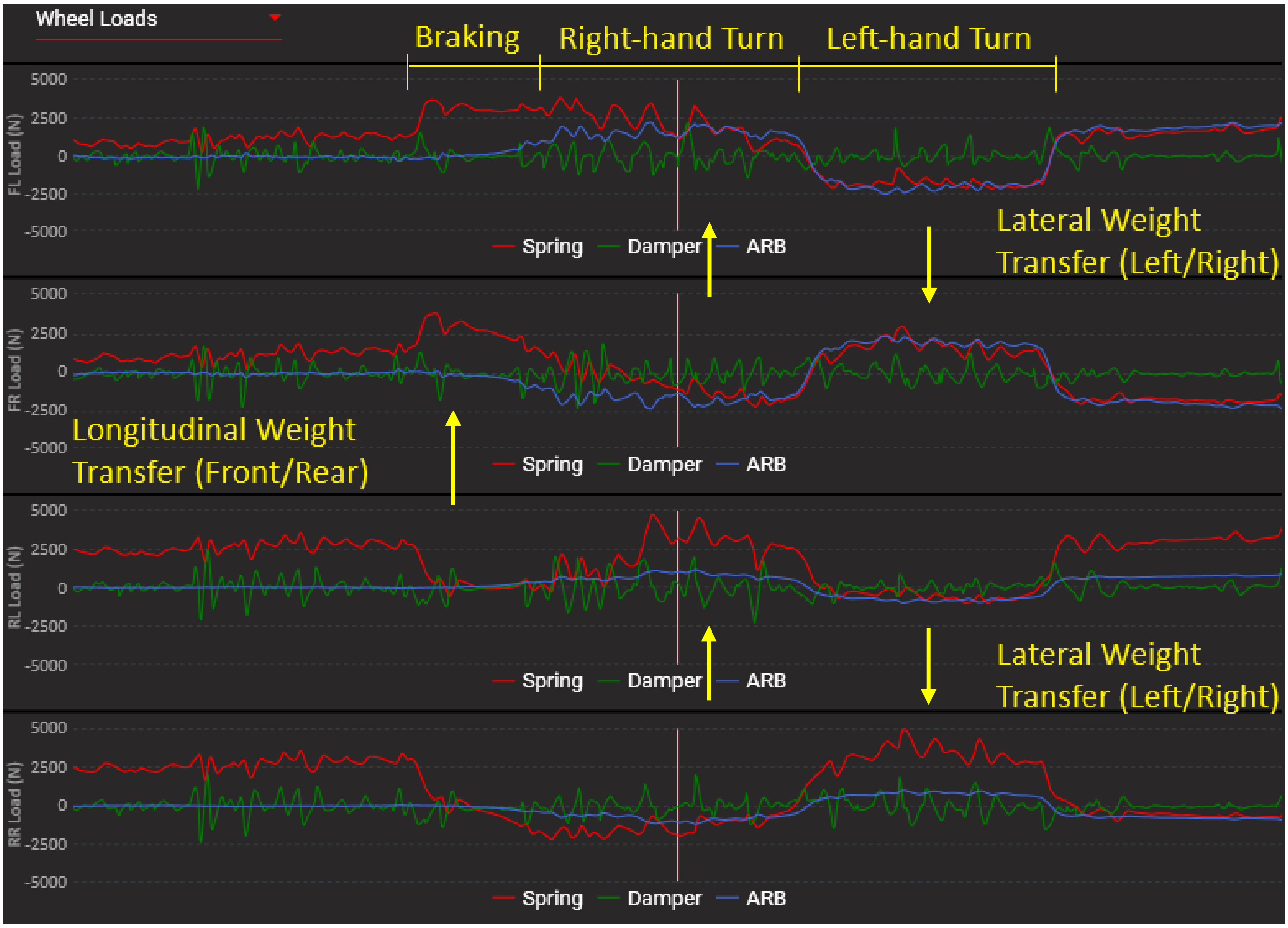

Figure 3.5: Longitudinal and Lateral Weight Transfer through Cornering Sequence

Braking:	In the braking zone load is shifted from the rear to the front wheels (longitudinal weight transfer). You can clearly see how the front wheel load increases while the rear wheels are unloaded. The ARBs are not contributing in this section because they're only activated during lateral load transfer. Damper forces are only existent during initial weight shift when the suspension is moving (transient).
Right-hand turn:	During turning load is shifted from right to left (lateral weight transfer). The ARBs are activated to limit the amount of body roll. There's no real steady state condition visible because the driver is braking into the corner, right until the apex. That's why there are damper forces acting.
Left-hand turn:	Now going from turn 1 into the right-hand turn 2, weight is transferred quickly from left to right (lateral weight transfer). Once again, the ARBs are in full effect to limit body roll. Damper forces are much lower because they're only caused by road surface irregularities during steady state cornering.

The Impact of Dampers on Load Transfer

Dampers aren't just there to keep your suspension from oscillating and minimize contact patch load variation. They're also powerful tools to adjust weight transfer rate in transient conditions.

For educational purposes (better visibility) the damper forces in the image below have been scaled up:

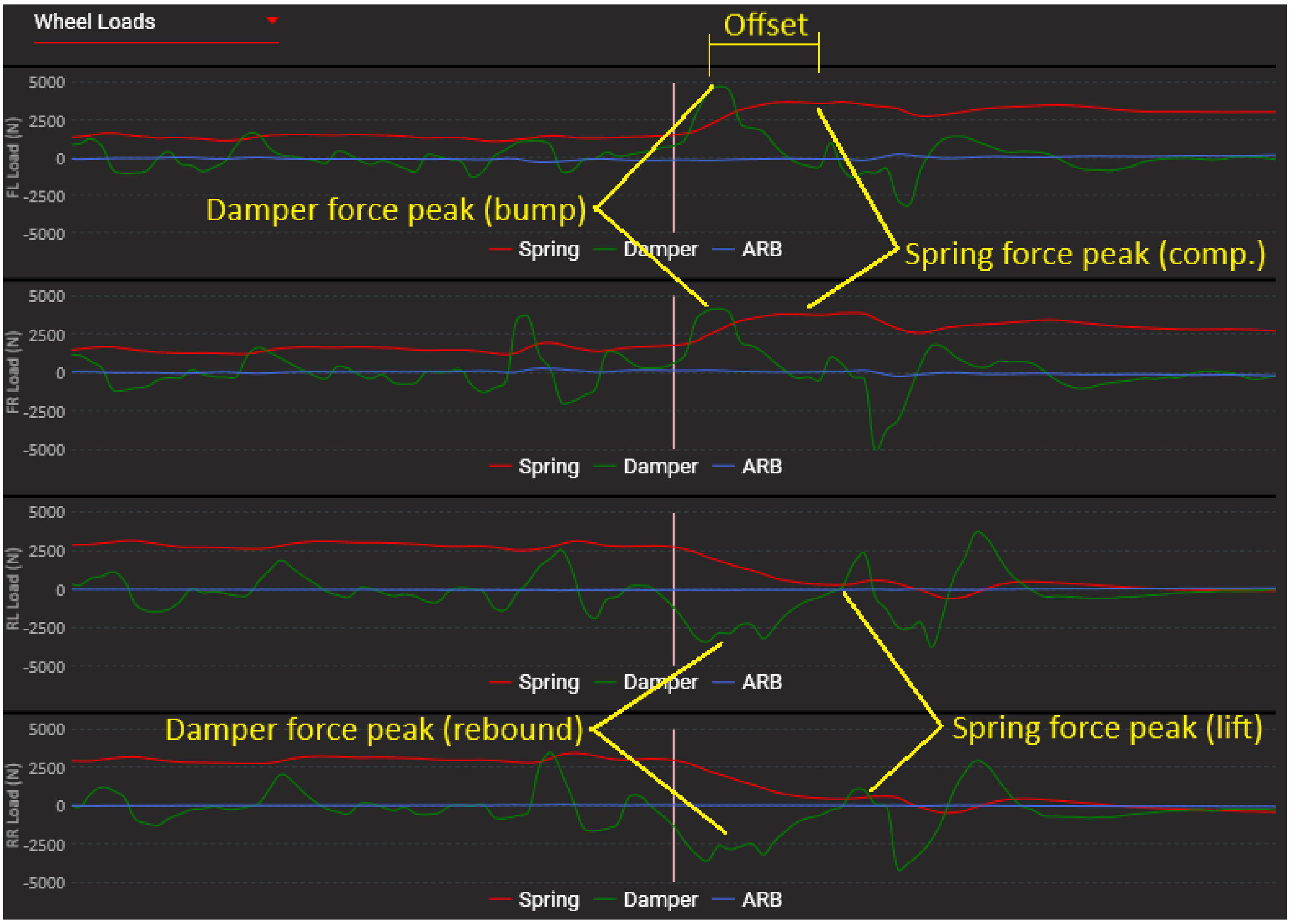

Figure 3.6: Spring and Damper Force Change in Transient Conditions

You can see there's a time offset between damper and spring peak forces.
While springs are reaching their peak force at maximum compression, the damper force peak happens at the highest suspension velocity.

Since the latter is reached earlier, weight transfer happens more instantaneously with a higher damping rate.

Use this knowledge to fine tuning car handling in transient conditions by deliberately loading (bump) or unloading (rebound) your tires.

Aero loads

While separate tools, dedicated specifically to aero tuning, are available in the app, you should be aware of the aerodynamics' effect on wheel loads.

Figure 3.7: Wheel Loads caused by Aerodynamics

Even though the vehicle in the above example is driving in a straight line, you can clearly see a dynamic vertical load on all wheels, caused by the car's aerodynamics.

There are two effects that you can observe here:

1) Aero loads are increasing with vehicle speed.
2) Aero loads are higher at the rear wheels. From this we can conclude that the center of pressure (aero balance) is located at the rear half of your car.

For more info on aero tuning, please check out chapter 3.6.

Bumps and Track Surface Irregularities

The constant, minor variations in wheel loads are a result of small surface irregularities, while larger ones are caused by bumps that can be easily detected, as shown in the image below:

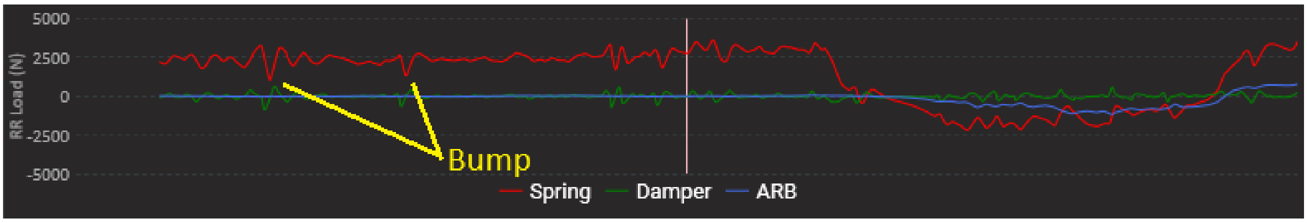

Figure 3.8: Recognizing Bumps in Wheel Load Graph

You can recognize those larger bumps by a variation in spring force and more importantly, by significant damper force peaks (high suspension velocity).

If the track is extremely bumpy and you're having traction issues because of this, you should soften your springs and adjust your high-speed damping rates.

Let's zoom into one bump and observe the forces acting on a front and rear wheel. Damper forces in the image below have been scaled up again for better visibility:

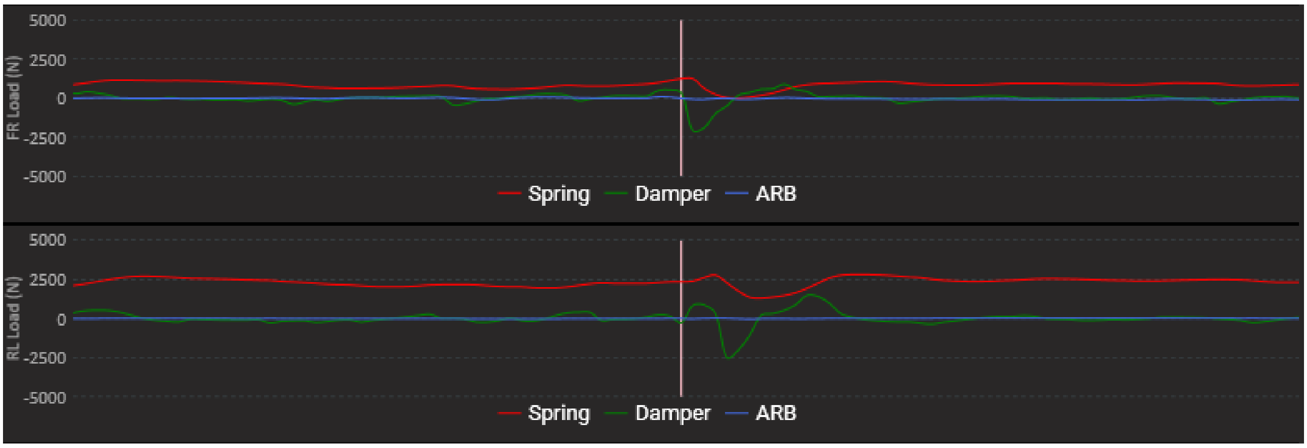

Figure 3.9: Damper / Spring Force Peak Offset and Front / Rear Axle Offset

There are two things of note here:

1) The damper force peaks earlier than the spring force, which has already been discussed in Figure 3.6.

2) The forces are peaking earlier at the front wheel, which is quite logical because the front is ahead rear axle and hits the bump first.

Wheels Loads on Banked Corners

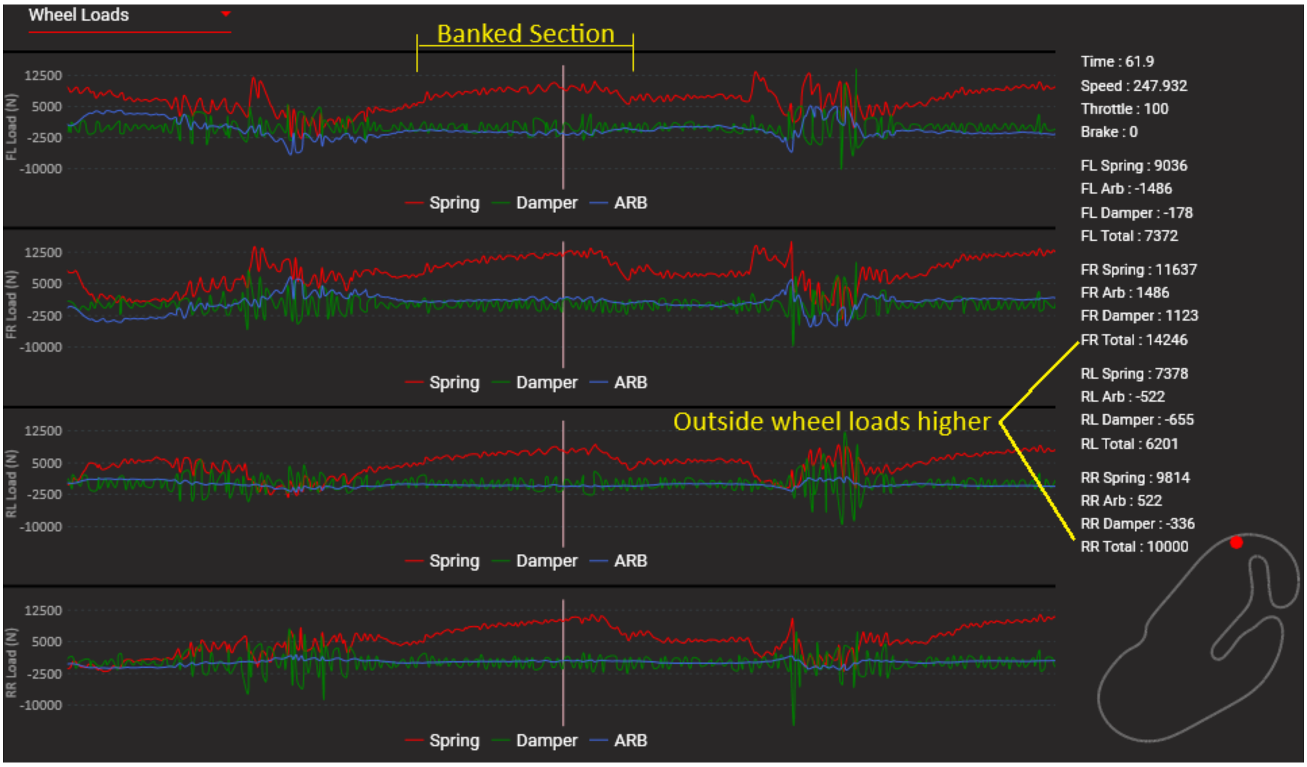

Figure 3.10: Wheel Loads in Banked Corners

Driving through banked corners results in increased vertical loads on all four tires, as shown in the image above.

Since wheel loads are usually the highest in those sections, you should set up your suspension and aero with this in mind.

You can also see that the outside wheel loads are higher than the inside ones. Obviously, an asymmetric suspension setup (different ride heights, spring and damper rates for left and right side) should be used to optimize performance in those high-speed sections.

3.3.2. Wheel Loads

The Total Wheel Loads charts represent the forces of all suspension components (springs, ARBs and dampers) acting on the car's wheels.

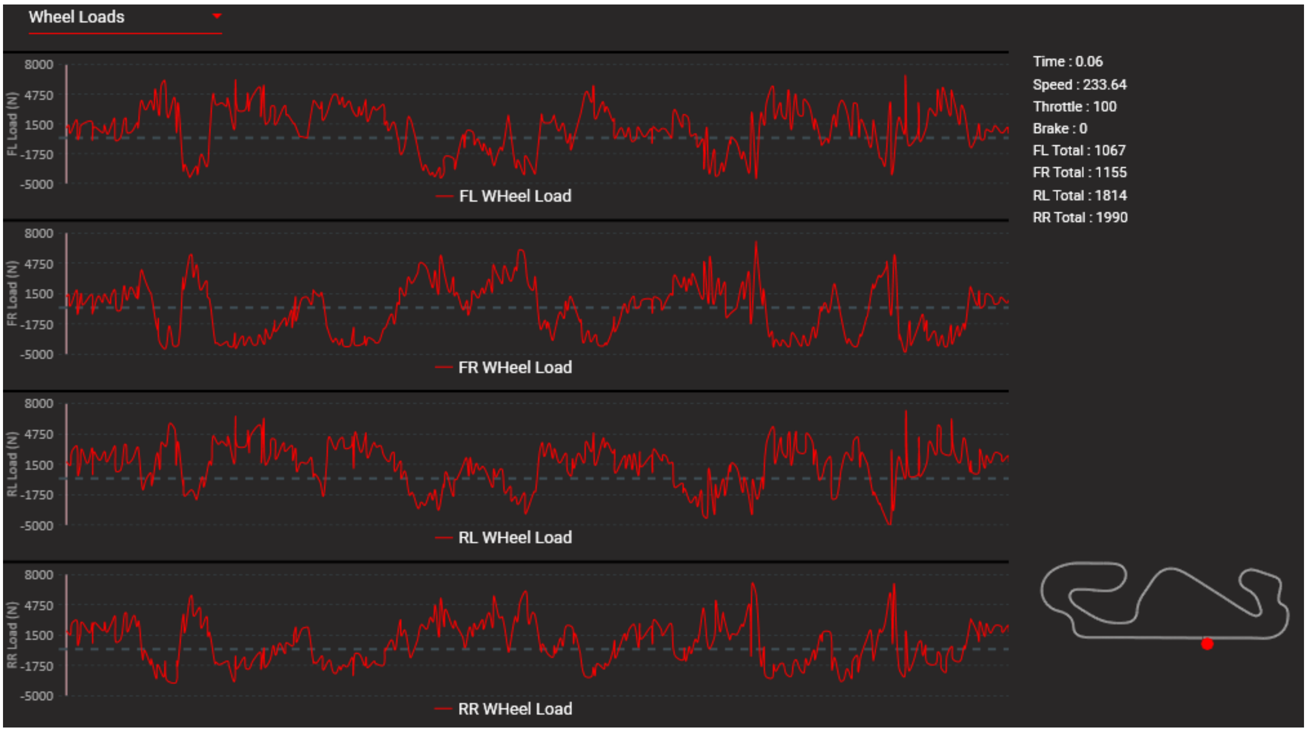

Figure 3.11: The Total Wheel Loads Chart

The wheel loads are defined as:	Positive	→	Bump / Compression
	Negative	→	Rebound / Extension

Like the component wheel loads, the total wheel loads are extremely useful to analyze multiple conditions:

1) Total longitudinal weight transfer
2) Total lateral weight transfer
3) Aerodynamic forces
4) Bumps and road surface irregularities
5) Banking effects

Please refer to chapter 3.3.1 to learn how to interpret the data for those conditions.

On top of that, total wheel loads are especially useful to judge the amount of damping of the car's suspension, by analyzing the "noise" (variance) in the wheel forces. This is crucial for high downforce cars, since a too low damping rate can lead to an unstable aero platform.

Check out the images below showing too low and sufficient damping:

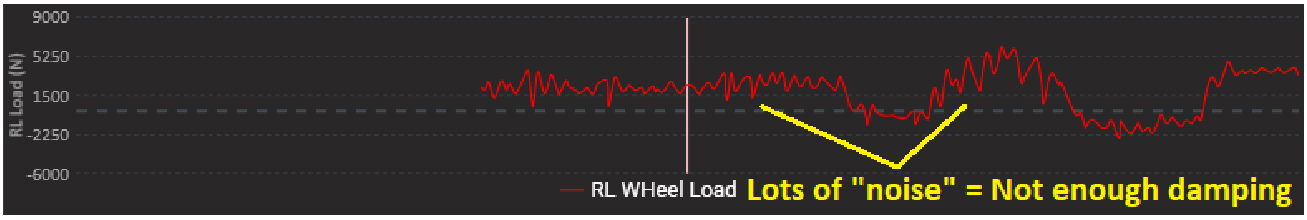

Figure 3.12: Wheel Load Variation in an Underdamped Suspension

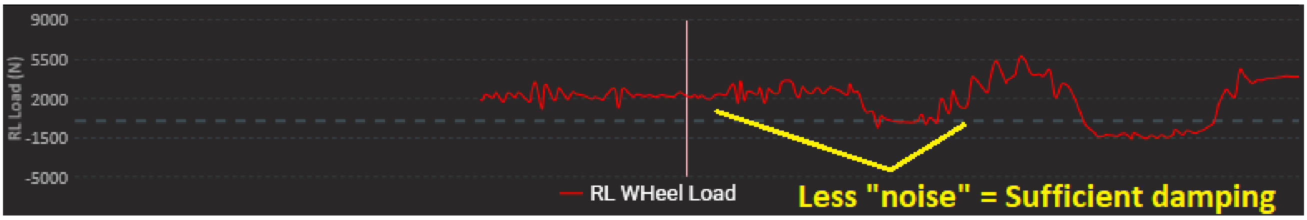

Figure 3.13: Wheel Load Variation in a Sufficiently Damped Suspension

3.3.3. Differential

Figure 3.14: The Differential Screen

The Differential screen's main functions are (you guessed it) differential tuning and brake balance adjustments. Its main features are graphs for throttle and brake input, front and rear wheel slip, wheel slip difference of the driven wheels, a channel data table that shows the values at the current cursor position and a track map for reference.

<u>The Input Graph</u>

This one mainly serves as a reference graph for you and shows your current throttle and brake application.

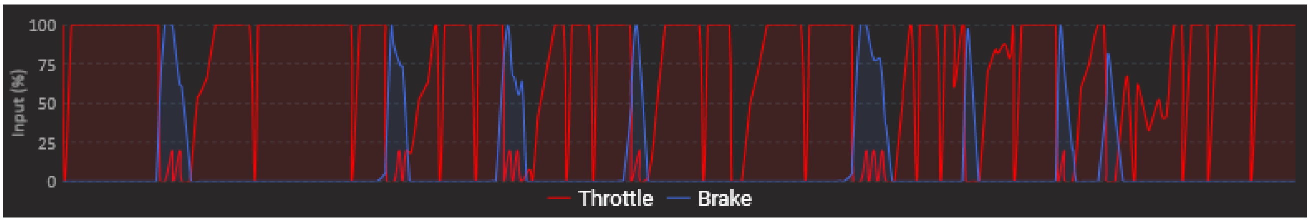

Figure 3.15 Input Graph

You should use it as reference for differential tuning to find out if the diff is unlocking under acceleration (power ramp), coasting (coast ramp) or neutral throttle (preload).

The Wheel Slip Graphs

With the Front and Rear Wheel Slip Graphs you can analyze the traction of your car and how your brake balance and differential settings affect it. As a general guideline you should know that most tires get the best grip at 7-15% of slip.

Figure 3.16: Front and Rear Wheel Slip Graphs

A negative wheel slip % value represents a wheel slipping from traction (acceleration) while a positive value means it's slipping from braking force.

These graphs are the main tool for brake pressure and balance tuning.

The Wheel Slip Diff. Graph

The Wheel Slip Diff. Graph is a math channel that represents the slip difference between your driven wheels, depending on the car used in that session.

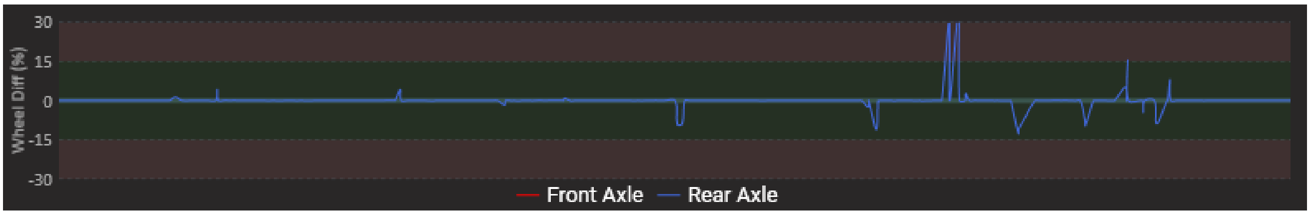

Figure 3.17: Wheel Slip Diff. Graph

It serves as an indicator for your differential's current status. If the line sits on the 0 node your differential is locked. As soon as it unlocks (allowing limited slip) you'll see upward or downward spikes, depending on which wheel is slipping and if it is during braking or under acceleration.

The Wheel Diff % values are defined as:	Positive	→	Left wheel spinning (accel.)
		or	Right wheel lock up (braking)
	Negative	→	Right wheel spinning (accel.)
		or	Left wheel lock up (braking)

Use this graph for differential tuning.

Brake Balance Analysis

For optimal brake balance you'll want all four tires to start slipping at the same time and by approximately the same amount. Otherwise your car will understeer (forward brake bias) or spin out (rear brake bias) when you're trail braking.

Unless you're exclusively braking in a straight line you should only focus on the outside front wheel when comparing wheel slip between the front and rear axle. Since the inside wheel is unloaded on corner entry it will naturally lock up a bit more than all other wheels and will therefore skew your results. Unless it's completely locking up, this is a non-issue and can be mostly ignored.

In Figure 3.18 you can see how forward; balanced and rear brake bias will typically look on the Wheel Slip % graphs:

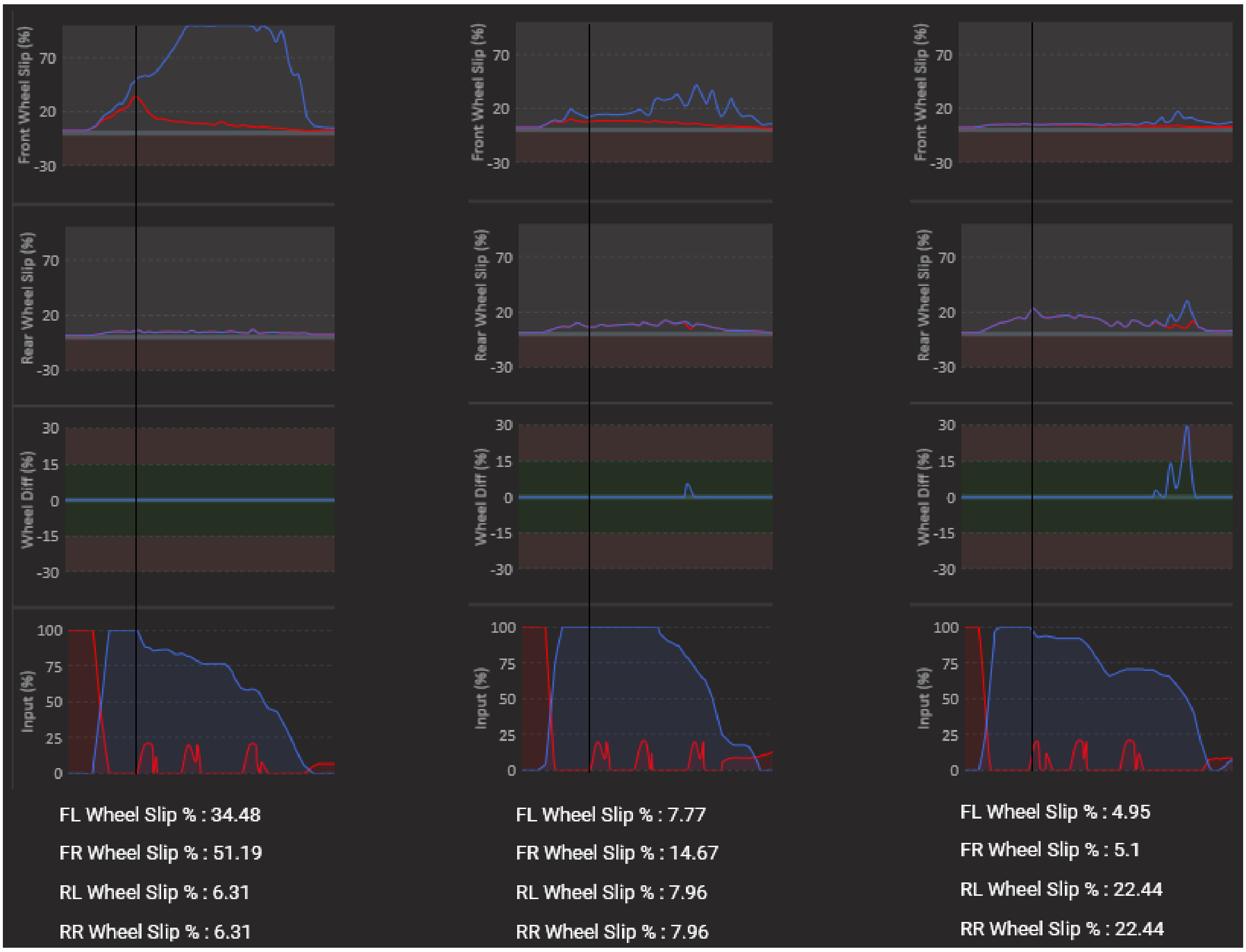

Figure 3.18: Forward (left), balanced (middle) and rear (right) brake bias

In this example we're braking into a right-hand corner and should mainly focus on the left front and the rear wheels.

Forward Brake Bias:	You can see how the front wheel slip is much higher than the rear one, causing severe understeer on turn in. The slip on the outside front wheel is multiple times higher than on the rear ones (34.48% : 6.31%) and the (unloaded) inside front wheel locks up completely, even after easing up the# brake pedal. The period of 100% brake force is very short because the driver tries to avoid front wheel, resulting in increased braking distance. If your graph looks like this, you might want to move your brake bias backwards.
Balanced Brake Bias:	This is how neutral brake balance will look like. The amount of wheel slip is similar on both axles (again, ignoring the unloaded inside front wheel). As a result, the 100% brake force period is comparatively long, minimizing your brake distance and coasting period.
Rear Brake Bias:	In the last image the amount of slip on the rear wheels is much higher than at the front (4.95% : 22.44%) and lots of brake pedal modulation can be seen in the Input graph because the driver tries to avoid spinning out by rear wheel lock up. If your graph looks like this, move the brake balance forward.
Brake Pressure:	If your Wheel Slip % graph is showing a balanced brake bias but the brakes are still locking up easily (wheel slip % too high on all 4 wheels and/or brake pedal modulation can be seen in the Input graph), you should reduce the overall brake pressure.

Differential Locking Analysis

When tuning your differential, you have to check the Wheel Slip Diff. Graph.

If the line sits on the 0 node your differential is locked. As soon as it unlocks (allowing limited slip) you'll see upward or downward spikes, depending on which wheel is slipping and if it is during braking or under acceleration. Check out the two images below to see the difference in wheel slip of a differential with low and high locking effect:

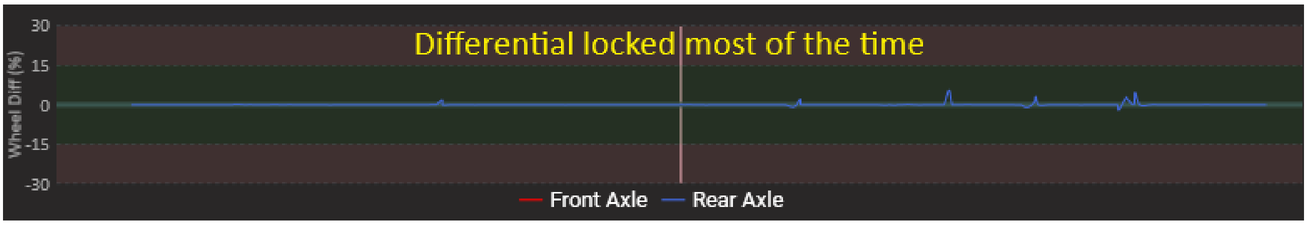

Figure 3.19: Wheel Slip Diff. Graph of a Differential with High Locking Effect

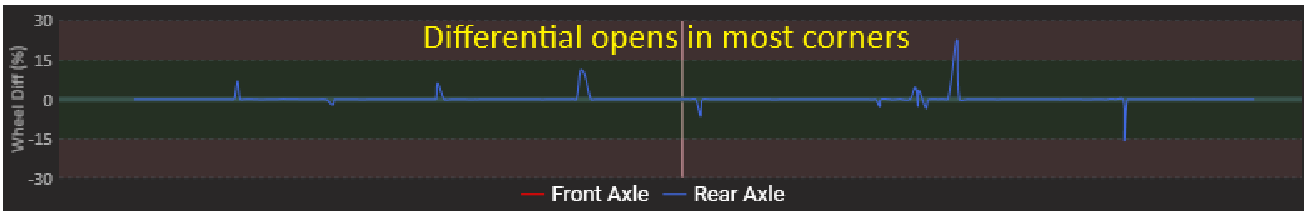

Figure 3.20: Wheel Slip Diff. Graph of a Differential with Low Locking Effect

There are multiple tools you can use to adjust your differential's locking behavior.

Power Ramps

On power you'd want enough locking effect (lower ramp angle) to get as much power down as possible but not too much so that you'll get snap oversteer and overheated rear tires.

Power Ramp too high: A high power ramp angle equals a low locking effect (0% at 90° ramp angle). While this setting is very stable, it also means you'll lose forward drive as soon as one wheel starts to slip. Since torque is more evenly distributed in a fairly open differential, the outside wheel torque is limited by what the inside wheel can receive. This will hurt your acceleration and is therefore not desirable.

Power Ramp optimal: With an optimal power ramp angle your inside wheel won't spin as easily and when it does, the outside wheel will still receive more torque (higher slip %) than with a fully open differential. That's the balance you want to achieve, enough stability and wheel torque.

Power Ramp too low: With a too low power ramp your differential will always stay locked. And while this helps bringing the power down (higher overall wheel torque) it'd also lead to snap oversteer because too much torque is transferred from the inside to the outside wheel, overloading it. This can let you suddenly spin out under hard acceleration.

It is important to know that this is only true for high torque situations (hard acceleration). Under light acceleration (low torque) a higher locking effect will lead to understeering because the locked driven wheels will create a yaw torque that acts contrary to your steering inputs. While this may be a rare situation for acceleration, it's important to understand it because it explains the behavior of your car during coasting.

The following two images show the difference between high and low power ramp angles:

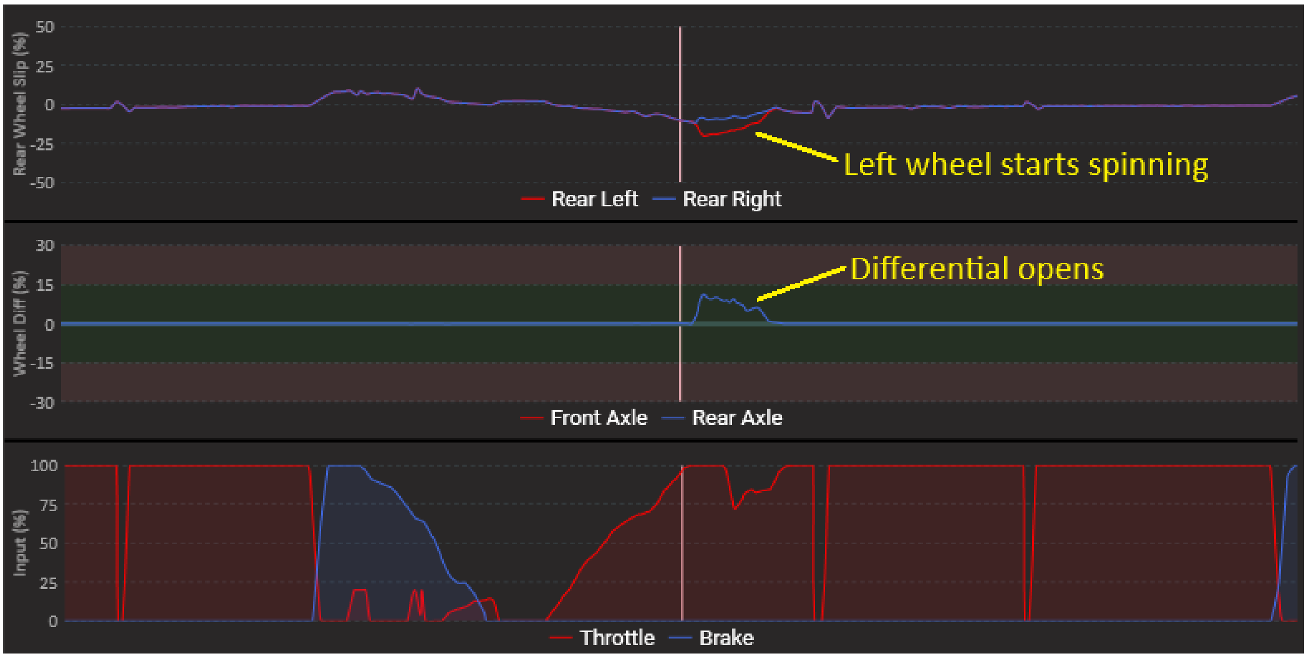

Figure 3.21: High Power Ramp Angle (Low Locking Effect)

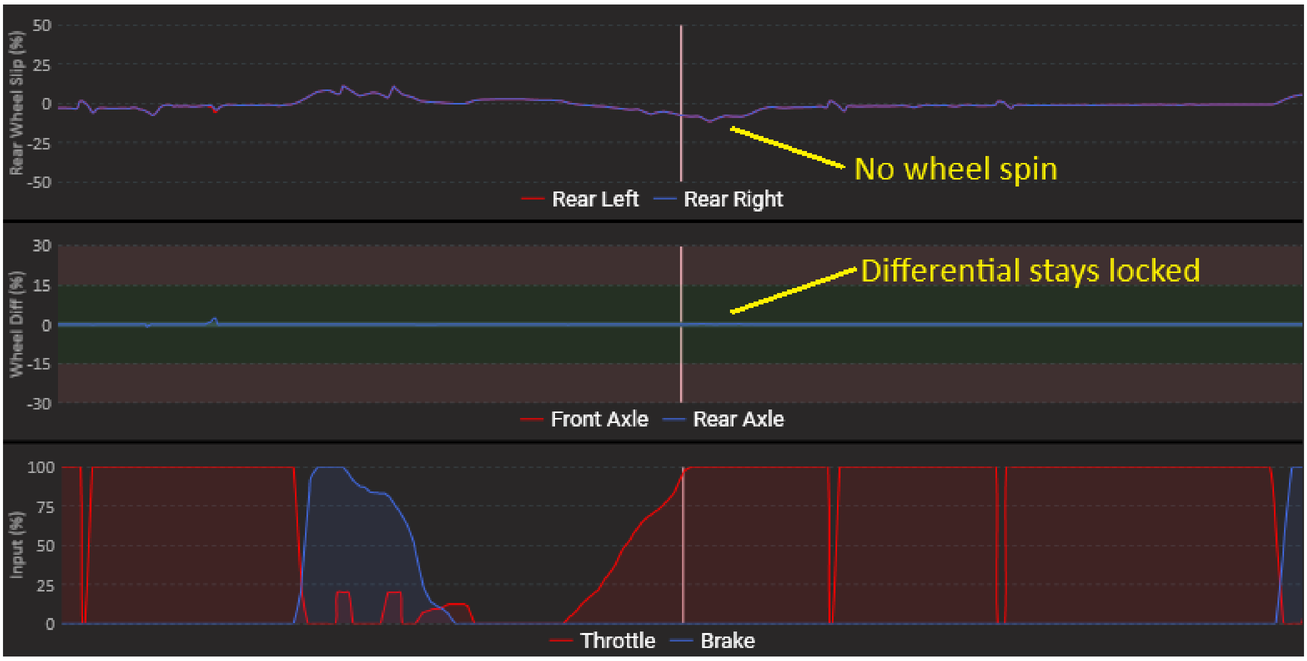

Figure 3.22: Low Power Ramp Angle (High Locking Effect)

Coast Ramps

Since coasting is a "low torque situation" the results of your coast ramp angle setting are different to what is happening under power (as already explained above).

During coasting you'd want an as high as possible ramp angle (low locking effect) to let the car easily rotate into the corner. But you don't want to set it too high to avoid your car becoming too "tail happy" and spin out on corner entry.

Coast Ramp too high:	With a high coast ramp angle and therefore low locking effect (0% at 90° ramp angle, the differential will open too earlier which could let you spin out on corner entry. If you're having trouble with lift off oversteer you might want to lower the coast ramp angle.
Coast Ramp optimal:	With this setting, your diff will only unlock at higher torque differences (tight corners) while it will stay locked and keep your car stable in not so tight turns. That's the balanced corner entry behavior you want to achieve.
Coast Ramp too low:	With a very low coast ramp angle your differential will stay locked in all situations. This will lead to understeering on corner entry which will slow you down significantly.

Again, let's compare two graphs which show the effect high and low coast ramp angles:

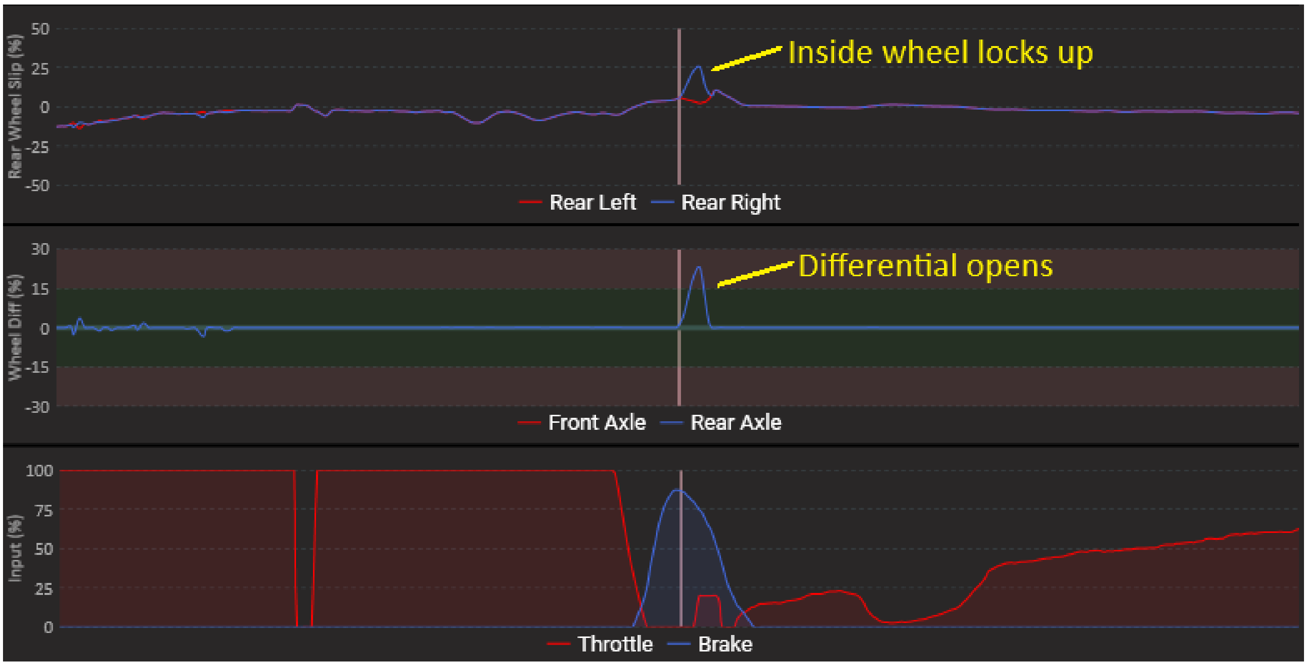

Figure 3.23: High Coast Ramp Angle (Low Locking Effect)

Figure 3.24: Low Coast Ramp Angle (High Locking Effect)

<u>Preload</u>

Preload is the value of the differential that acts as a threshold. If you're cornering and the torque received by the differential is below the preload the differential will remain locked. If the differential exceeds the preload values the differential will then use the combination of clutches and ramp angles you set to determine the amount of locking.

Since the amount of preload (unlike the locking effect from ramp angles) is <u>torque independent</u>, it's your main dial in close to zero torque situations (transition from coasting to acceleration).

Preload too low:	With a low preload the car won't transition very well from coasting to acceleration and feel "lazy".
Preload optimal:	With an optimal amount of preload the car will feel agile and coast acceleration transition will happen smoothly.
Preload too high:	The car can feel nervous when transitioning from coasting to accelerating.

Theoretical Background

To tune your LSD effectively you need to (at least partly) understand how it works. This is what a typical Salisbury Differential looks on the inside:

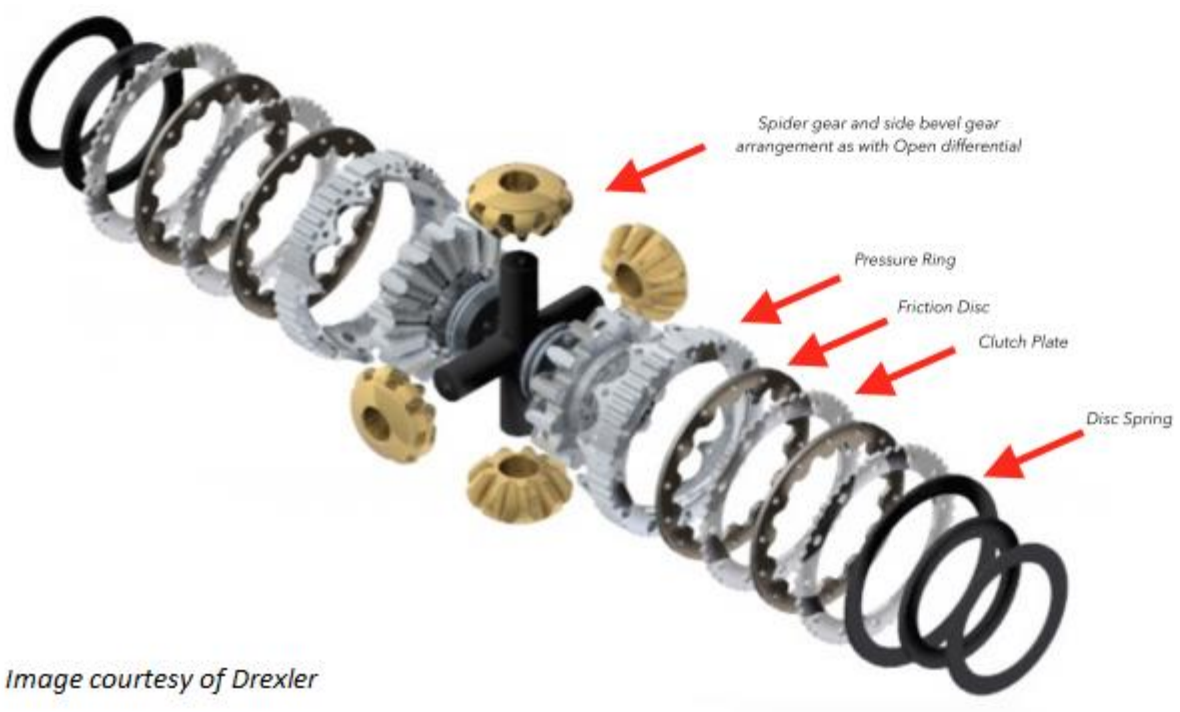

Figure 3.25: Exploded Drawing of a Limited Slip Differential

In simple terms, the LSD uses the friction of the clutches to lock the inside with the outside wheel when torque is applied. It's used to **control the torque distribution between the wheels** to get the desired car behavior during coasting and acceleration.

You can adjust the locking characteristics of the differential with three different factors:

Preload

You can imagine preload like a spring that is located between the left side and the right-side pressure rings. This spring pushes the pressure rings against the clutches (positive preload) or pulls the rings away from them (negative preload). It is used to add a small, constant amount of locking (or add a delay to the locking effect when it's negative), even when no torque is applied.

When the torque difference between outside and inside wheel is less than the preload, the differential will remain locked. When the torque difference of the wheels exceeds the preload, the differential starts to allow slip, and that is when your settings will come into play.

Clutches

They increase the locking effect "gained" by the ramp angles. Adding more clutches simply multiplies the overall settings without altering the power or coast ramp angles.

Power and Coast Ramp Angles

When acceleration or coasting, the spider axle is wedged into the ramps located on the pressure rings. The lateral component of the resultant force is then pushing the rings outwards, compressing the clutch plates. The higher the applied torque is the larger friction on the clutch plates becomes.

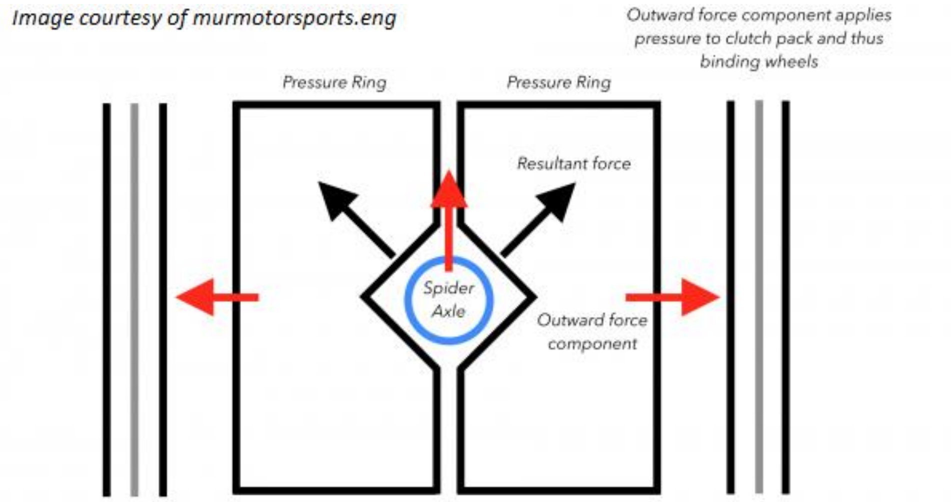

Figure 3.26: Working Principle of a Limited Slip Differential

As shown in the following image, different angle combinations on those ramps determine the amount of locking force applied to the clutches upon acceleration and deceleration:

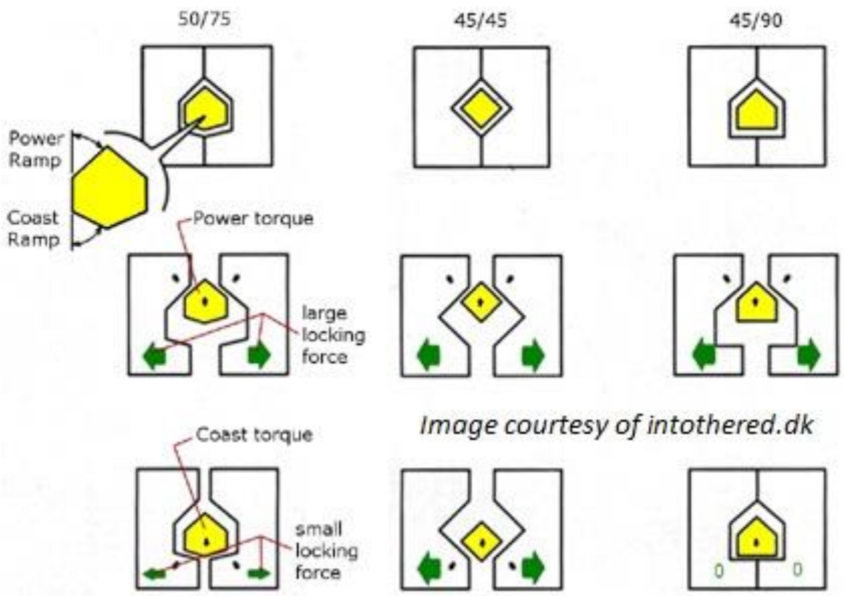

Figure 3.27: Ramp Angles Explained

You can see that lower ramp angles will increase the lateral (outward) component of the resultant force and therefore increase the locking effect of the LSD.

Impact of the Limited Slip Differential during cornering

Corner Entry

Use the highest coast ramp angle (lowest locking effect) possible such that the car turns in without resistance but still doesn't induce oversteering. If your ramp angle is too low the car will not turn in quick enough because of the high locking effect of the LSD.

Mid Corner / Apex

In this neutral throttle condition, the Preload will affect the balance of the car when cornering and affect the smoothness of transition from off-throttle to on-throttle.

If the car doesn't respond well when transitioning from coasting to accelerating, you might want to increase preload.

If the car feels too nervous when transitioning from coasting to accelerating, you should decrease preload.

Corner Exit

For good acceleration on corner exit you want to find the lowest possible power ramp angle (highest possible locking effect) possible to get as much torque on the wheels as possible. However, a too low power ramp angle will result in power oversteer because too much torque is transferred to the outside wheel.
A too high power ramp angle on the other hand will limit the possible acceleration because of not enough torque being transferred from the spinning inside wheel to the outside one with more grip.

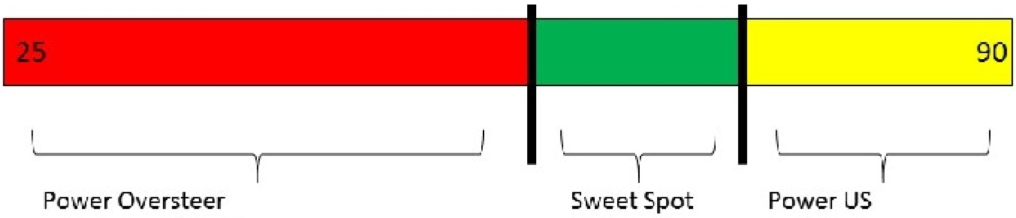

Figure 3.28: Optimal Locking Effect

Recommended Locking Ratios

Depending on general car balance and driver preference the following lock ratios are recommended as a good starting point:

Power Lock: 10 – 30%

Coast Lock: 70 – 90%

To quickly set your desired locking ratios, please refer to the chart below:

	Acceleration / Deceleration Locking Ratio				
	Clutches				
Power/Coast Ramp	2	4	6	8	10
20	44	88	132	176	220
25	34	69	103	137	172
30	28	55	83	111	139
35	23	46	69	91	114
40	19	38	57	76	95
45	16	32	48	64	80
50	13	27	40	54	67
55	11	22	34	45	56
60	9	18	28	37	46
65	7	15	22	30	37
70	6	12	17	23	29
75	4	9	13	17	21
80	3	6	8	11	14
85	1	3	4	6	7
90	0	0	0	0	0

Figure 3.29: Locking Ratio Calculation

3.3.4. Damper Speeds

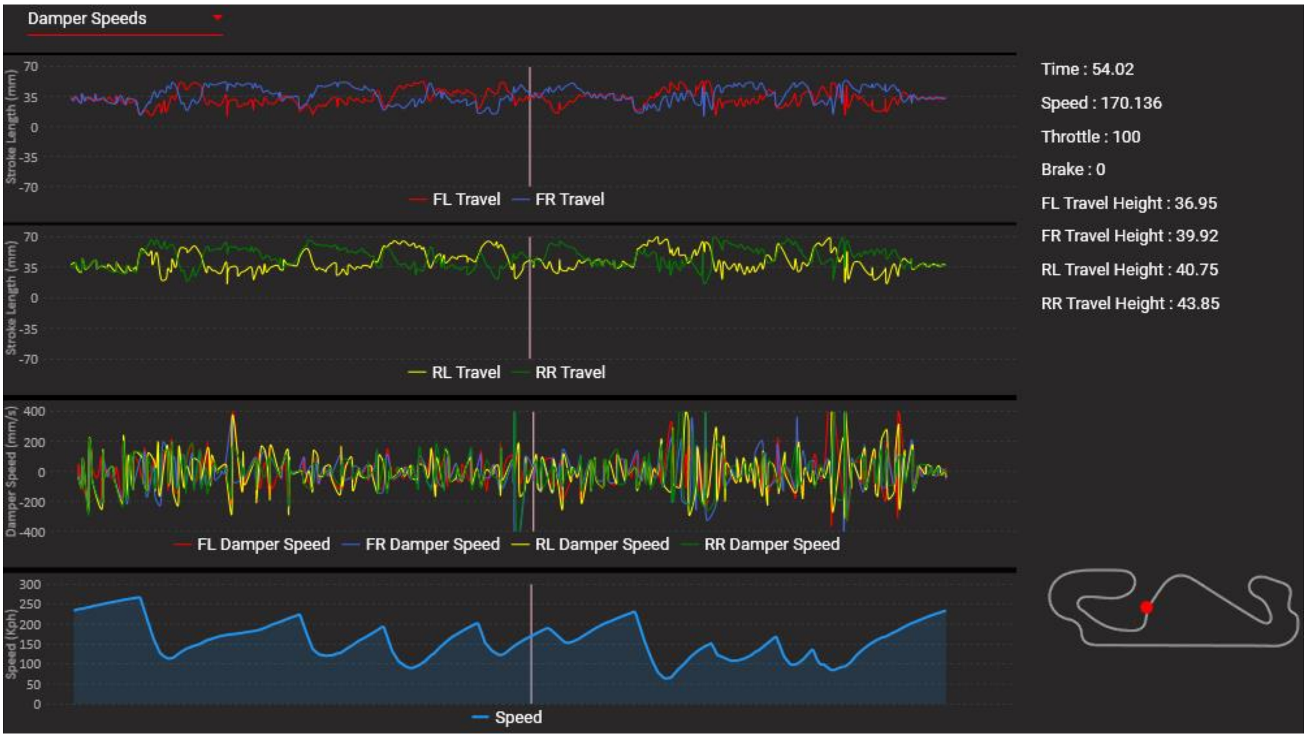

Figure 3.30: The Damper Speeds Tab

In this screen you can see the remaining travel and suspension velocities. Its main purpose is setting your bump stops and adjusting your dampers (especially transition speeds) with respect to track smoothness and driving line / style.

<u>Stroke Length / Travel</u>

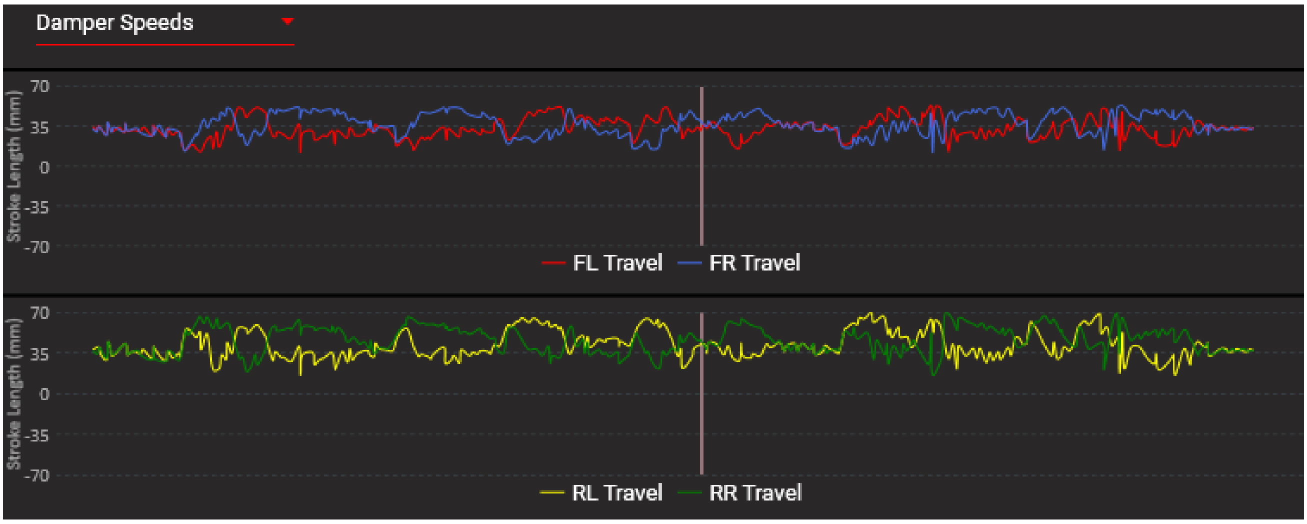

Figure 3.31: Stroke Length / Travel

The Stroke Length charts display the travel remaining before you hit the bump stops. Use them for bump stop and ride height (to a degree) tuning.

Damper Speed Graph

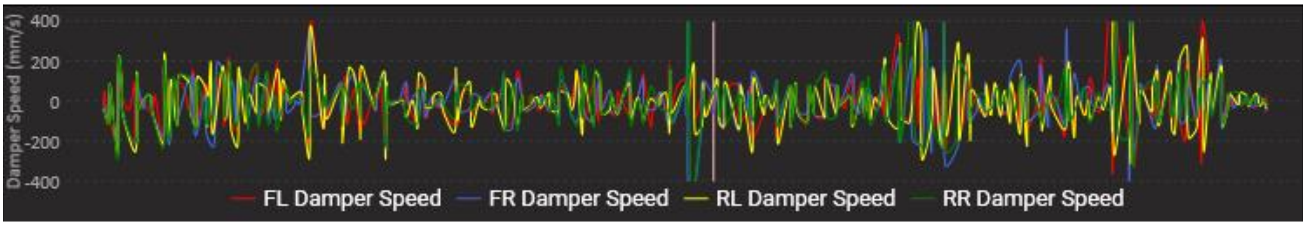

Figure 3.32: Damper Speed Graph

This graph displays the suspension velocities and can be used to recognize various track surface characteristics (surface irregularities or bumps) and suspension response to driver inputs like braking and cornering maneuvers or driving over curbs, as shown in the image below:

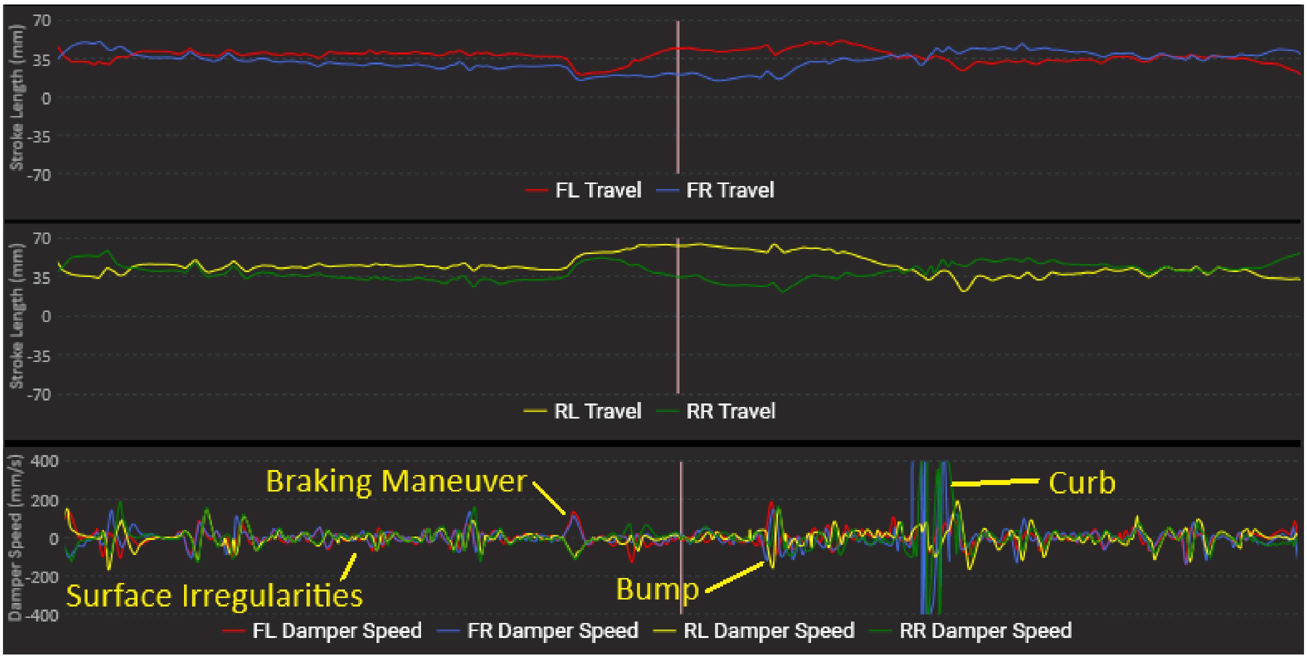

Figure 3.33: Interpreting Damper Velocities

3.4. Suspension

3.4.1. Damper Histograms

The Damper Histogram screen is a tool that allows you to dial in your damper/suspension settings. The purpose behind it is to ensure that for our circuit-car-driver combo we are dissipating equal amounts of energy in bump and rebound.

Quick Guide to Damper Histogram Analysis

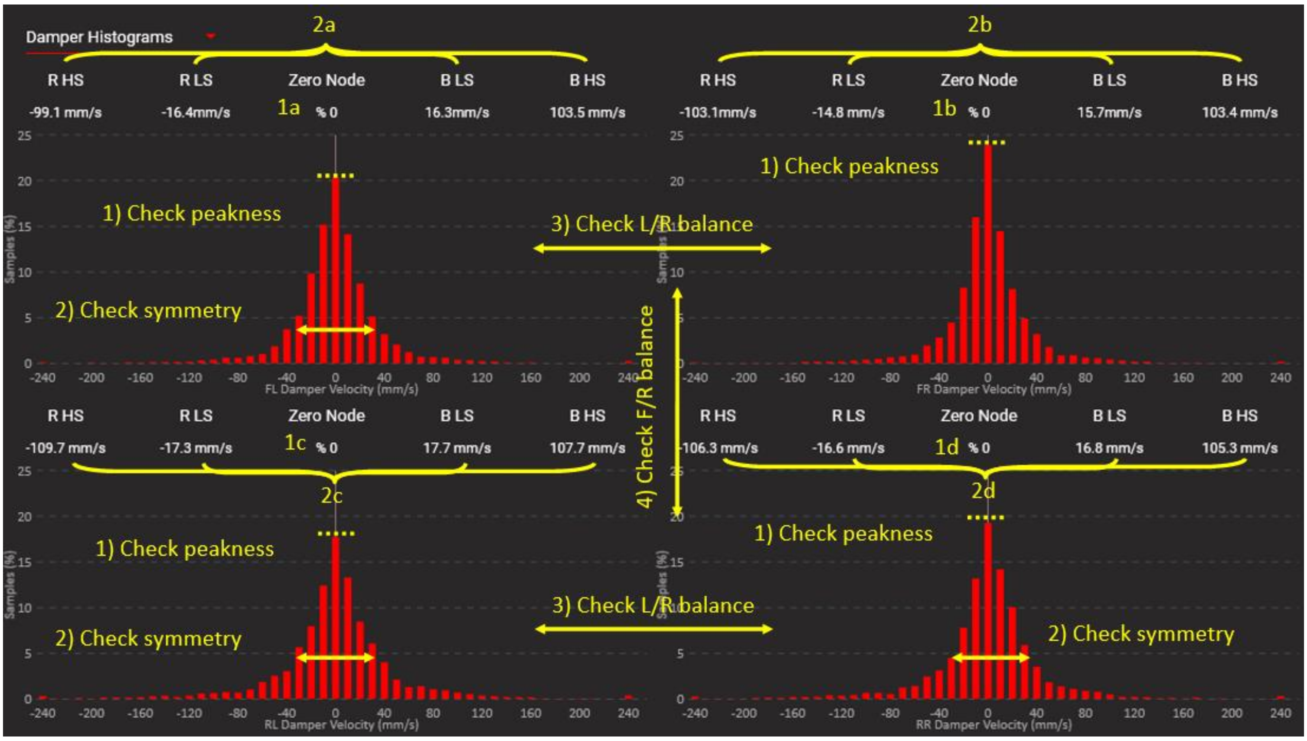

Figure 3.34: Damper Histogram Screen

1) Measure the peakness of each graph to estimate the amount of critical damping. Check the 0 bin % values in the data table. Adjust your damper settings to achieve the desired critical damping rate.
2) Look at each graph and its symmetry about the 0 node. Confirm your observations by comparing the average bump and rebound velocity numbers above the graph. **The lower the average velocity, the higher the damping rate.** Adjust your damper settings if the histogram is skewed to one side.
3) Analyze the balance between left and right wheels by comparing the histograms and the data table.
4) Analyze the balance between front and rear wheels by comparing the histograms and the data table.
5) Remember to re-check your Damper Histograms after every significant suspension setup change

Before diving into the theory behind damper histograms let's analyze the example from chapter 2.3 in more detail for a better understanding of what's happening when damper adjustments are made.

The image below shows the histogram of the baseline setup of a Ford GT LMGTE:

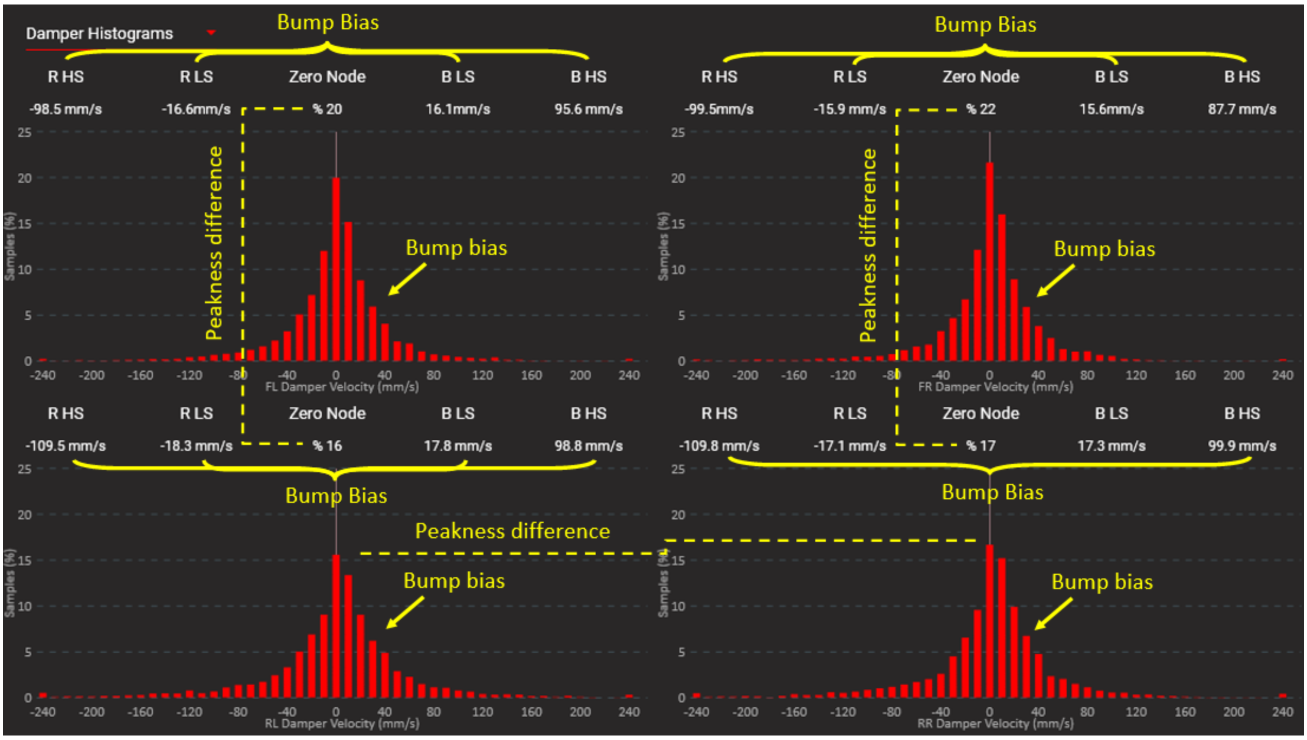

Figure 3.35: Baseline Damper Setup

There are multiple issues with our damper setup that can be observed.

1) The rear axis has less overall damping compared to the front (0 node is lower).
2) All dampers are bump biased (histogram is skewed to the positive velocity values and the average velocity is lower on the bump side).
3) There's also an imbalance between left and right side but that's mostly caused by the track layout. We could even out this too but that's not a critical issue, so we'll ignore that for initial damper setup.

Since the rear dampers display both critical issues (underdamped + bump bias), we will increase rebound damping and leave bump damping as is.

The overall damping rate at the front is already enough, so we will increase rebound and lower bump damping equally.

With our improved damper setup now looks like this:

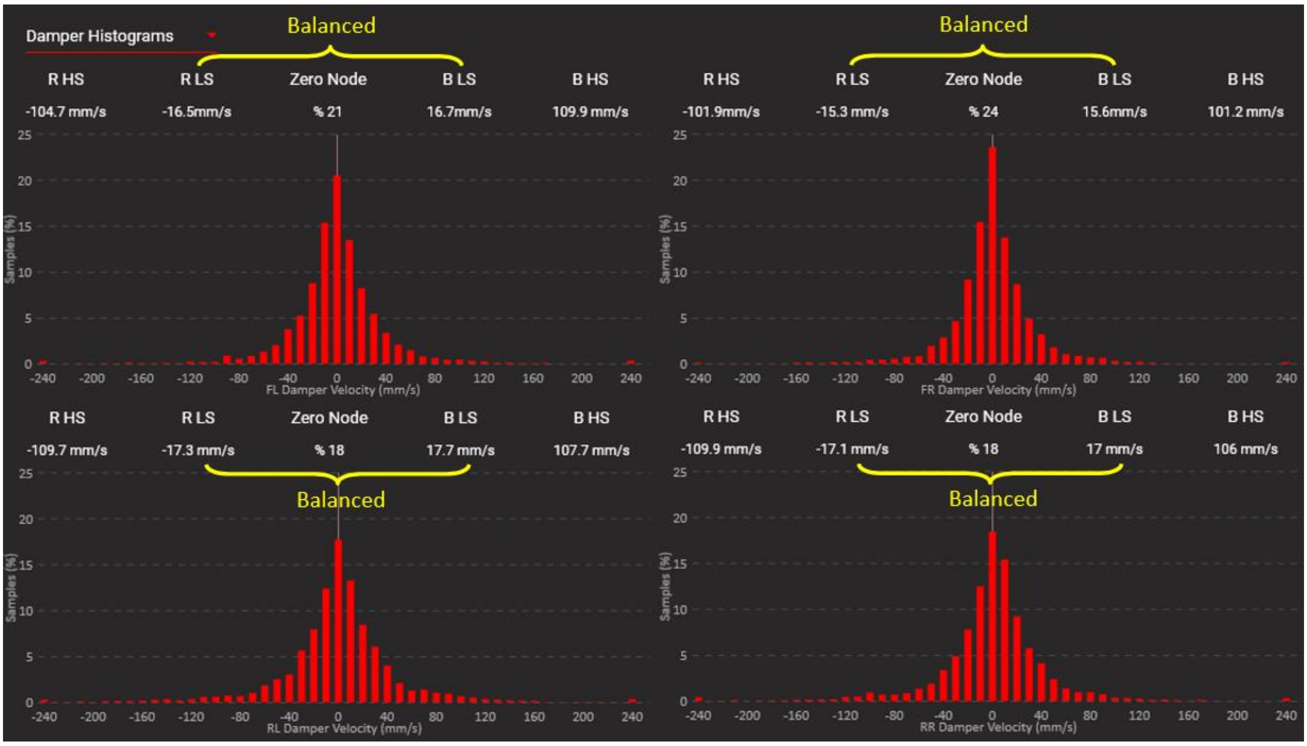

Figure 3.36: Balanced Damper Setup

The overall damping is now roughly equal on both axles (peakness equalized) and the bump bias has been tuned out (histograms are more symmetrical about the 0 node).

As a final step, let's try to equalize the front and rear axle histograms. For this we'll increase the rear spring and damping rate:

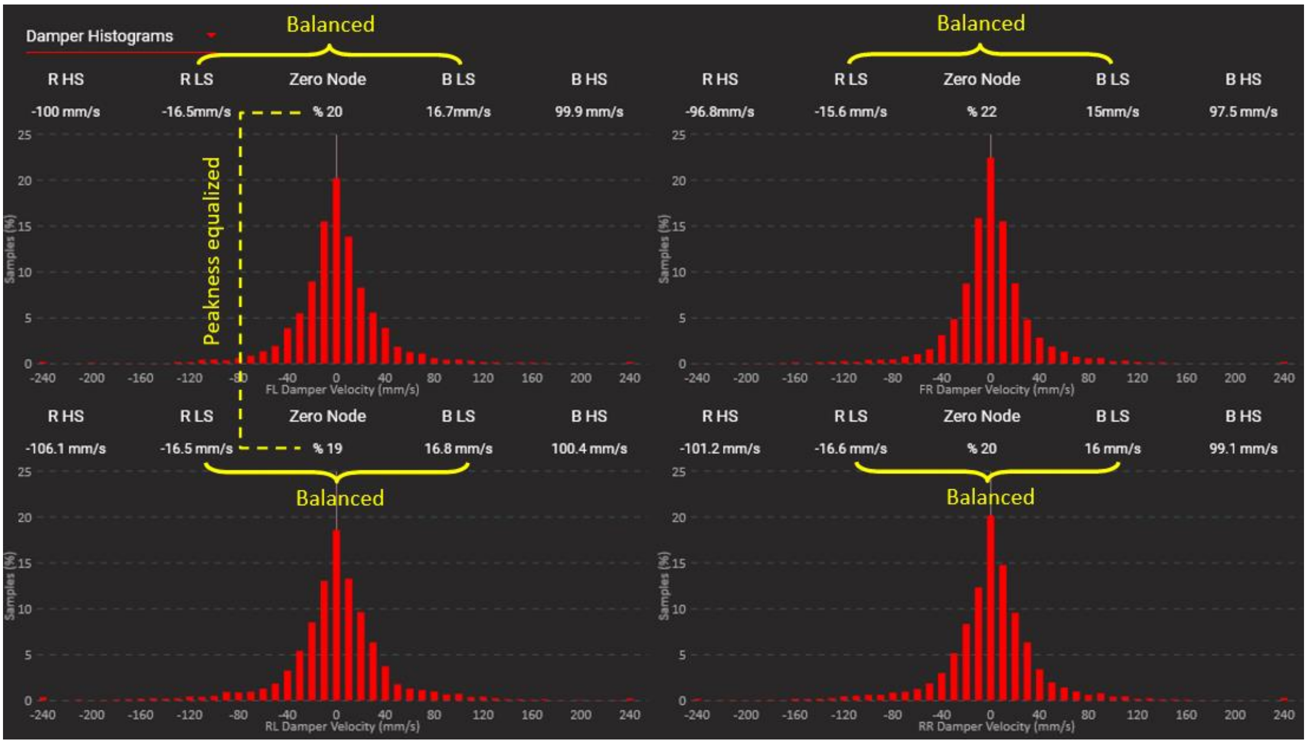

Figure 3.37: Balanced Damper Setup & Increased Rear Spring Stiffness

As you can see, there are two effects visible on the rear damper histograms.

1) Peakness increases and is basically equal to the front axle.

2) The average damper velocity decreases because of the higher damping rate.

If we increase the rebound damping rate even further, the histograms will look like this:

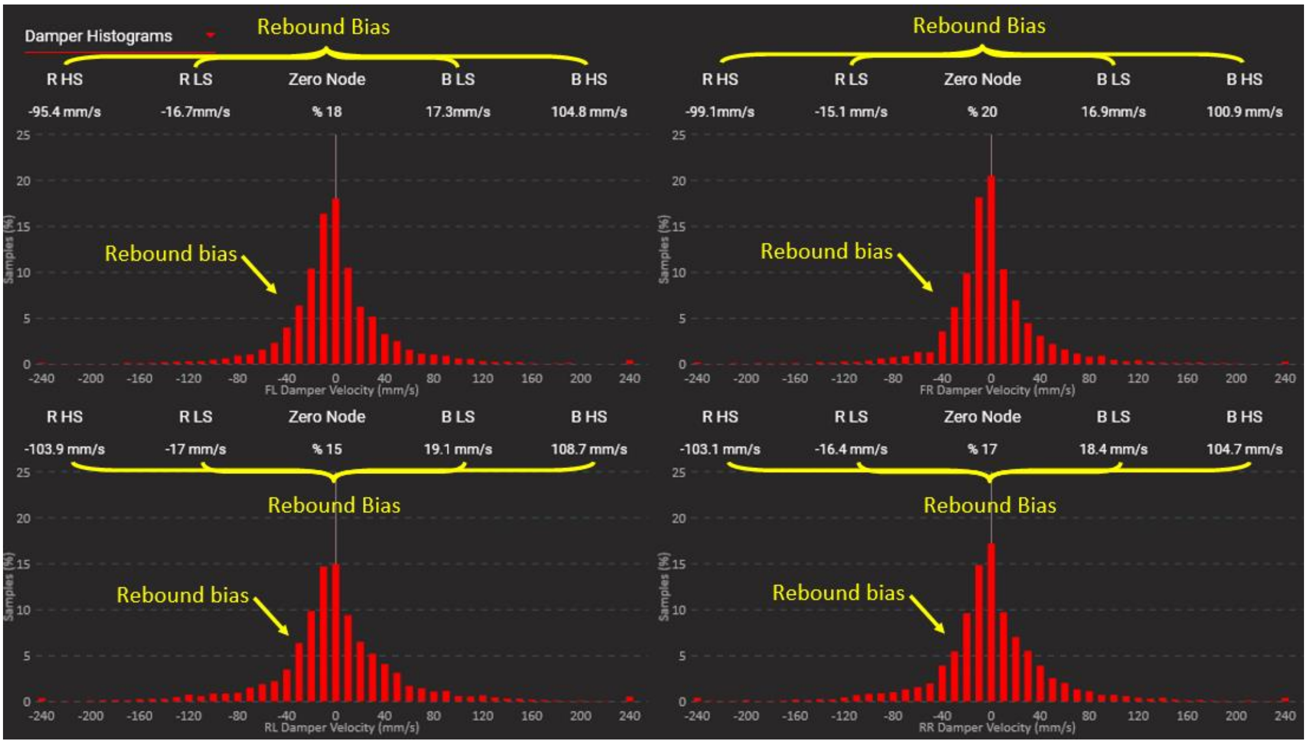

Figure 3.38: Rebound Biased Damper Setup

The histograms are now skewed to the negative velocity values and the average damper velocities are lower on the rebound side (rebound bias).

While it’s generally recommended to aim for symmetrical damper histograms, a slight bump or rebound bias can positively affect the vehicle’s performance in transient. This is mostly based on driver preference, so don’t hesitate to experiment with purposely unbalanced dampers.

If we wanted to, we could also go for a much softer suspension setup with less overall damping as shown in the image below:

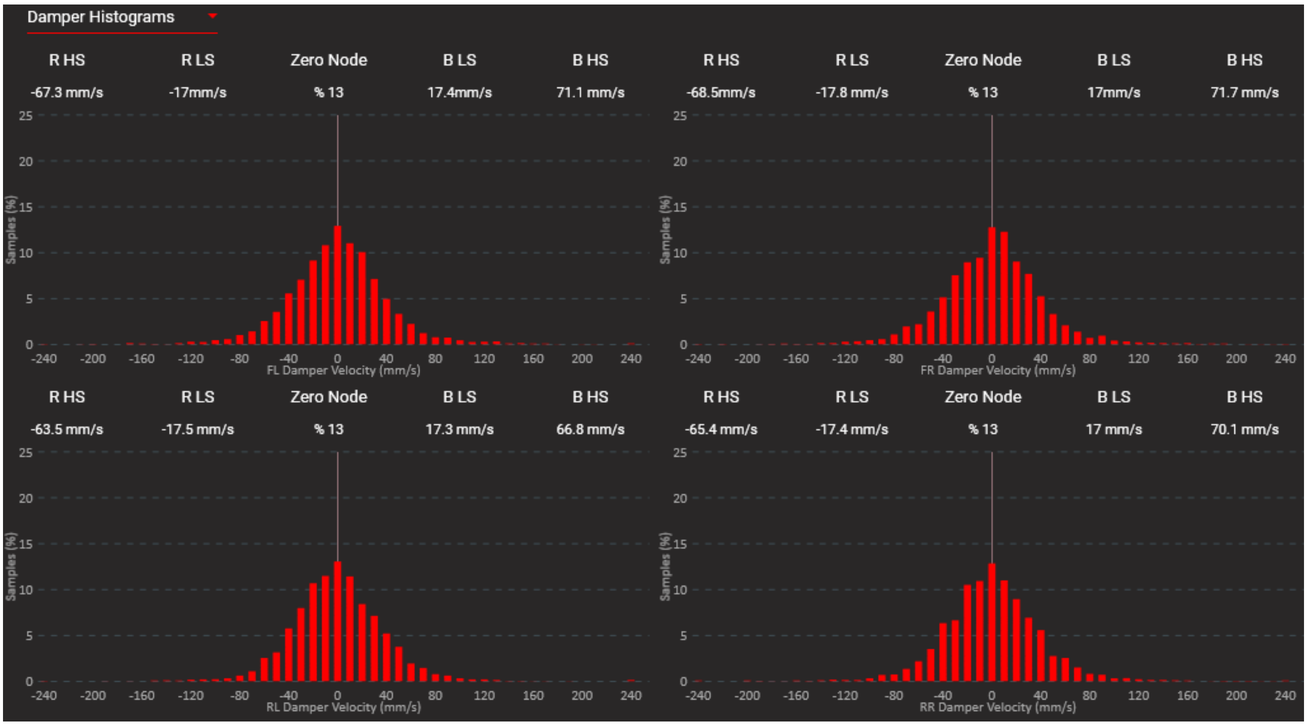

Figure 3.39: Balanced Damper Setup but Lower Overall Damping Rate

Such a setup does have its advantages, especially on slow track were mechanical grip is more important.

In general, a softer suspension setup with a lower damping rate is preferred for slower, low downforce cars that are mostly relying on mechanical grip.

On the other hand, high downforce cars (F1, LMP1, etc.) require a much stiffer suspension and higher damping rate, providing a stable aero platform and controlling chassis movement.

Histogram Comparison View

The Comparison View screen overlays all four damper histograms and lets you recognize differences easily. It's a great tool to fine tune various parameters of your suspension setup.

In the following example we're trying to optimize the damper setup of an LMP car that includes significant bump bias (which is a good way to stabilize the aero platform). The initial setup doesn't look too unbalanced and just needs some fine tuning:

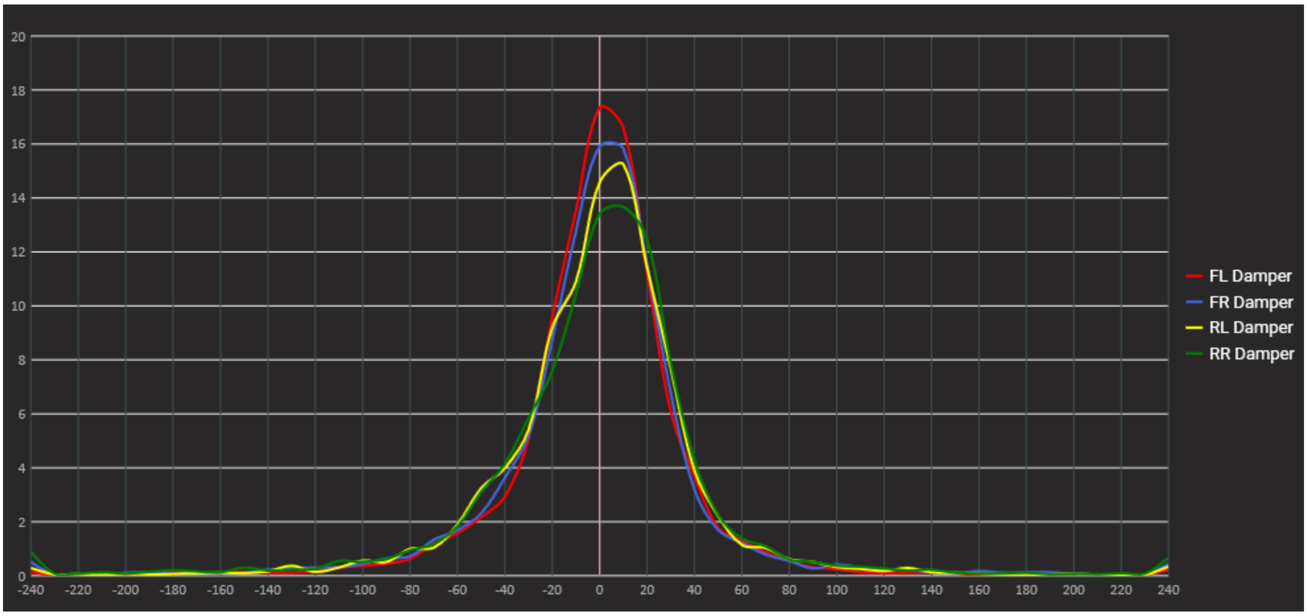

Figure 3.40: Initial Damper Setup

As a first step we're going to increase the rear bump and rebound damping rate (since it's already bump biased) to equalize the peaks of the bell curve shaped histograms:

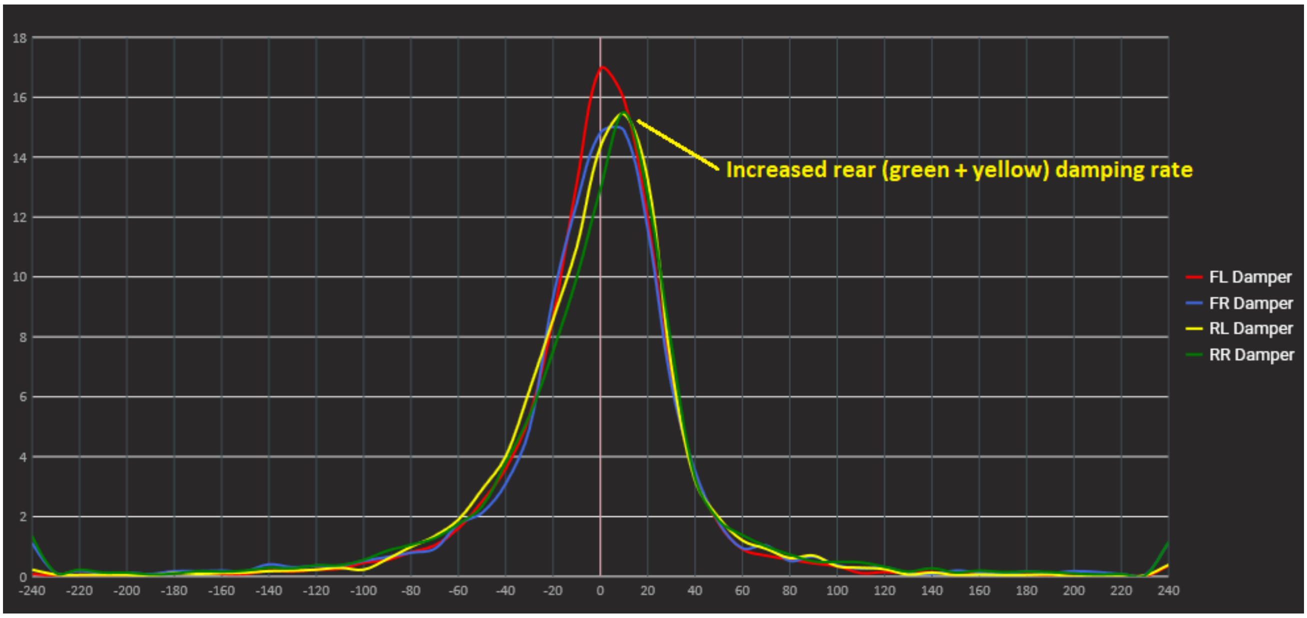

Figure 3.41: Adjusted Rear Damping Rate

Now we decrease the front left rebound damping rate to lower the peak value and increase the bump bias simultaneously:

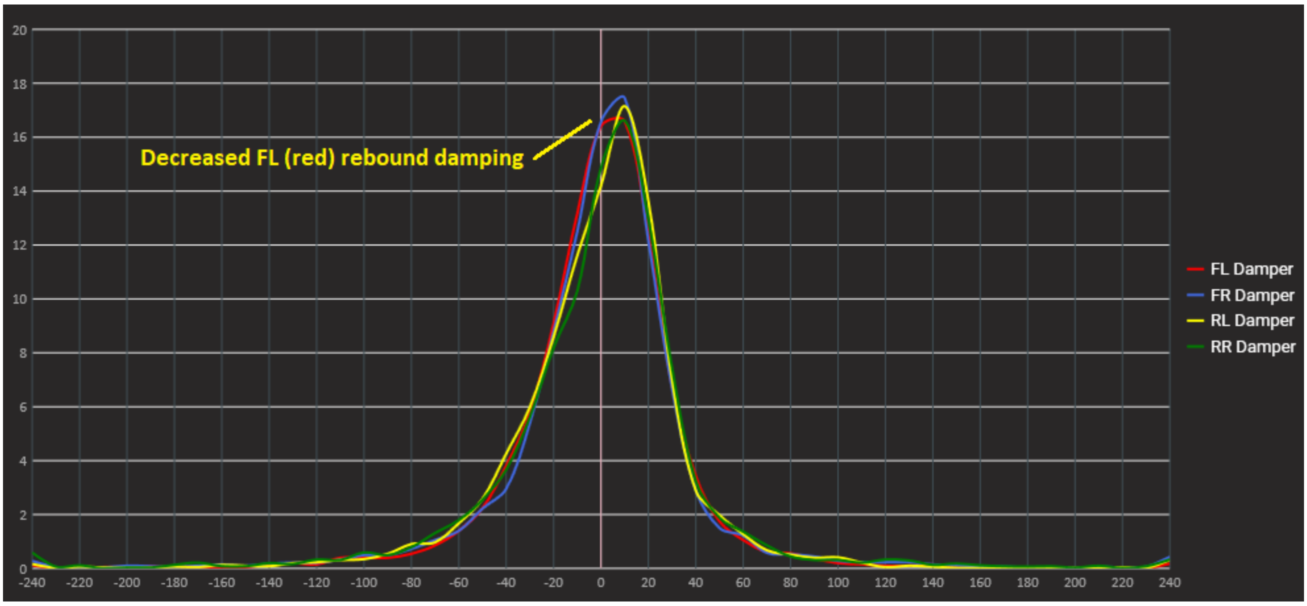

Figure 3.42: Front Rebound Damping Decreased

Although the shapes of the histograms are similar, some small improvements can still be achieved.

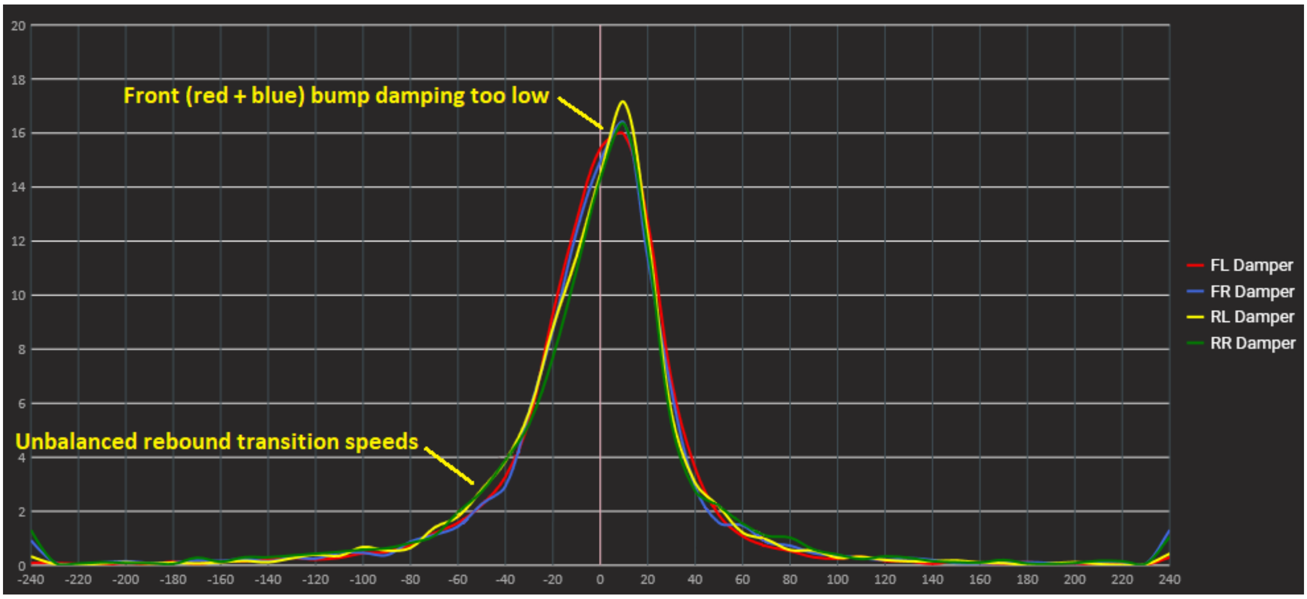

Figure 3.43: Unbalanced Damping Rate and Transition Speeds

As shown in the image above, the front bump damping still needs to be increased a little bit. We can also fine tune the transition speeds to align the histograms at the bottom of the bell curve. In this case we'll lower the front bump and rebound transition speeds to reduce the damping rate in this region.

The following image displays the optimized damper setup:

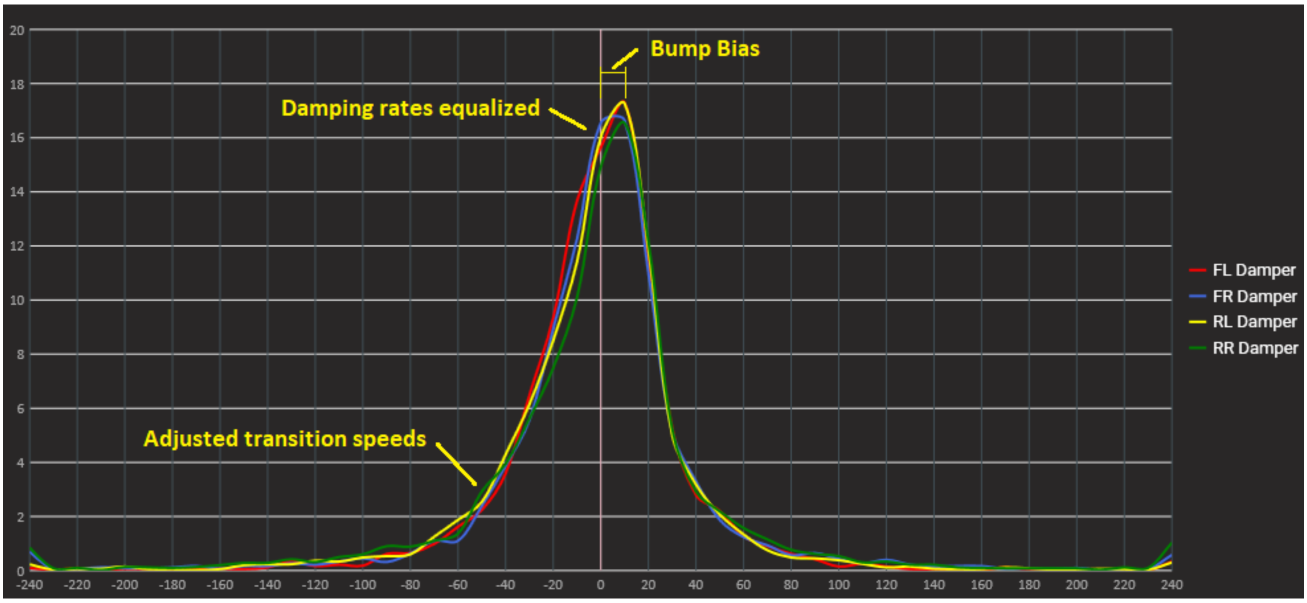

Figure 3.44: Optimized Damper Setup with Bump Bias

All four histograms are well aligned and the desired bump bias is clearly visible since the whole histogram is shifted slightly into the bump range (positive values).

Theoretical Background

The picture below is what you would expect from a typical damper histogram:

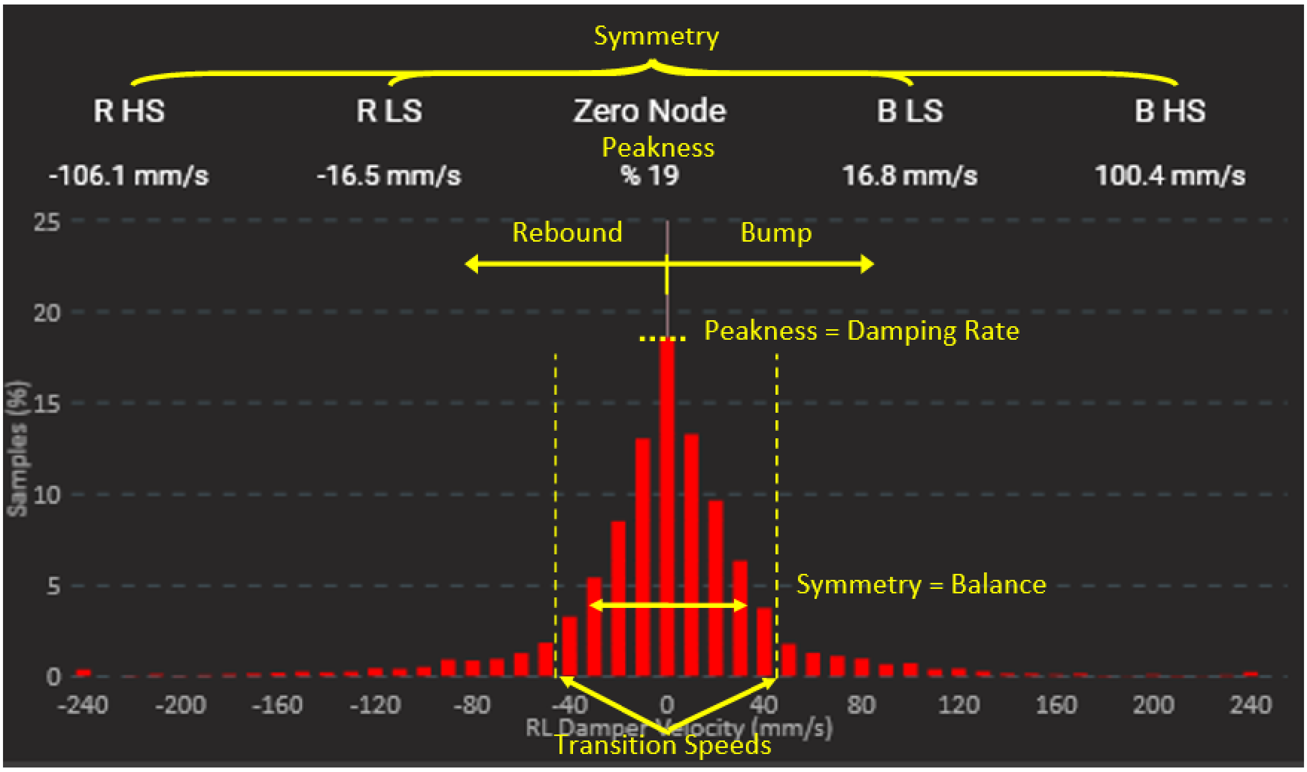

Figure 3.45: The Damper Histogram Explained

On the X-Axis we have the Damper Velocity, and, on the Y-Axis, we have the % of time spent in that velocity.

When analyzing the damper histogram there are two important things to look for:

1) Symmetry and

2) Peakness

Both concepts are outlined in the sections below, but before we talk about analyzing them, we first need to discuss the makeup of a damper histogram.

For the graph above, the damper's transition speed was calculated to 50mm/s. You can see this by the yellow dashed lines added to the histogram. Velocities crossing this line will transition in the damper from the low-speed to the high-speed setting.

Check out chapter 2.3 for more info about how to calculate the damper transition speeds.

Now you may be asking, “What transition speeds should I design for?” and the true answer for this is complicated, but as a rule of thumb, a typical makeup for a circuit will consist of the following:

Suspension Velocity	Description
Below ±5 mm/s	Friction in our suspension (not important)
0 – ±40 mm/s	Chassis motion (roll, pitch and heave) aka Cornering
±40 – 200 mm/s	Road imperfections (bumps)
>200 mm/s	Curbs

Typically, we want our transition to occur such that our chassis motion is in the low-speed region, and bumps/curbs are in the high-speed Region.

On most tracks, a general recommendation is to set your transition speeds to somewhere in the 50-75 mm/s range.

Peakness

For Damper Histograms the 0 mm/s bar should be the tallest one, because it is centered around 0 mm/s this bar is called the “0 node”. In a properly set up suspension, as we move away from the 0 node, the bump and rebound bars will start to decrease, and the rate at which they decrease is purely a function of the overall stiffness you have implemented in your suspension setup.

A setup that is stiff will have a histogram shape that is “Tall and Skinny”. This is because the suspension doesn’t move as much because it requires more energy to displace the suspension, and as such the bars around the 0 node will be much taller than the ones on the outskirts of the histogram.

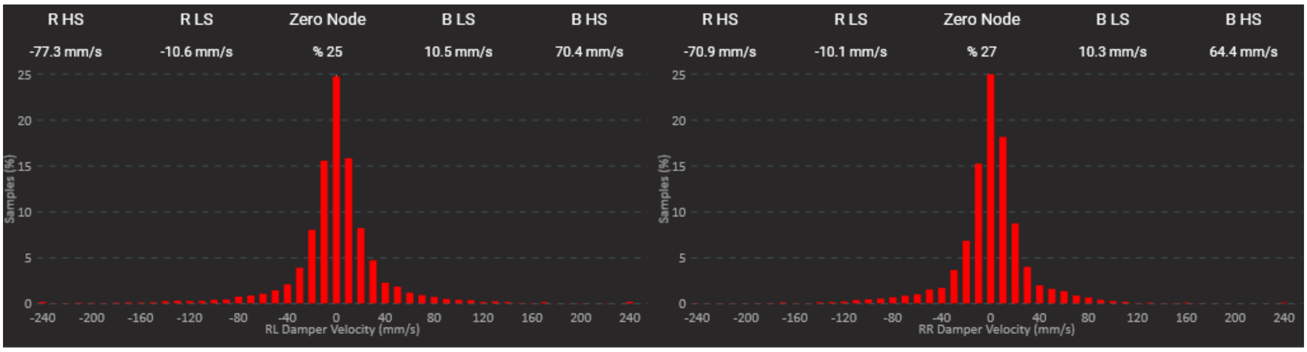

Figure 3.46: “Tall and Skinny” Damper Histogram

A setup that is soft will have a histogram shape that is “Short and Fat”. This is because the suspension moves a lot and therefore will spend little time in the 0-node range.

Typically, the 0-node bar will still be the highest bar, but the surrounding bars will be much higher than they would be if the suspension was stiff.

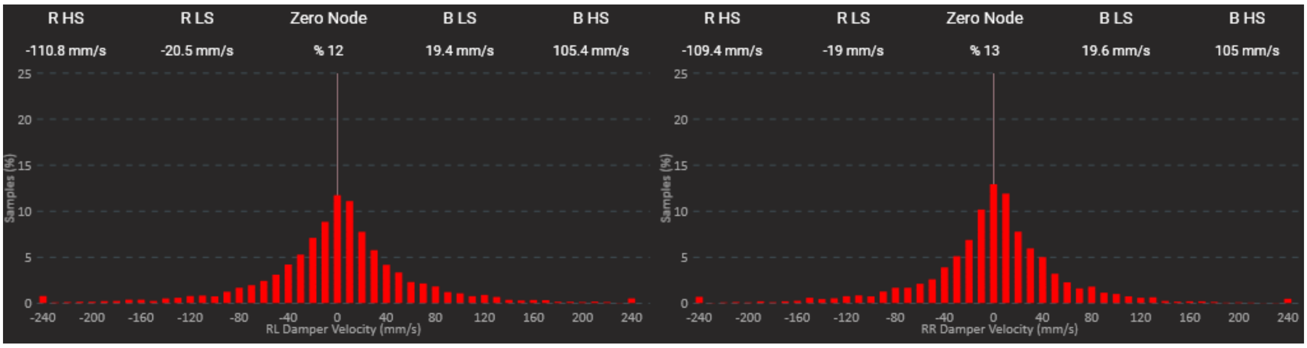

Figure 3.47: “Short and Fat” Damper Histogram

How soft or how stiff you set up your suspension will differ from track to track, but as a rule of thumb, the softer the suspension the slower and more sluggish the driver inputs will feel but the more mechanical grip we can achieve.

The Stiffer the suspension, the more reactive and twitchier the driver inputs will feel. However, we will also have less mechanical grip.

Ideally you want to set your suspension as soft as possible without the driver inputs feeling too sluggish.

Symmetry

The next important concept when analyzing your damper histograms is your symmetry. It is very important that the histogram is symmetric about the 0 node because this means you are dissipating equal amounts of energy in bump and rebound.
If you were not symmetric about the 0 node, you could get into a behavior called Jacking Down, or Jacking Up. This occurs when the damper has too much of an imbalance, and essentially causes the ride height of the car to keep rising (Jacking Up) or falling (Jacking Down) until the car is running on the bump stops. The two pictures below show a suspension setup that has too much rebound (left picture), or too much bump (right picture).

Histogram Skewness

In addition to eyeing the histogram you can also observe the bump & rebound % values in the data table. This will tell us if your histogram has any bias built into it. The goal is to get those values as equal as possible. Which type of damping you need to adjust to achieve this is explained below:

Skewness / Bias	Increase or Decrease Overall Damping	Which Damper to Change
Bump	Less Overall Damping	Decrease Bump
Bump	More Overall Damping	Increase Rebound
Rebound	Less Overall Damping	Decrease Rebound
Rebound	More Overall Damping	Increase Bump

Conclusion

In closing, the damper histogram is a very effective way to determine how much balance you have built into your suspension setup, as well as the overall stiffness of the suspension.
It is the goal of the race engineer to get the damper histograms as symmetric as possible for a specific car / track combination.

And, as always, as other components of the car are changed you will need to re-evaluate the histogram to ensure balance.

3.4.2. FFT

The Suspension FFT is another tool that allows you to analyze your dampers in a scientific way and to determine if your suspension is over- or underdamped. Its purpose is to find the main frequencies your suspension is operating at and to detect unwanted suspension activities that could hurt your car's overall balance. Remember, FFT and Damper Histogram analysis always go hand in hand and are a powerful combination to help you getting the best out of your tune.

Quick Guide to Suspension FFT Analysis

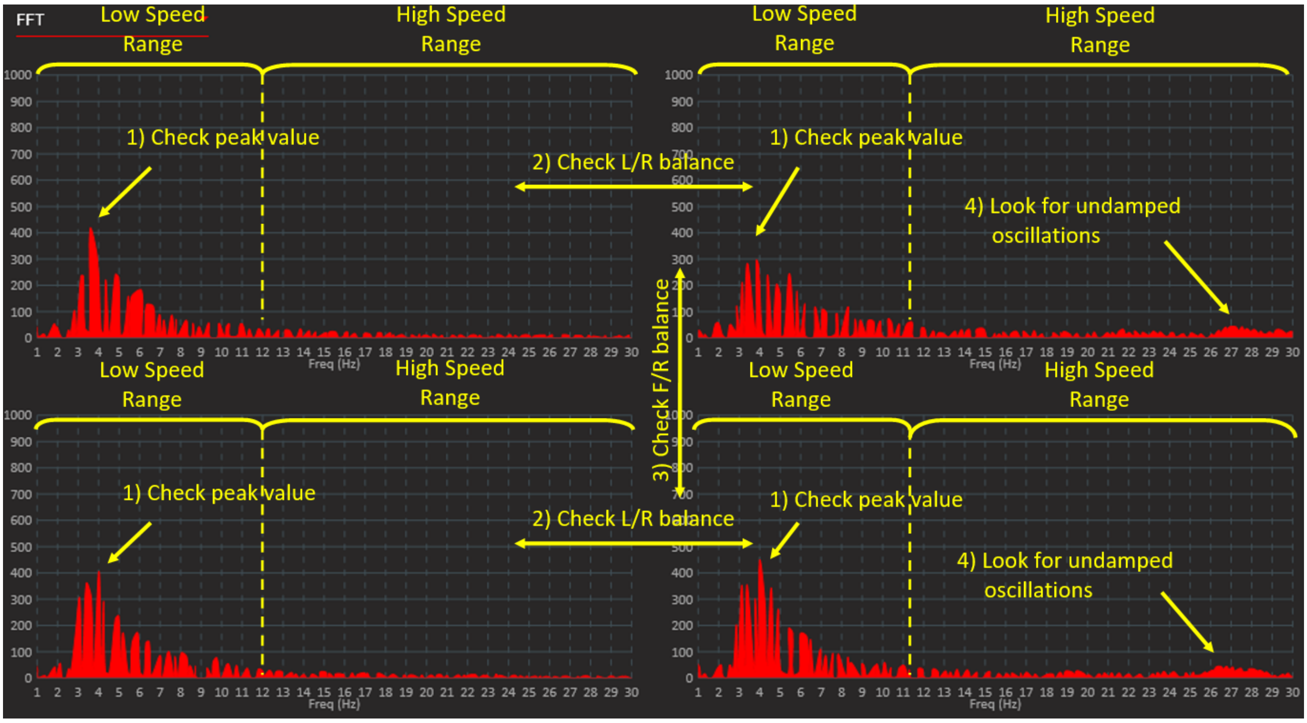

Figure 3.48: FFT Analysis Screen

1) Look at each graph and its peak value at the ride frequency. Adjust your damper settings if the peak is too high/low.
2) Analyze the balance between left and right wheels by comparing the peak levels. If the left side peak value is higher, increase left side damping or decrease right side damping.
3) Analyze the balance between front and rear wheels by comparing the peak levels. If the front wheel peak value is higher, increase front damping or decrease rear damping.
4) Check the high-speed region beginning at 8 – 12Hz for undamped oscillations and increase your high-speed damping to get rid of them.
5) Remember to re-check your suspension FFT graphs after every significant suspension setup change.

Theoretical Background and Analysis Example

FFT Stands for Fast Fourier Transform, and the reason this mathematical tool is so powerful is that it takes a signal that is in the time domain (x-axis) to one that is in the frequency domain.

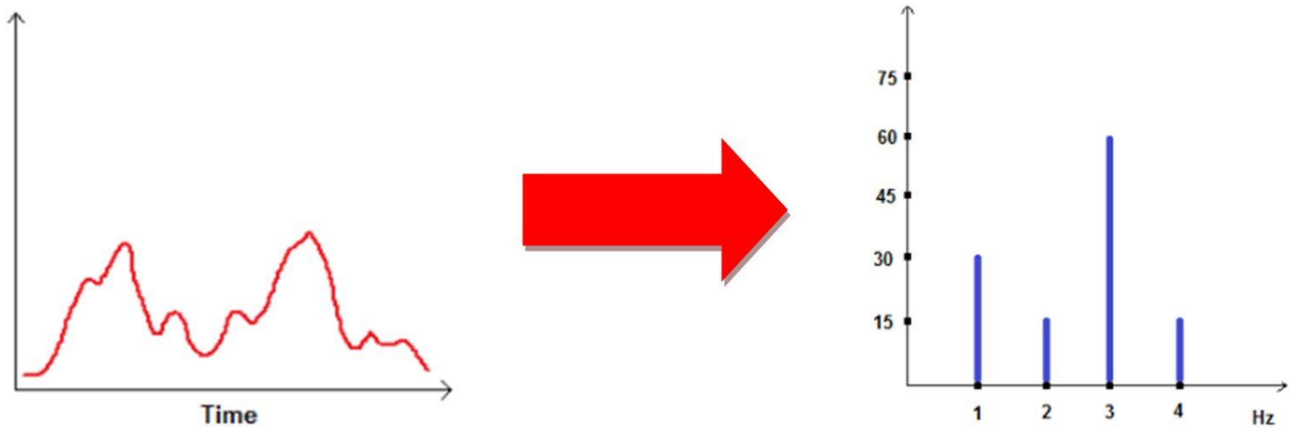

Figure 3.49: Transforming Data from Time to Frequency Domain

When we analyze our suspension in the frequency domain, we can get a better picture of where our suspension is operating at, for a given circuit. We can then use this data to determine if we need to increase or reduce the overall damping, as well as if the adjustments are needed in the high-speed or low-speed regions.

The FFT is a complex but very useful tool, and if you would like to learn more about the FFT in general, there are numerous videos and documentations out there. However, learning how to generate an FFT is out of the scope of this help document, so instead, we will look at the different components of an FFT, and how we can analyze them to improve the tune of the car.

The suspension FFT is also directly related to the transmissibility of your spring-damper system (Transmissibility is explained in more detail later in this chapter).

In the image below, we can see that there are two regions in each FFT plot.
The lower frequencies (0-12 Hz) typically represent your low speed damping and the higher frequencies (12-30 Hz) your high-speed damping region. That's only correct most of the time though because the frequency is not in direct correlation with speed, so it becomes more complex to determine where exactly that region is located. However, if your transition speeds are at the generally recommended 50-75 mm/s, then it would be safe to assume your transition frequency is around 8 – 12 Hz.

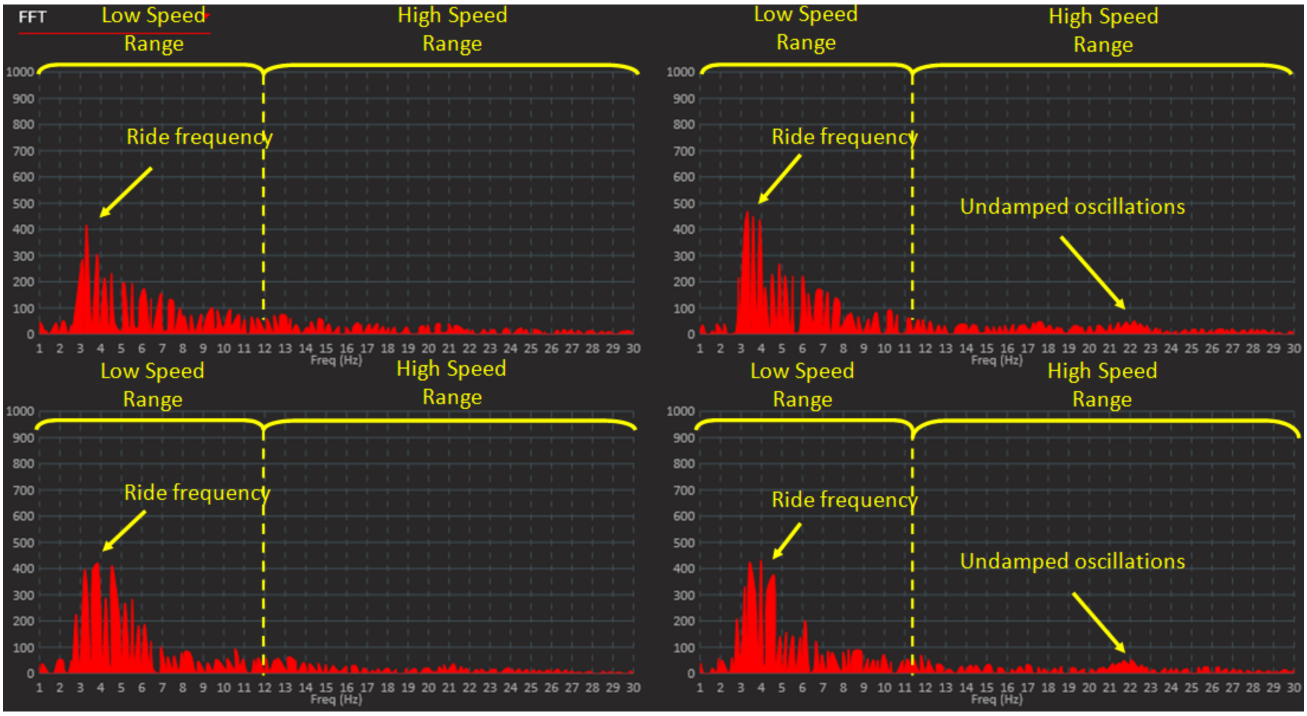

Figure 3.50: FFT Example of a Baseline Setup

The example image was taken from a hotlap in a Ford GT LMGTE at Catalunya GP.

The larger amplitude peak we have in the low speed region is our ride frequency which lies somewhere between 3.5 – 4.0 Hz. Because of this being the natural mode of the suspension, you can see a clear peak.

The amplitude (~400) and ride frequency (3.5 – 4.0 Hz) represents a good baseline for a GT3 or GTE car on a GP track.

You will also notice that to the right of the ride frequency the amplitudes of the other frequencies quickly drop off but there are small peaks around the 22 Hz mark on the right side, indicating that a little bit more high-speed damping is needed.

Although the low-speed damping seems to be sufficient already, we are increasing it by a small amount to show the effect this has on the FFT chart.

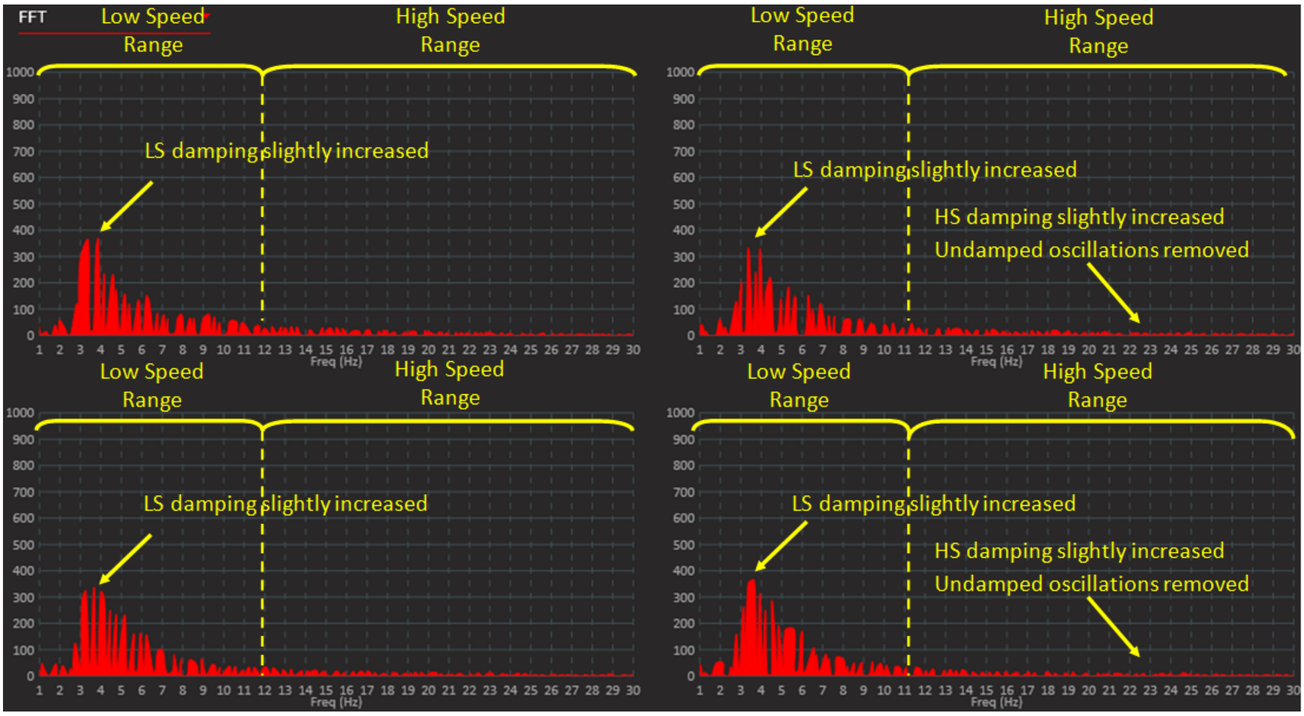

Figure 3.51: FFT Example with Adjusted Damping Rates

After slightly increasing both, low-speed and high-speed damping rate you can see in the image above how the amplitude at the ride frequency has been slightly lowered and the undamped oscillations at ~22 Hz have successfully been removed.

<u>Conclusion</u>

The Fast Fourier Transform (FFT) on suspension data is a great way to see at what frequencies your suspension is operating at, and to determine if you will need more or less overall damping. Using the FFT and Damper Histogram charts together reduces the time to tune significantly and takes the guesswork out of suspension tuning.

As an engineer, it's your job to continually check the results after making adjustments to determine if the car needs more or less damping based on the FFT.

Notes on Transmissibility

When we drive over a bump, our suspension displaces, and we hope that it is absorbed without disturbing the orientation of the car. However, if our suspension is not ideally set up, the suspension could in effect “amplify” the displacement of the car. This means that the car displaces more than the initial bump it has received.

This is undesirable because we end up disturbing the suspension system more than just the bump itself. The definition of transmissibility is:

$$TR = \frac{output\_amplitude}{input\_amplitude}$$

Or, to put it in simpler terms:

Transmissibility Value	Description
Transmissibility > 1	Car displaces more than initial bump
Transmissibility = 1	Car displaces equal to the initial bump
Transmissibility < 1	Car displaces less than initial bump

Now that you have a better understanding of what transmissibility is, you may be wondering how you can determine your setup’s transmissibility. The answer to that question is you can’t, but it's important to understand the concept because it has a significant impact on the car's grip levels.

With an understanding of this concept you can apply the theory to your setup strategy based on the circuit you’re going to drive on. The reason is that your critical damping value determines the level of transmissibility.

Looking at the graph below, you can see that low critical damping values produce more transmissibility in the low-speed region, while the opposite is true in the high-speed region.

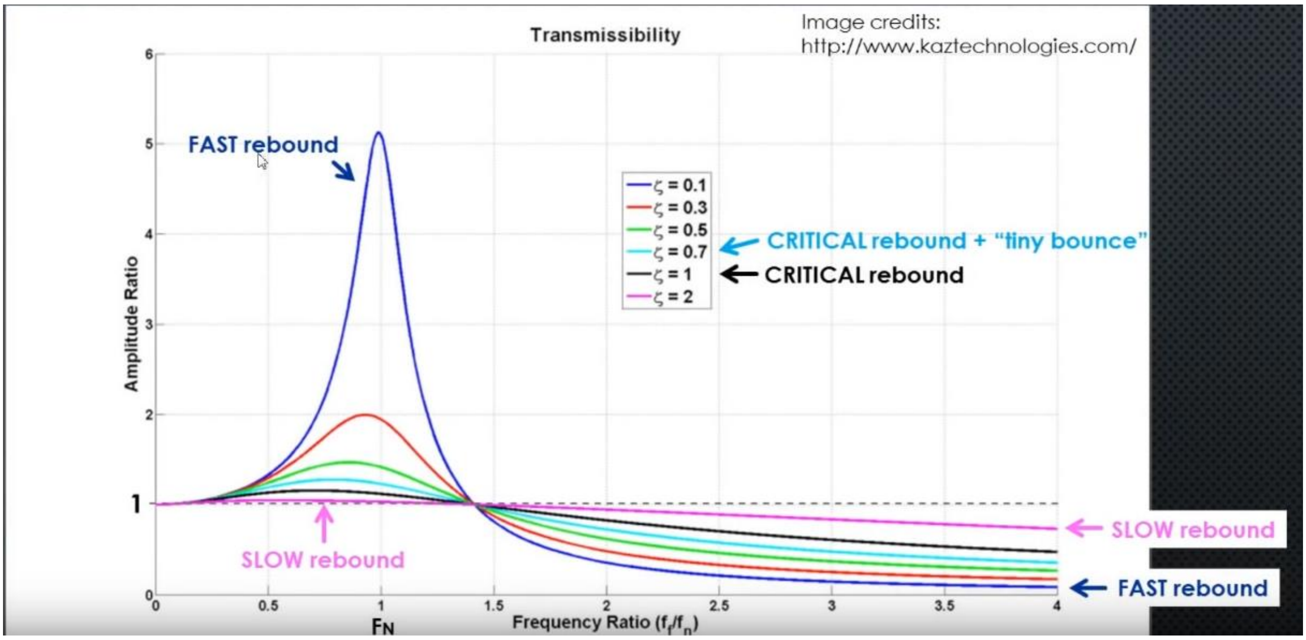

Figure 3.52: Transmissibility Explained

Region	Low % Critical Damping	High % Critical Damping
Low Speed	More Transmissibility	Less Transmissibility
High Speed	Less Transmissibility	More Transmissibility

Looking at the table it now makes sense why high-performance race cars use a "two speed" damper, meaning they optimize transmissibility by using high critical damping values in the low-speed region and low critical damping values in the high-speed region.

Using a "two speed" damper ensures that our damper is producing the least amount of transmissibility for the entire region. If you'd use a "one speed" damper, meaning your critical damping values were constant over the entire frequency range, you would have to compromise by optimizing the damping to give you the lowest transmissibility where the car would spend the most time in.

3.4.3. Roll & Pitch Gradients

These two graphs illustrate your car's suspension movement versus lateral (roll) and longitudinal (pitch) acceleration, as shown in Figure 3.53.

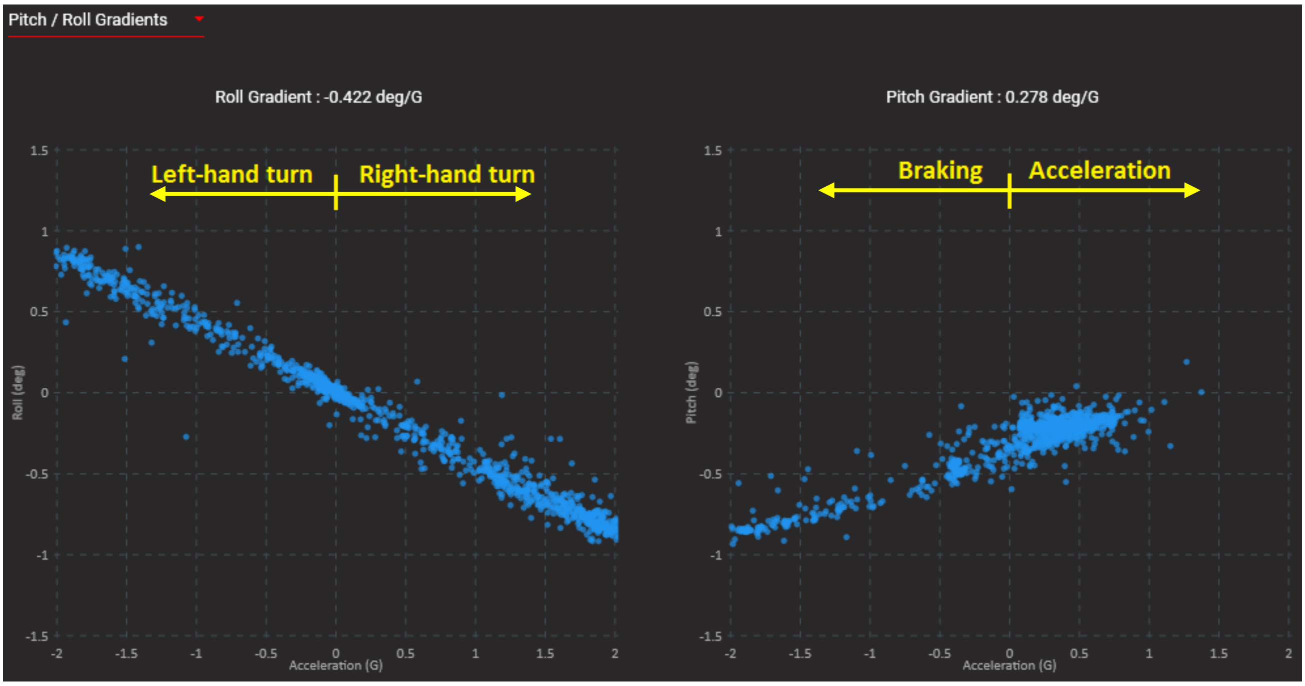

Figure 3.53 Roll & Pitch Gradient Graphs

The roll gradient (RG) is a direct indicator of your vehicle's roll stiffness and is expressed in normalized form as degrees of body roll per unit of lateral acceleration [°/G]. In other words, the stiffer your suspension, the less body roll per unit G you'll achieve and the lower your RG will be.

Choosing the correct RG is so essential when optimizing performance that it's the second most important setup choice to make, right after ride frequency. You'll have to find the right balance between a stable aero platform with great steering responsiveness (low RG) and high mechanical grip in slower corners but more sluggish steering responsiveness (high RG).

In general, high downforce cars demand a stiffer suspension and therefore lower RG to handle the increased lateral acceleration in high speed corners, while low downforce cars may benefit from the increased mechanical grip with a higher RG.

The following table states a few advantages for low and high roll gradients. As with everything setup related you have to choose the right compromise, depending on your car / track combo.

Low Roll Gradient	High Roll Gradient
Less suspension movement	More independent suspension
More instantaneous lat. load transfer	Higher mechanical grip
Better steering response	Better tire heat management
Stable aero platform	Better traction on bumpy tracks

The best way to set your desired RG is by adjusting your antiroll bars. Since they act parallel to your regular springs their impact on roll stiffness is higher and they won't affect your longitudinal suspension stiffness and therefore mechanical grip under acceleration / braking at all.

Keep in mind that adjusting your RG will not affect the total lateral weight transfer directly. It does have an indirect effect however since it allows you to lower your ride height and therefore the height of the center of gravity.

The tables below were collected from various literature resources and can be used as a guideline to achieve the desired roll stiffness.

Typical Roll Gradients [B-2]	
Very soft–Economy and basic family transportation, pre-1975	8.5°/G
Soft–Basic family transportation, after 1975	7.5°/G
Semi-soft – Contemporary middle market sedans	7.0°/G
Semi-firm – Sport sedans	6.0°/G
Firm–Sport sedans	5.0°/G
Very firm – High performance (e.g., Camaro Z28, Firebird Trans Am)	4.2°/G
Extremely firm – Contemporary very high-performance sports (e.g. Corvette), street cars extensively modified to increase roll stiffness	3.0°/G
Hard–Racing cars only	1.5°/G

Typical Roll Gradients [B-3]	
High performance sports cars	3.0–4.0°/G
Low downforce sedans	1.0–1.8°/G
Stiff high – downforce race cars	0.2–0.7°/G

Typical Roll Gradients for Various Types of Race Cars [B-1]	
2002 Formula One car	0.03 – 0.10°/G
2001 IndyCar	0.10 – 0.20°/G
2010 Superleague Formula single – seater	0.08 – 0.15°/G
2004 Dodge Viper GTS-R race car	0.44 – 0.55°/G
2004 Corvette C5R GT1 race car	0.20 – 0.40°/G
2006 Corvette C6R GT1 race car	0.25 – 0.35°/G
2011 Audi LMS GT3 race car	0.30 – 0.50°/G

The pitch gradient (PG) is the equivalent to the roll gradient under longitudinal acceleration. It's expressed in normalized form as degrees of body roll per unit of longitudinal acceleration [°/G].

A correct PG is important to control your rake angle and front ride height variance (which is the most sensitive factor in a stable aero platform) and optimize your aero efficiency. That's why a low pitch gradient is preferable on high downforce cars. It's again a case of finding the right compromise between more mechanical grip and a stable aero platform.

Both, low and high pitch gradients have their advantages and you should choose according to your car / track combo.

Low Pitch Gradient	High Pitch Gradient
Less suspension movement	Better tire heat management
More instantaneous long. load transfer	Higher mechanical grip
Less aero balance shift under braking	Better traction on bumpy tracks

Unlike the RG, the PG is often nonlinear since anti-dive and anti-squat geometries are common on many race cars. An example of this can be seen in Figure 3.54. It shows a car that's equipped with anti-dive geometry.

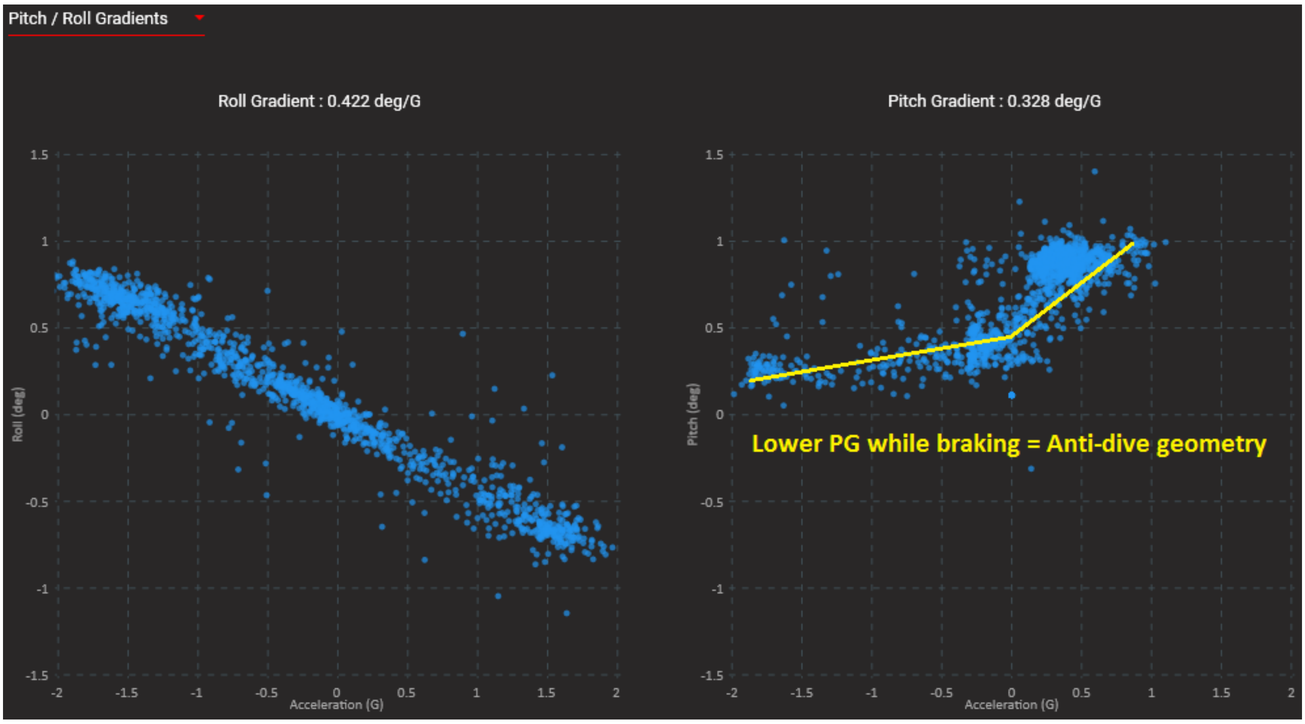

Figure 3.54 Impact of anti-squat on pitch gradient under acceleration

Anti-geometry reduces (and sometimes even reverts) chassis motion under longitudinal acceleration by dictating the ratio of the weight transfer instantaneously acting through the suspension links and the one acting elastically through springs and dampers.

3.4.4. Modes

The various suspension system modes can tell you a lot about your car's attitude and suspension movements and, to a degree, about track characteristics:

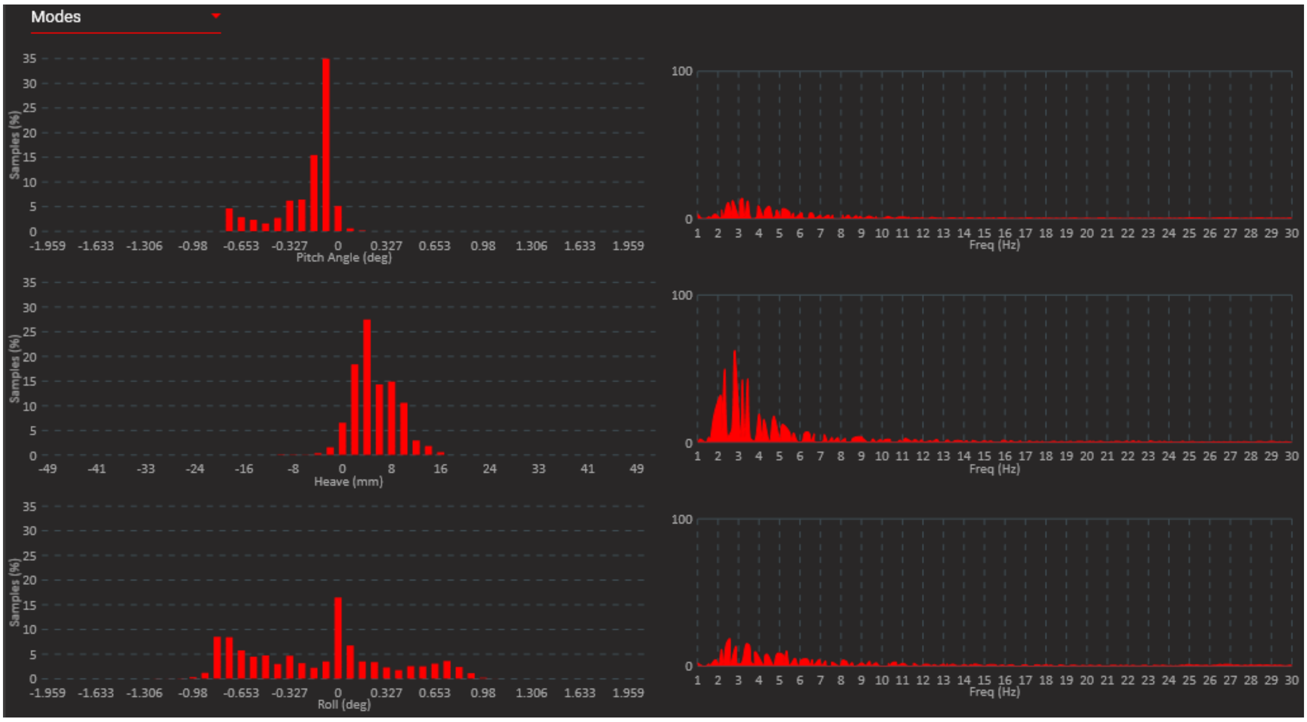

Figure 3.55: Suspension System Modes Histograms and FFT

Use this tool to analyze (and limit) chassis movement by adjusting springs and 3rd springs (pitch, heave) and ARBs (roll).

Pitch

With the Pitch Histogram and FFT you can analyze the chassis attitude and movement during acceleration and braking.

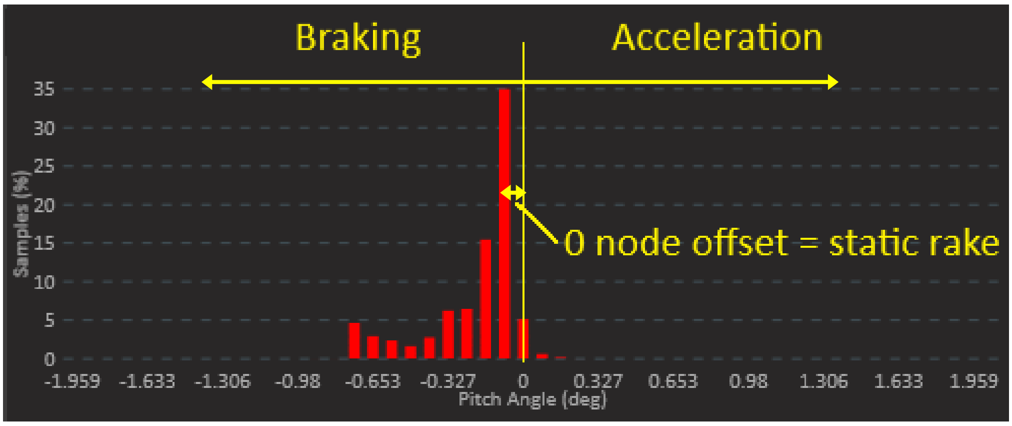

Figure 3.56: Pitch Angle Histogram

The pitch definitions are: positive → Front RH higher than rear RH (acceleration)

negative → Front RH lower than rear RH (braking)

As you can see there's a 0-node offset which is caused by the static rake (rear RH – front RH) from your car setup.

Another observation you can make is that the pitch angle under braking is much higher compared to acceleration. This is caused by the naturally higher longitudinal grip potential in braking. For more info on this, check out chapter 3.4.5.

To reduce the amount of pitch angle change you should stiffen the springs or, if you're already happy with your roll stiffness, the 3rd springs (if available).

The FFT is an indicator of suspension stiffness in pitch motion.

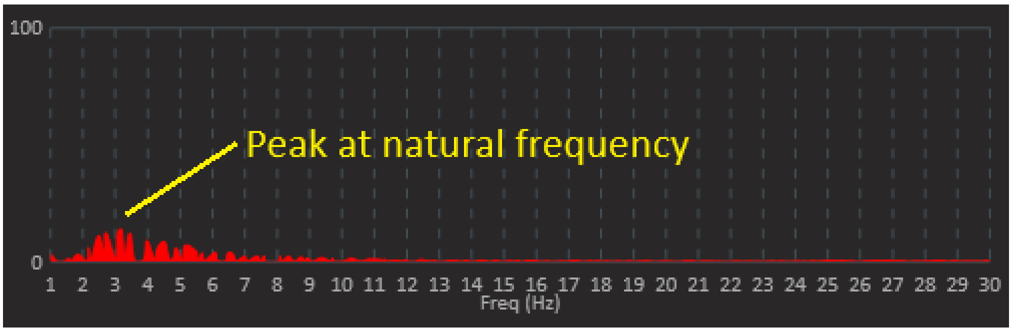

Figure 3.57: Pitch Angle FFT

The higher the amplitude the softer your suspension is. It's often compared to the Roll FFT to determine pitch versus roll stiffness.

The peak value is located at the natural pitch frequency of your chassis which takes springs and dampers into account.

Heave

The Heave Histogram and FFT reflect the resulting chassis compression caused by synchronous movement of all four suspended corners in the same direction:

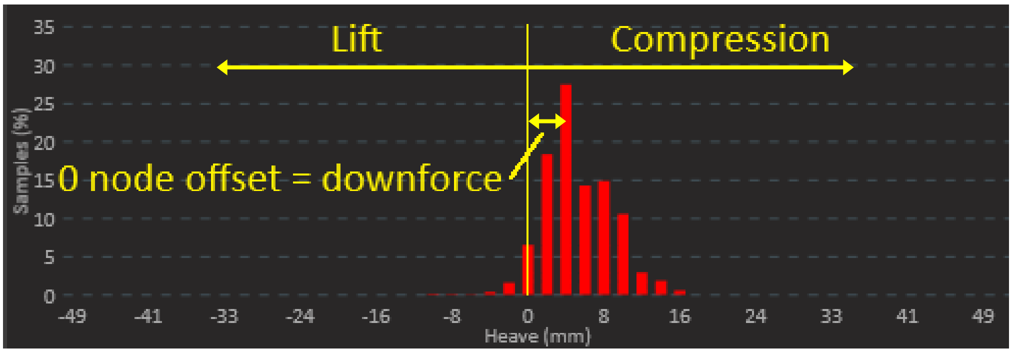

Figure 3.58: Heave Histogram

The heave definitions are:	positive	→	Current RH lower than static RH (compression)
	negative	→	Current RH higher than static RH (lift)

Once again there's a 0-node offset which is this time caused by downforce (and fuel load).

Like with pitch you may want to stiffen the springs or 3rd springs to reduce the amount of heave. This is particularly important on high downforce cars to provide a stable aero platform for optimal aero efficiency.

The FFT is an indicator of suspension stiffness in heave motion.

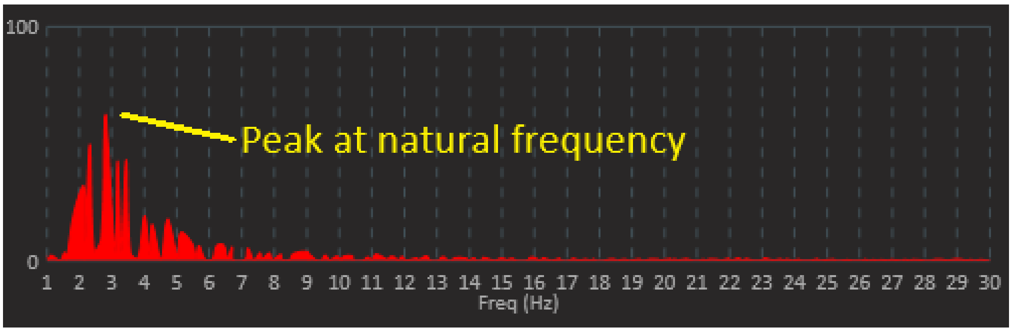

Figure 3.59: Heave FFT

Compared to pitch and roll, the amplitude at the natural frequency peak is significantly higher in the Heave FFT. This is to be expected since the chassis moves in heave almost the whole time, which is mainly caused by road surface irregularities and varying downforce values from velocity changes.

Roll

Finally, with the Roll Angle Histogram and FFT you can analyze the chassis roll angle distribution of all cornering sections during a lap:

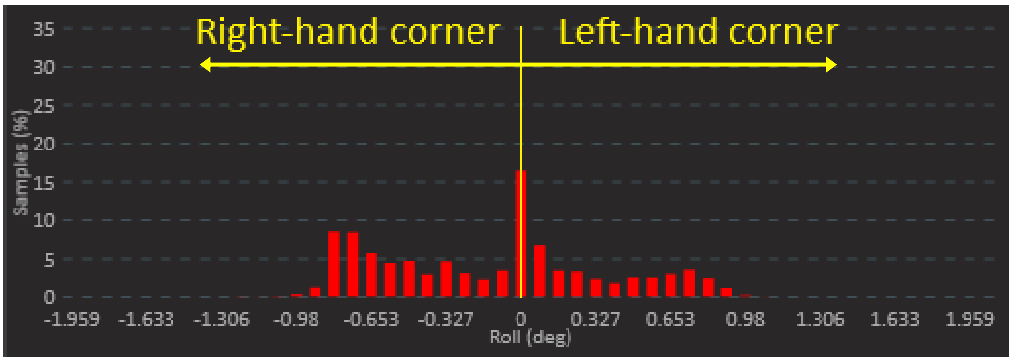

Figure 3.60: Roll Angle Histogram

The roll definitions are:	positive	→	Left RH higher than right RH (left-hand turn)
	negative	→	Left RH lower than right RH (right-hand turn)

Use this graph to quantify and limit body roll in corners. If your maximum roll angle is too high you should stiffen your ARBs to keep enough ground clearance on the outside corners.

In the example above you can also see that the car spends more time in right-hand corners which tells you a lot about the track profile.

The FFT is an indicator of suspension stiffness in roll motion.

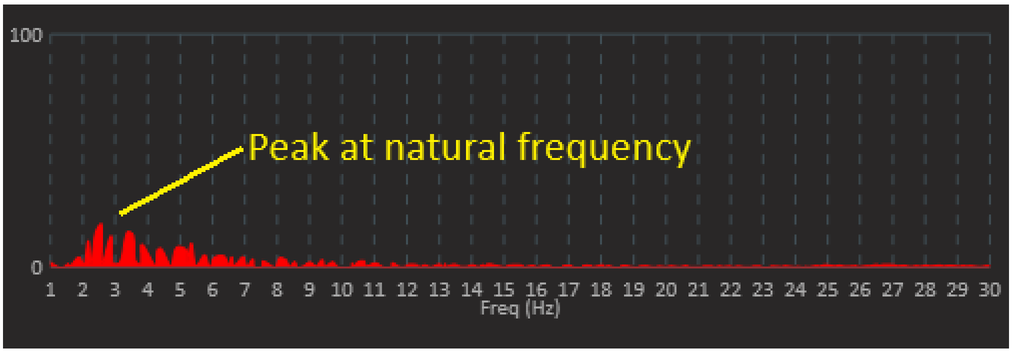

Figure 3.61: Roll FFT

As already mentioned earlier, the Roll FFT often compared to the Pitch FFT to determine pitch versus roll stiffness.

The peak value is located at the natural roll frequency of your chassis which takes springs and dampers into account.

3.4.5. Traction Circle

The Traction Circle screen reflects the grip potential developed by the tires and how it's utilized in various driving conditions:

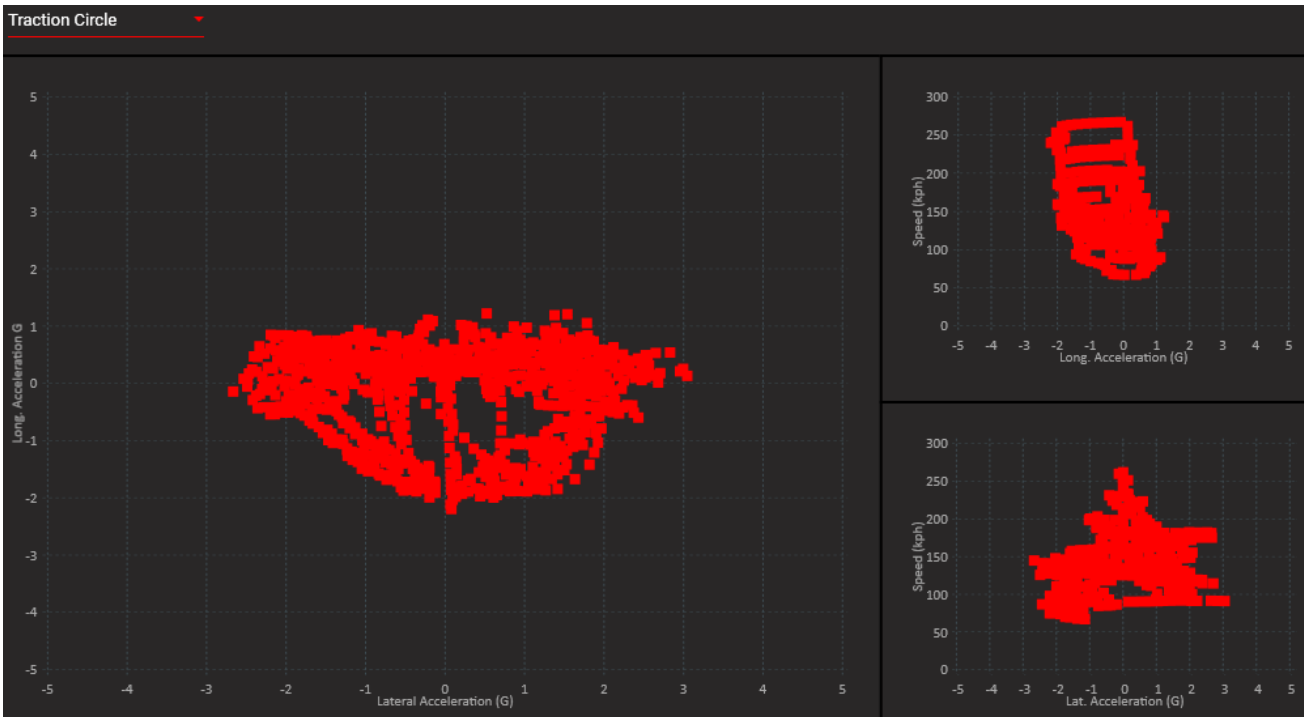

Figure 3.62: The Traction Circle Screen

Use those charts to evaluate acceleration, braking and cornering performance of your car and to find out which track sections you should focus on while tuning it.

You can combine all three charts into a 3D graph called the G-G-V Diagram. For more info on this diagram and the traction circle check out our RST Blog here.

The Traction Circle Chart

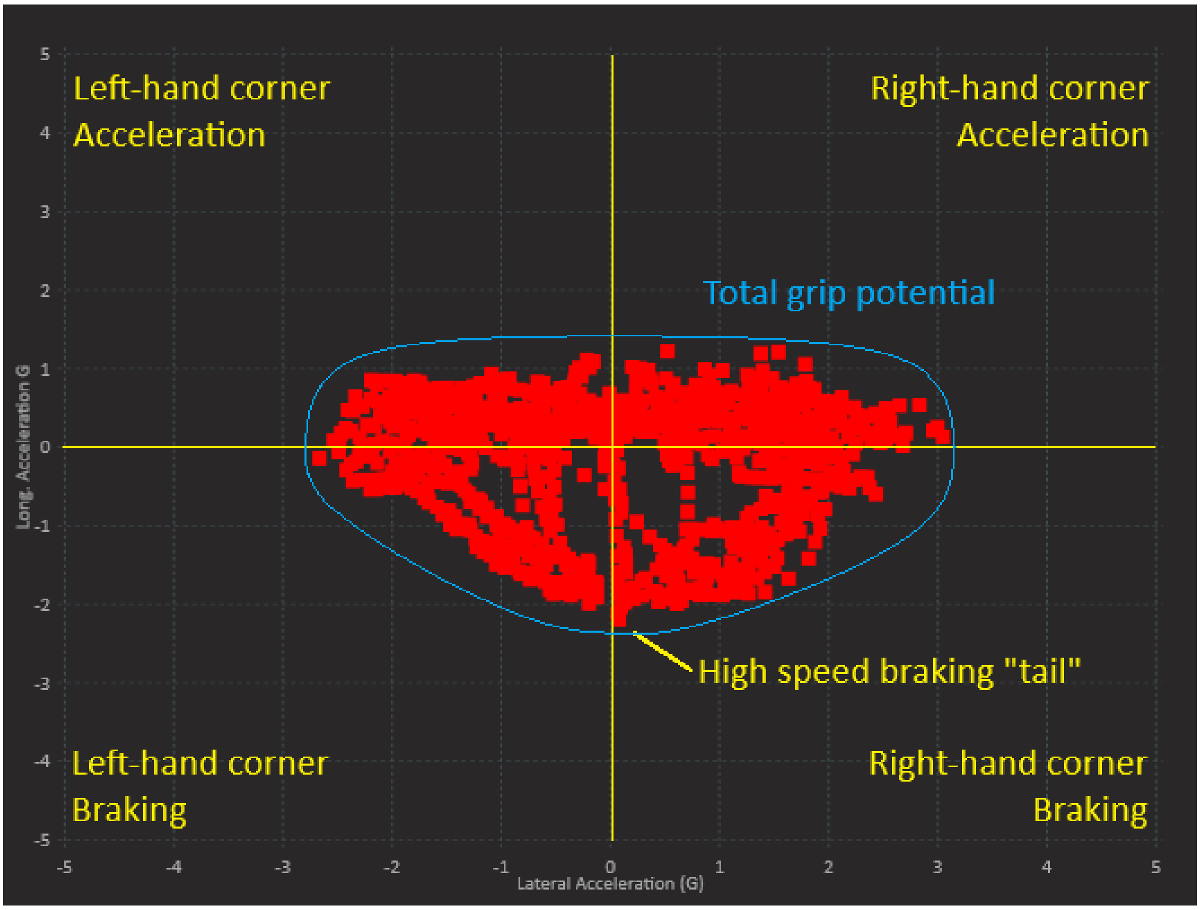

Figure 3.63: Traction Circle

The first thing you'll notice in the image above is that the traction circle actually resembles an ellipse and not a circle. That's caused by the longitudinal acceleration being limited by engine power and aerodynamic drag. Since aerodynamic drag and downforce will support your brakes in slowing down the car, the longitudinal acceleration will always be higher during deceleration. You may also notice the high-speed braking "tail" which is caused by braking maneuvers from top speed at the end of the longest straight.

You can also see that the peak lateral acceleration varies between left-hand and right-hand corners. Higher lateral G's are generated most of the time in high speed corners where aero increases tire loads and therefore grip potential. Together with the variation in data point density the traction circle can tell you a lot about the track profile and which track sections you should focus on while working on your car setup.

The area that’s covered by the traction circle represents the total grip potential of your car. Your ultimate goal should be to increase this area as much as possible.

The shape of the traction circle is also a direct indicator of the driver's performance and should resemble the theoretical total grip potential (blue line in the image above) as close as possible. The presence of "dents" / large inconsistencies in its shape indicates that the car's grip potential is only partly utilized by the driver in this section.

Longitudinal Acceleration vs Vehicle Speed Chart

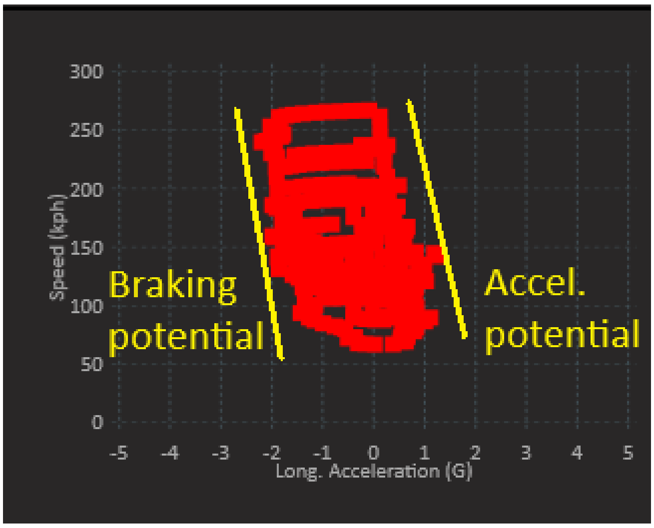

Figure 3.64: Longitudinal Acceleration vs Vehicle Speed

This chart resembles the car's longitudinal grip potential (acceleration and braking). Your goal should be to widen the graph's shape as much as possible.

To achieve this, you should try to extend the increase of braking potential with speed by increasing your vertical tire loads (downforce) and to lower the loss of acceleration potential by minimizing aero drag.

Lateral Acceleration vs Vehicle Speed Chart

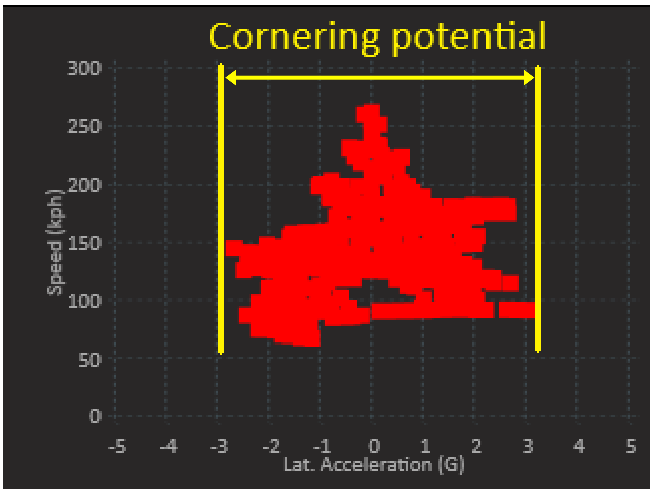

Figure 3.65: Lateral Acceleration vs Vehicle Speed

In this chart, the car's lateral grip potential (cornering) and how it changes in relation to vehicle velocity is displayed. Once again, your goal should be to widen its shape as much as possible for maximum performance.

3.4.6. Lateral Stiffness Distribution

The Lateral Stiffness Distribution screen is a powerful tool to achieve a balanced suspension setup.

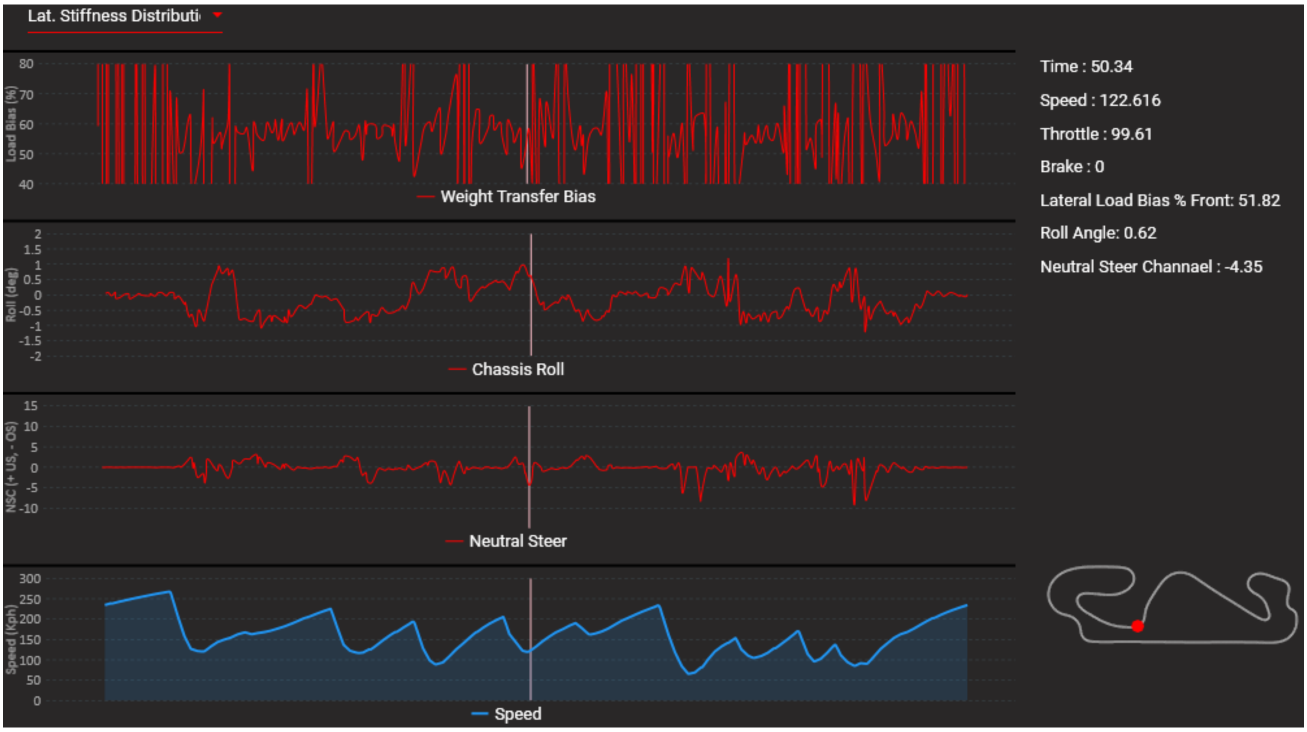

Figure 3.66: Lateral Stiffness Distribution Screen

Use it to balance your springs and ARBs for steady state conditions (mid-corner) and adjust your damper rates and bias for transient conditions (corner entry and exit).

Check out the detailed example shown in Figure 3.70 to learn how to read those graphs effectively.

Weight Transfer Bias Chart

The Weight Transfer Bias chart describes the ratio of weigh transfer between the front and rear axle. Since weight transfer bias is a direct indicator of mechanical balance (aero excluded), this graph is particularly useful to balance your suspension setup.

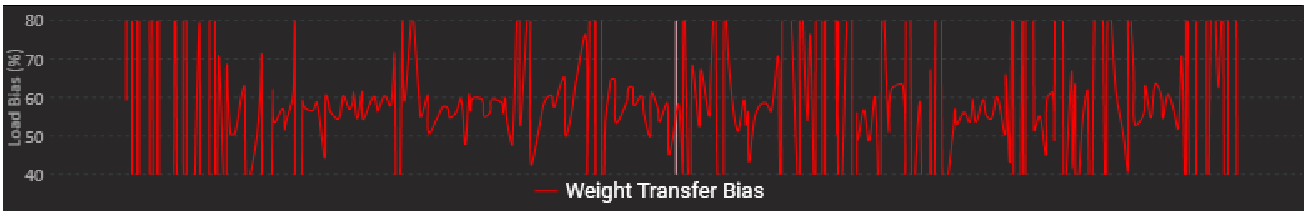

Figure 3.67: Weight Transfer Bias Chart

The Load Bias % values are defined as: >50% → Forward bias

<50% → Rearward Bias

You may have noticed that there is a lot of distortion in the data on straight lines. This is caused by the math that's used to calculate the load bias. But since suspension balance is most important in corners anyway, simply focus on those sections and ignore the distorted data on the straights.

For a balanced suspension setup aim for ~55% forward bias in steady state as a starting point.

On top of tuning your springs and dampers, this graph also enables you to balance your damper setup for corner entry and exit.

The Total Roll Angle Chart

This chart shows the current roll angle of your chassis at any point of the track.

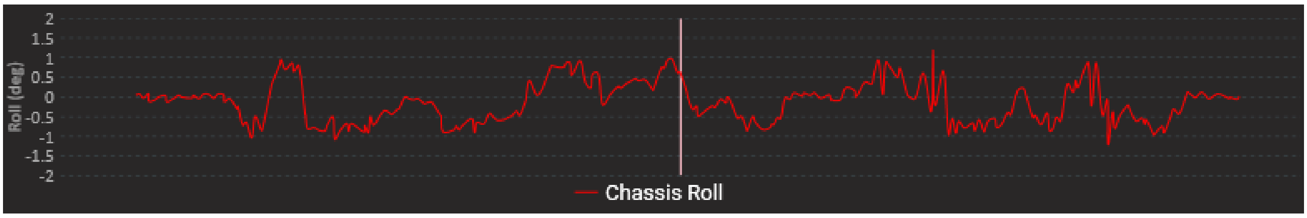

Figure 3.68: Total Roll Angle Chart

The roll angle values are defined as:	positive	→	left-hand corner
	negative	→	right-hand corner

Not only can you determine the maximum amount of body roll, but also if the car is negotiating a left-hand or right-hand corner. You can also spot steady state (constant roll angle; horizontal line) and transient (roll angle changes; inclined line) conditions.

The Neutral Steering Channel

The Neutral Steering Channel will show you when your car is understeering (US) or oversteering (OS) during a corner.

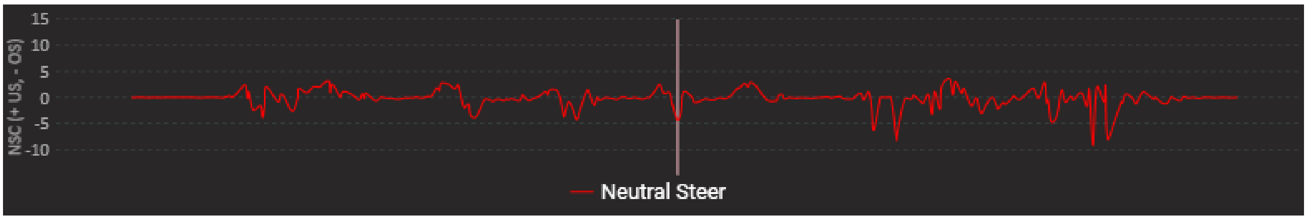

Figure 3.69: Neutral Steering Channel

The steering angle values are defined as:	positive	→	understeer
	negative	→	oversteer

Your goal should be to keep the trace as close to zero (neutral steering) as possible.

Due to the mathematical model behind it the validity of this graph is limited at high slip angles. But it does a good job in illustrating understeer and oversteer nonetheless.

Let's analyze a complex cornering sequence for example (Turn 1 – 3 at Circuit de Catalunya):

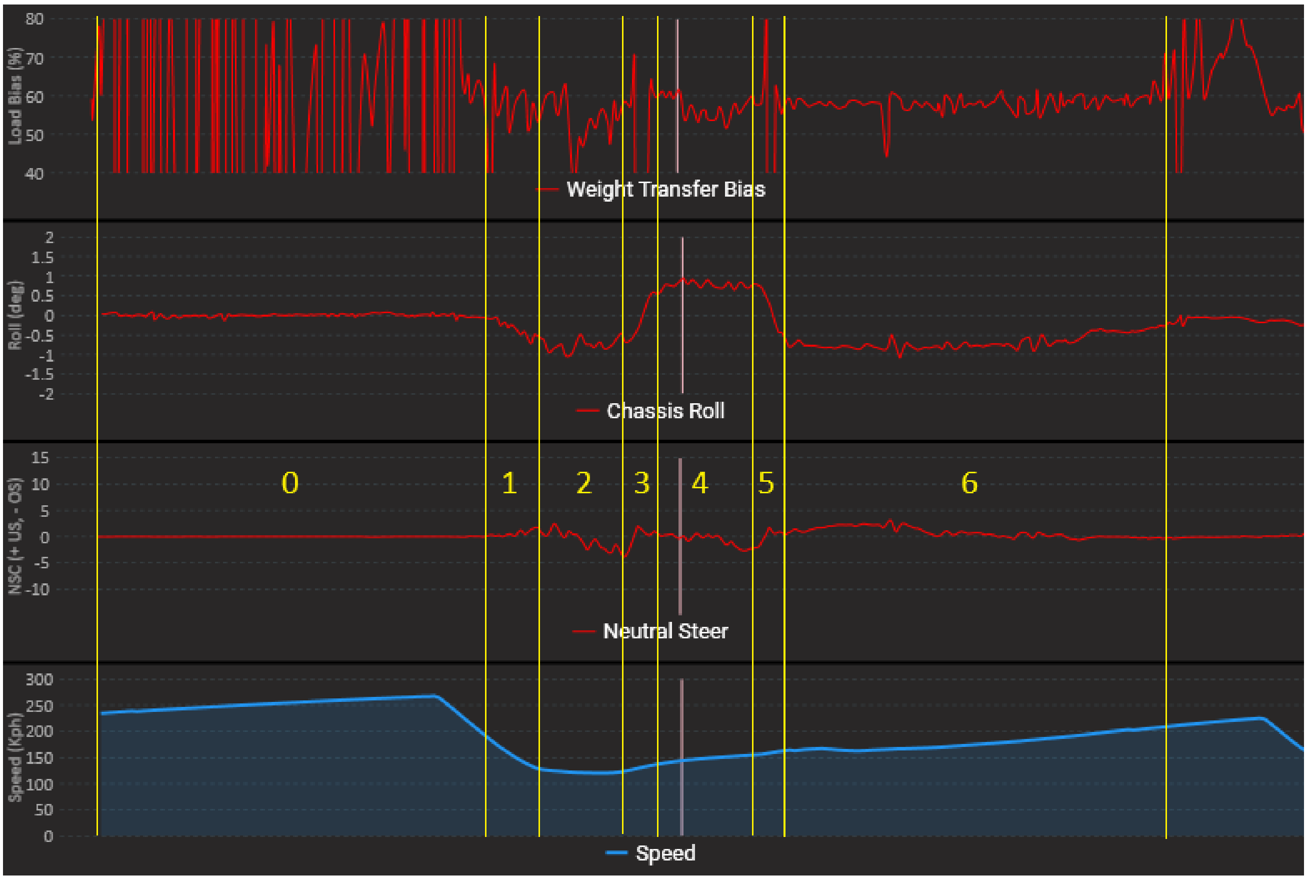

Figure 3.70: Analysis of a Car Negotiating a Multi-Corner Sequence

0) Due to the math behind this chart, straight line data will always look distorted. Ignore this data.

1) Initial turn-in: The load bias spikes forward, indicating understeer in transient conditions (see NSC). Adjust your dampers if you feel that car behavior is different in transient compared to steady state.

2) Steady state slow corner: The NSC indicates slight OS which is caused by the car's mechanical (springs + ARBs) balance.

3) Transient maneuver right to left hand turn: The load bias spikes forward again, indicating understeer in transient conditions (see NSC) caused by the damper setup.

4) Steady state slow corner: The NSC indicates slight OS again caused by the car's mechanical (springs + ARBs) balance. The load bias % is constant at 50-55% which is quite optimal.

5) Transient maneuver left to right hand turn: The load bias spikes forward again, indicating understeer in transient conditions (see NSC) caused by the damper setup.

6) Steady state fast corner: There's slight US visible in NSC. Since the steady state in slow corners expressed slight OS, this indicates that the aero balance is too far to the rear.

3.5. Gearing

3.5.1. RPM Histogram

The RPM Histogram helps you optimizing your gearing setup by displaying the time you spent in a specific RPM range.

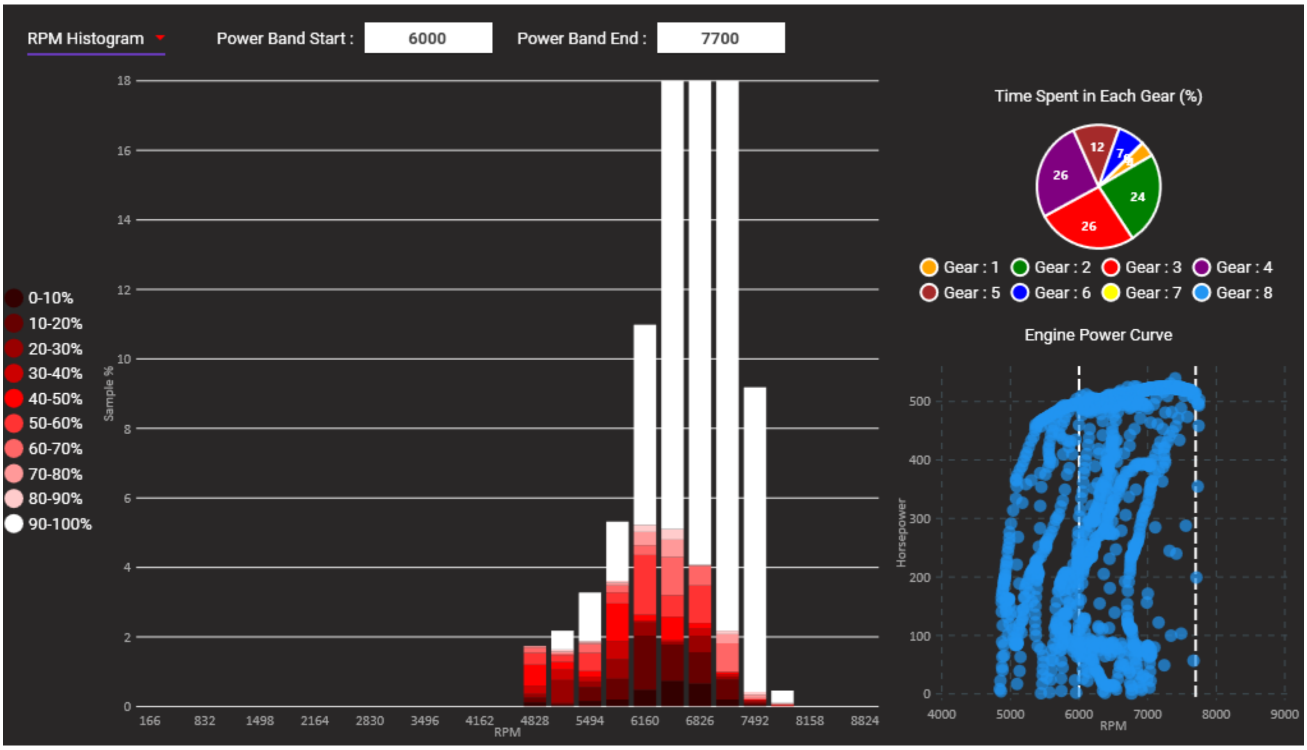

Figure 3.71: RPM Histogram Chart

On top of showing the RPM range you spend the most time in, the coloring of the graph reflects the throttle position during this time.

When a bar is mostly white it means that you're on full throttle most of the time while being in that particular RPM range. If the amount of dark red is reaching higher levels within the white bar, it means you're spending more time in this RPM range while off throttle, or at less than full throttle.

Your target should be to minimize the time spent in lower RPM ranges below the power band and therefore to maximize your power output.

On top of that you should try to go full throttle as much as possible in the power band RPM range (reduce the amount of red in those bars), which can be identified by checking the blue engine power curve on the right side of the chart.

In the example above, the peak of the power band is mostly between 6000 and 7700 RPM. Once identified, you can enter the lower and upper end of the power band in the cells above the RPM Histogram. The dashed white lines in the engine power curve serve as visual reference of your power band input.

Additionally, the pie chart in the upper right shows the distribution of time spent in each individual gear.

3.5.2. RPM Gearing

With the RPM Gearing chart, you can analyze your gearing setup and shifting points to assure that the engine is operating in the power band range most of the time.

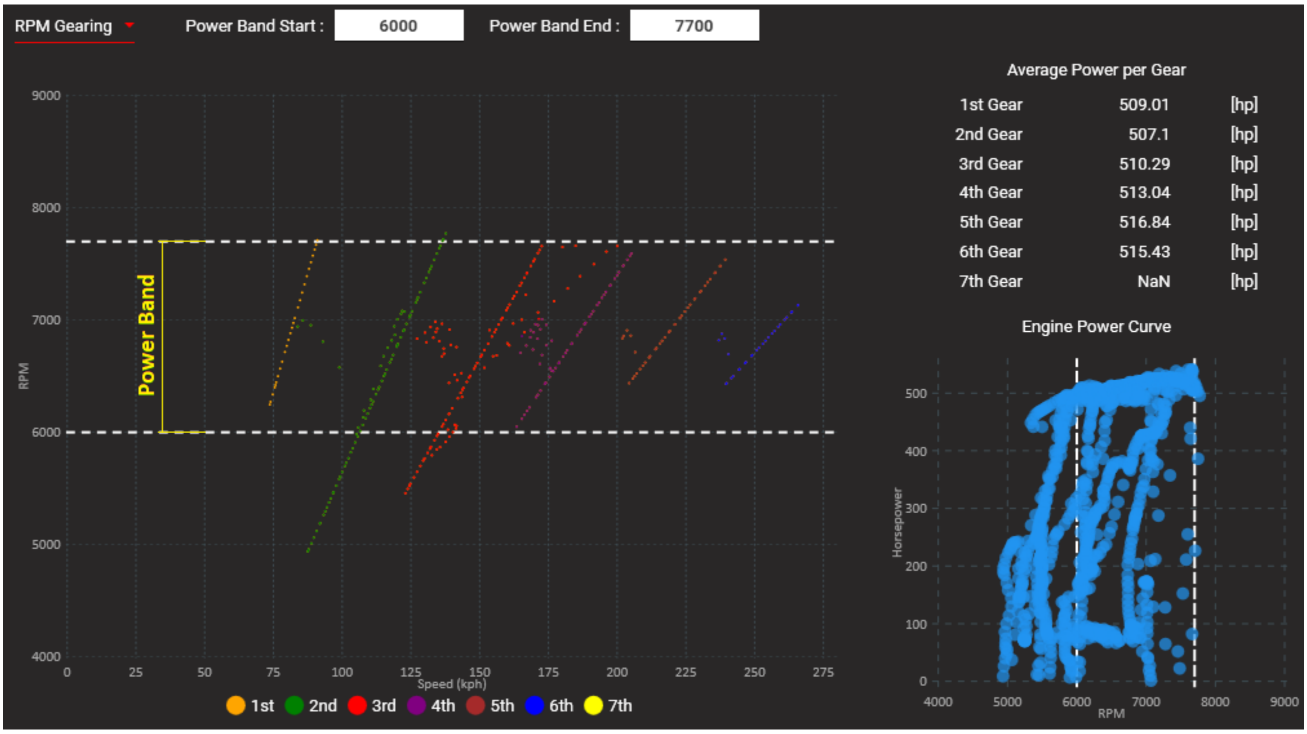

Figure 3.72: RPM Gearing Tab

As we already established, the power for this example car is mostly between 6000 and 7700 RPM, which is our target range that we've entered in the cells at the top and is indicated by the dashed white lines.

The speed – RPM plot shows an RPM range for second and third gear that starts below 5000 RPM. This means there's room for improvement in our gearing setup and that we should adjust it to get rid of these low RPMs. This could also be a result of too early upshifting though, so we may pay more attention to our shifting points.

We can also see that max RPM for fourth to sixth gear is lower compared to the other gears. This indicates that we're shifting up too early and not using the engines full potential.

Another indicator for good gear selection is the Average Power per Gear table. Obviously, your goal should be to maximize the power values displayed here. To achieve this you need to maximize the time spent in the power band range.

3.5.3. Theoretical RPM

To get the best possible corner exit, it is important to keep the engine in the correct RPM range (i.e. the correct gear) while cornering. This is what the Theoretical RPM chart is used for.

Figure 3.73: Theoretical RPM Chart

Based on our gearing setup, the chart calculates the theoretical RPM your engine would operate at for every gear at any point on the track.

Let's analyze an example corner and find out if taking it in a different gear might improve our corner exit:

Figure 3.74: Theoretical RPM Analysis per Corner

As we can see, the minimal RPM at corner apex are ~4900.

As indicated by the dashed white lines in the theoretical RPM graph we can conclude that taking this specific corner in second gear could lead to a better corner exit, as its minimal RPM would be right within the power band range.

3.6. Aerodynamics

With the Aerodynamics tab you can verify if your downforce is balanced between front and rear (CoP), if your ride height is correct and if the car's angle of attack (rake) is correctly set according to your downforce settings.

The optimal location to analyze aero data is right at the end of the fastest straight of the track where max top speed is reached (normally the start-finish straight).

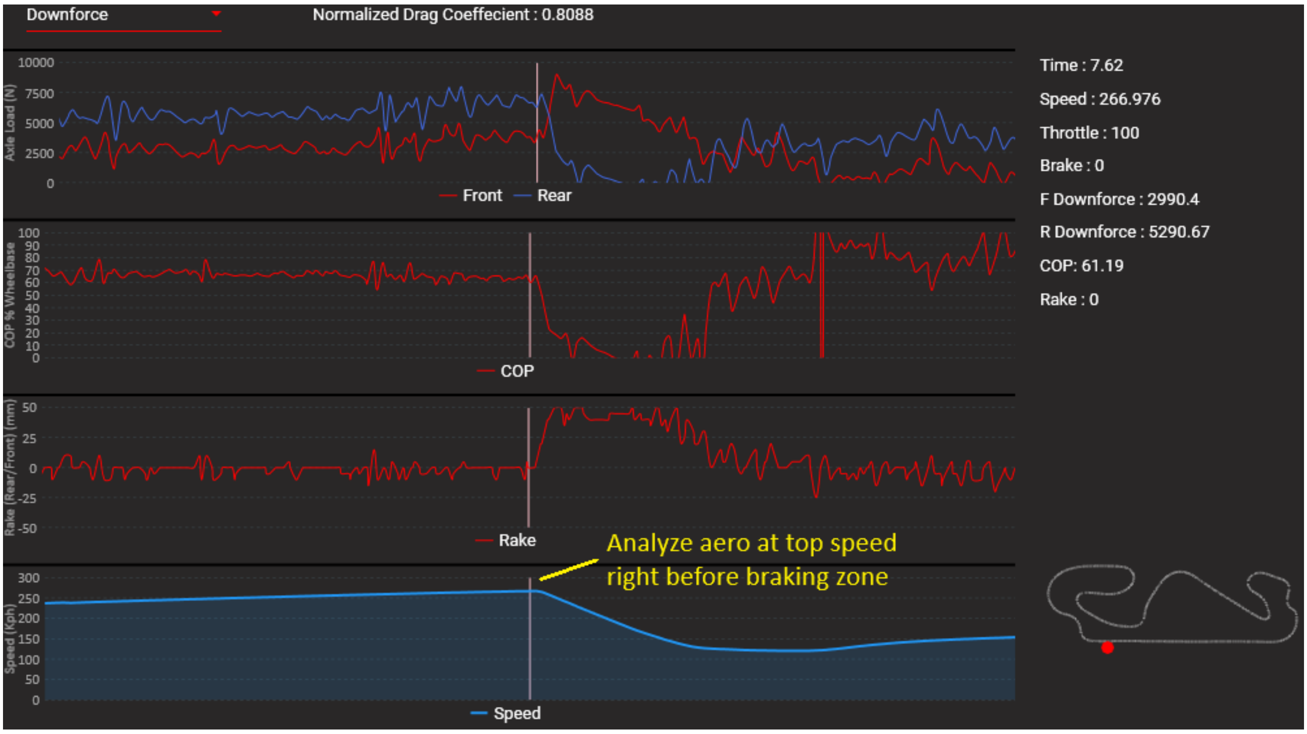

Figure 3.75 Aero Data Analysis at Top Speed

Quick Guide to Aero Analysis

1) Verify that your downforce is balanced by checking the Center of Pressure chart at the end of a straight.
2) Check your ride height to make sure you're not bottoming out and to find the perfect height for maximum downforce and minimal drag.
3) Analyze the rake angle of your car to make your diffuser work at maximum efficiency.
4) Use the maximal downforce levels to confirm that all your ride height and DF settings are correct.
5) Always re-check this section when you've changed your spring settings or ride height.
6) Check out the detailed aero tuning example in chapter 2.4 if you're struggling with the aero setup.

3.6.1. Ride Height

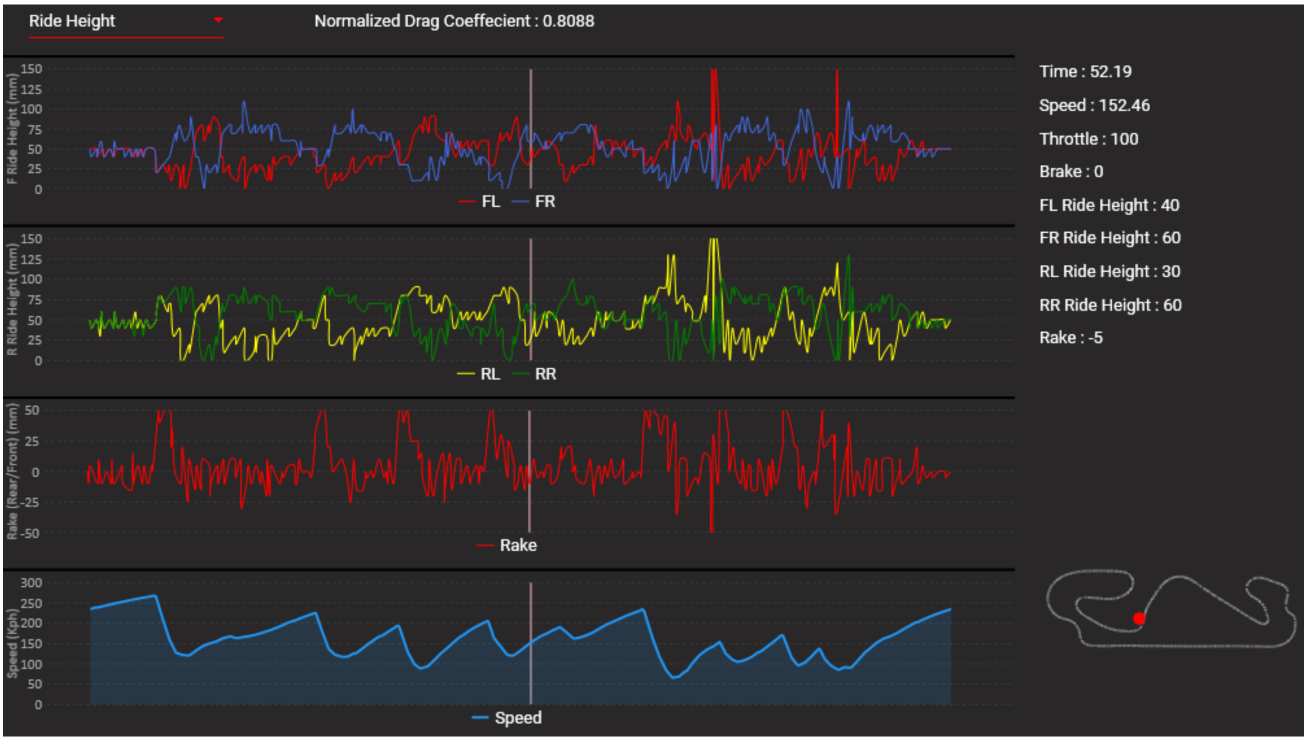

Figure 3.76: The Ride Height Screen

The main function of this screen is the optimization of ride height and angle of attack (rake) to improve aero efficiency and provide enough (but not excessive) ground clearance.

Front & Rear Ride Height Graphs

Figure 3.77: Front & Rear Ride Height Graphs

Use the Ride Height graphs to optimize (which means minimize in most cases) your ride height without extensively bottoming out over bumps and during cornering.

Besides having enough ground clearance, finding the correct ride height is also crucial to maximize the efficiency of your diffuser and to minimize drag.

Ride height too low: While front downforce is still working well at very low ride heights, your rear downforce will suffer because not enough air is reaching the diffuser.

Ideal ride height: At optimal ride height your aero is working most efficiently. Ground effect is working well, and enough air can reach the diffuser. This is the state you want to achieve.

Ride height too high: With too high ride height you will lose overall downforce. Reason is that too much air is bleeding out at the side skirts, which decreases the ground effect and the efficiency of your diffuser.

Unfortunately, there's no golden rule for actual ride height values when it comes to downforce tuning. Since every car is different, you'll have to try out which values will work best.

Important note: Ride height is measured at different locations in the various supported games and not necessarily at the lowest point of the chassis. So please be aware that this data isn't always comparable between games but more importantly, that **you can get chassis/aero damage from bottoming out although the data shows sufficient ground clearance.** In that case, increase your ride height to avoid damage from too low ride height.

The Rake Graph

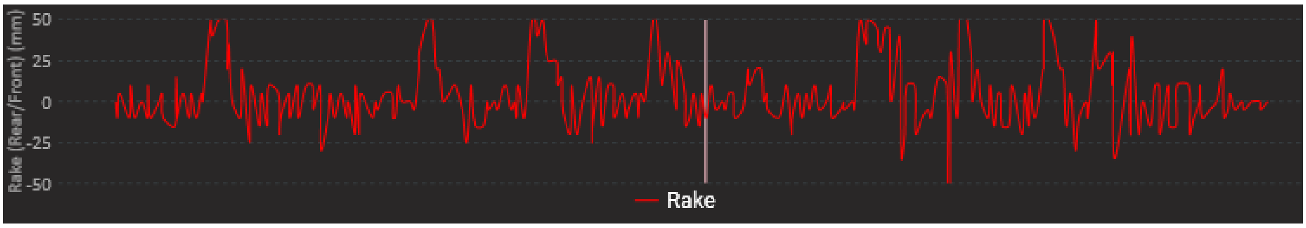

Figure 3.78: Rake Graph (Rear - Front Ride Height)

Setting up the optimal rake angle is crucial for high aero efficiency (maximal downforce and minimal drag).

For most cars it is recommended to aim for zero rake (front ride height = rear ride height) at top speed.

Rake angle too low:	When your rake angle is too low or even negative (front higher than rear) you will lose a lot of downforce and aero balance will shift to the rear, leading to high speed understeering. Either go lower at the front or higher at the rear axle, depending on your car's optimal ride height.
Ideal rake angle:	At optimal ride height your aero is working most efficiently. Ground effect is in full effect and enough air can reach the diffuser. This is the state you want to achieve.
Rake angle too high:	With a too high rake angle you will lose downforce mainly at the rear axle. This is caused by the diffuser stalling out because of its too high angle of attack, leaving you with almost just the downforce from your rear wing. Reduce rear ride height to get your diffuser working again.

As with ride height there's no absolute rule how to set up your rake angle. Some cars like a rake of 10+ mm at maximum velocity for optimal downforce while others work best with zero rake.

Depending on your spring rate and downforce settings you might even have to adjust your car's rake angle on a track to track basis. For example, if you'd lower your rear downforce you could still suffer from loss of top speed because the higher rake angle could increase the drag of your car.

Aside from aero balance, rake angle can also affect your car's overall OS/US tendency by altering of the roll axis inclination.

3.6.2. Downforce

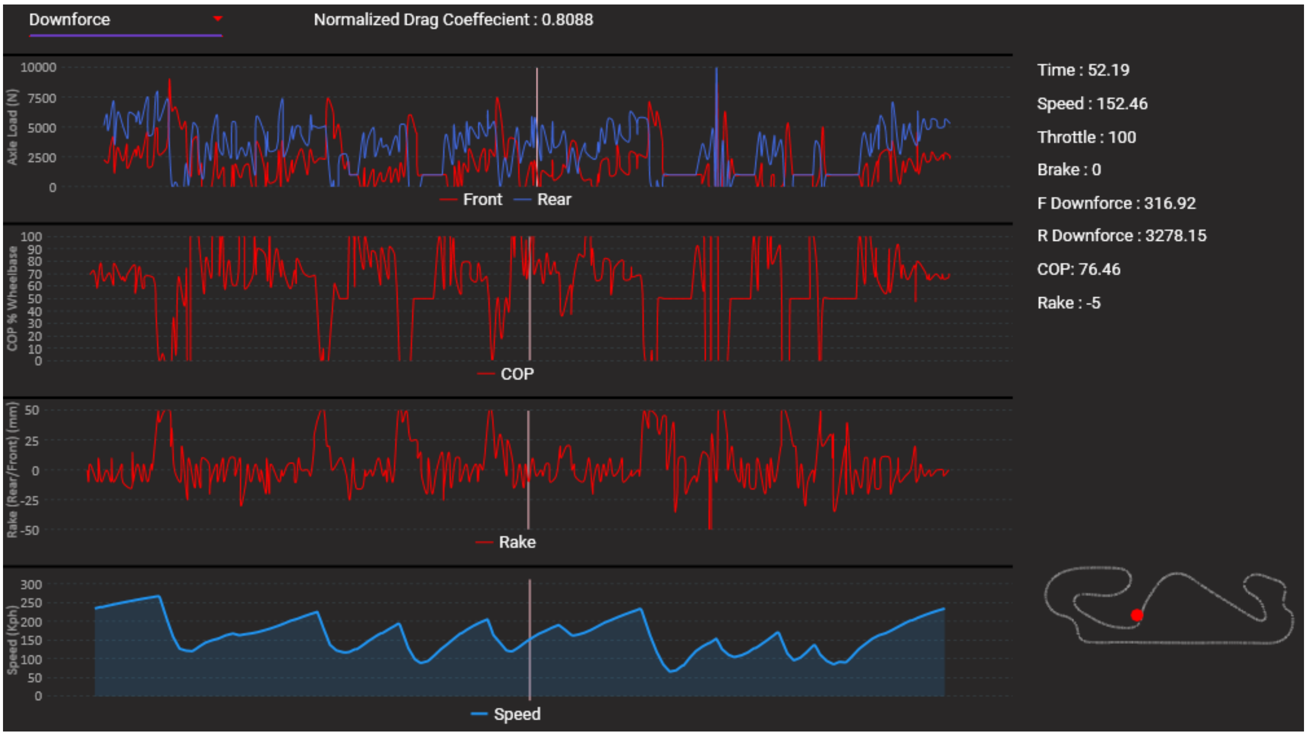

Figure 3.79: Downforce Analysis Screen

The Downforce screen's main purpose is the analysis of the aero balance and efficiency of your car. Make sure to check this screen after every significant suspension stiffness, ride height or wing adjustment.

<u>Front & Rear Axle Loads / Downforce</u>

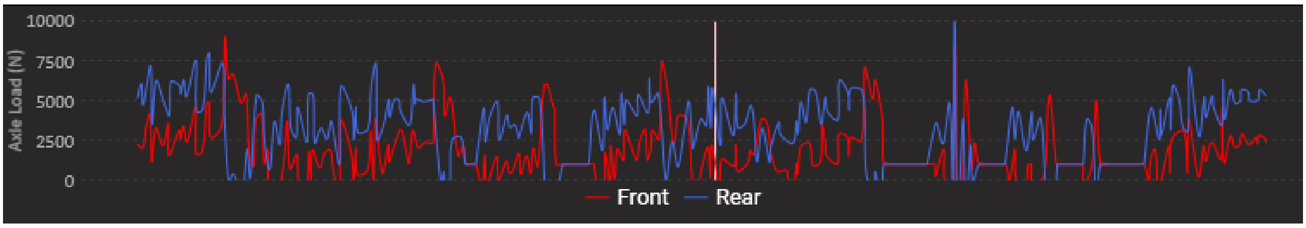

Figure 3.80: Front & Rear Axle Loads

The Axle Loads chart provides the downforce values for front and rear axles. Use it to analyze the effect of ride height, rake and wing adjustments on your car's aero efficiency.

It is important to know that the RST Software doesn't measure downforce values directly. The graphs you see in the Aerodynamics tab are actually normal forces of your tires with the car's own weight already subtracted (with the exception of AC and R3E where vehicle weight is included in the wheel loads).

That's why you will see spikes in braking zones and when driving over bumps or curbs. When analyzing downforce ignore those spikes and focus on straight-line high-speed sections.

Center of Pressure (CoP) Graph

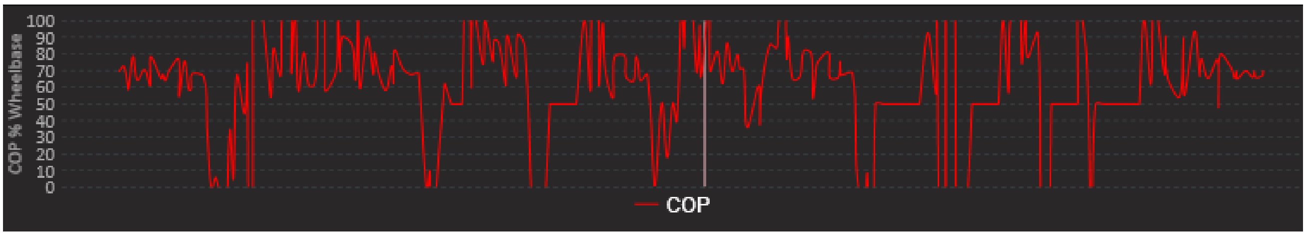

Figure 3.81: Center of Pressure (CoP) Graph

The CoP graph should be analyzed every time you're adjusting your aero or suspension setup to validate your aero balance. If you can set this up correctly your car will show similar behavior at all velocities.

The CoP % values are defined as:	>50%	→	Rearward bias
	<50%	→	Forward Bias

As a rule of thumb, the CoP should be located **5 – 10% further to the rear than the car's longitudinal weight distribution**.

Forward Aero Bias:	With a forward aero bias your car will feel loose (oversteering) at high speeds which can result in loss of traction. Either lower the front or increase the rear aero to balance this out.
Balanced Aero:	A balanced aero means your car is behaving predictable through fast corners (if your suspension setup is balanced). This is normally the state you'd want to achieve when tuning your aero.
Rear Aero Bias:	When your rear wing value is set too high, the center of pressure will shift towards your rear axle during acceleration. This will cause high speed understeering which will compromise your high-speed cornering ability.

Additional Notes on Aero Efficiency

In aerodynamics, there is a topic called aerodynamic efficiency which is defined as C_L/C_D.

C_L/C_D is the Coefficient of Lift over the Coefficient of Drag (aka Lift-to-Drag-Ratio). A diffuser typically has a higher aerodynamic efficiency than a wing. If you are looking to optimize your downforce, your goal should be to get the most downforce you can from rake by finding the ideal angle that lets your diffuser work at its maximum efficiency and then using wings to refine it further.

When you perform it this way, you will get more lift with less drag at the same time.

If you use this method of determining the downforce, it is absolutely required to control the attitude of the car, because slight variations in rake will cause you to lose downforce very quickly.

Therefore, you typically see high downforce cars using very stiff springs to keep a stable aero platform, and a lot of rebound damping, because it controls the unsprung weight of the car body.

This way, when you hit a curb you won't go flying off into a field because you lost all your downforce.

Notes on 3rd Springs

Most high downforce cars have an additional spring as a setup option. Its primary function is to help control the chassis platform in order to keep consistent aerodynamic performance. High heave rate settings will result in less ride height change while the car rides over bumps and while the downforce is increasing as vehicle speeds go up versus softer heave rate settings.

The key in adjusting this component is finding the appropriate amount of stiffness to help aide the aerodynamics while maintaining an adequate amount of front mechanical grip.

At faster tracks the best compromise might be to use a very stiff heave rate and give up some mechanical grip in exchange for better aerodynamics control, whereas at much slower tracks where raw tire grip would take precedence, perhaps less heave rate would be required.

Use the third spring to keep a stable aero platform while still maintaining comparatively low roll stiffness for more mechanical grip at lower velocities.

3.6.3. Downforce Efficiency

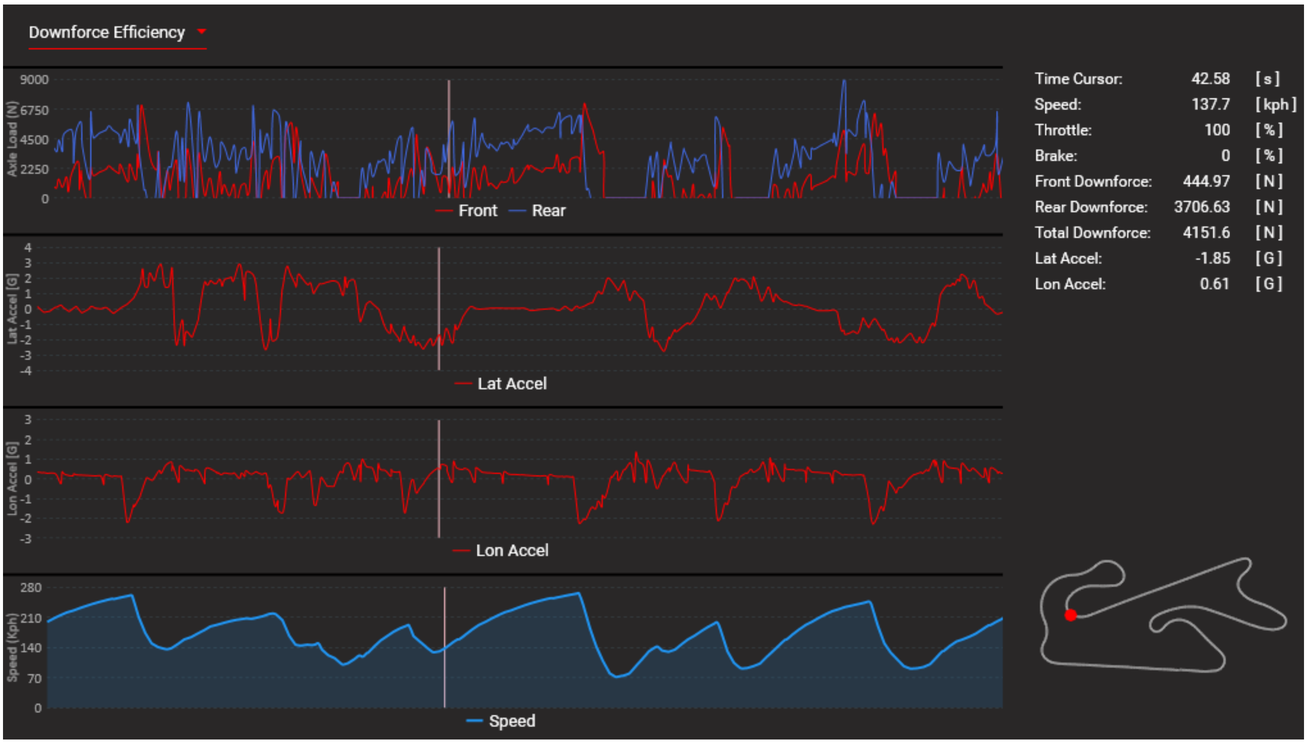

Figure 3.82: Downforce Efficiency Screen

With this screen you can judge the car's grip potential via lateral and longitudinal accelerations depending on your aero (and mechanical) setup. Those acceleration charts are the base of the Traction Circle (see chapter 3.4.5) but let you analyze vehicle performance per corner.

Front & Rear Axle Loads / Downforce

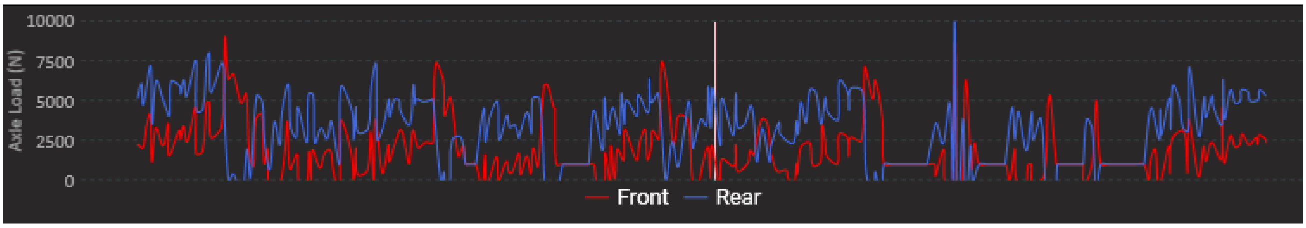

Figure 3.83: Front & Rear Axle Loads

The Axle Loads chart provides the downforce values for front and rear axles. Use it to analyze the effect of ride height, rake and wing adjustments on your car's aero efficiency.

It is important to know that the RST Software doesn't measure downforce values directly. The graphs you see in the Aerodynamics tab are actually normal forces of your tires with the car's own weight already subtracted (with the exception of AC and R3E where vehicle weight is included in the wheel loads).

That's why you will see spikes in braking zones and when driving over bumps or curbs. When analyzing downforce ignore those spikes and focus on straight-line high-speed sections.

Lateral and Longitudinal Acceleration Graphs

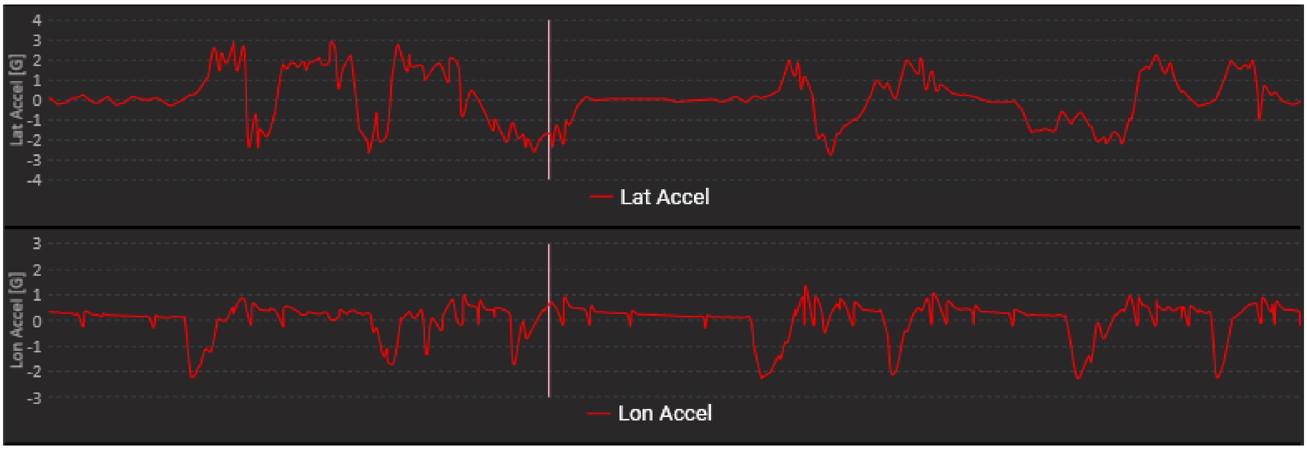

Figure 3.84: Lateral and Longitudinal Acceleration Graphs

Use those graphs to analyze the car's cornering (Lat Accel) and braking and acceleration potential (Lon Accel).

The lateral accelerations are defined as:	Positive	→	Right hand turn
	Negative	→	Left hand turn
The longitudinal accelerations are defined as:	Positive	→	Acceleration
	Negative	→	Braking

The following table shows some basic rules of thumb, how your car's performance will change depending on your setup choices, based on the track profile:

Track Section	Low Downforce Setup Slow Track	Low Downforce Setup Fast Track	High Downforce Setup
Acceleration	+Lon. Acceleration (Low drag)	+Lon. Acceleration (Low drag)	-Lon. Acceleration (High drag)
Braking	-Lon. Acceleration (Low drag)	-Lon. Acceleration (Low drag)	+Lon. Acceleration (High drag)
Slow Corner	+Lat. Acceleration (Softer suspension → Higher mechanical grip)	-Lat. Acceleration (Stiffer suspension → Lower mechanical grip)	-Lat. Acceleration (Stiffer suspension → Lower mechanical grip)
Fast Corner	-Lat. Acceleration (Low Downforce)	-Lat. Acceleration (Low Downforce)	+Lat. Acceleration (High Downforce)

There are many exceptions to those basic rules like cars with 3rd springs for example that can keep a stable aero platform and high mechanical grip at the same time.
Another exception can be a stiffer suspension setup which in theory has less mechanical grip but can still be faster through tight corners because of its increased responsiveness.

3.7. Temperatures

3.7.1. Tire Temps

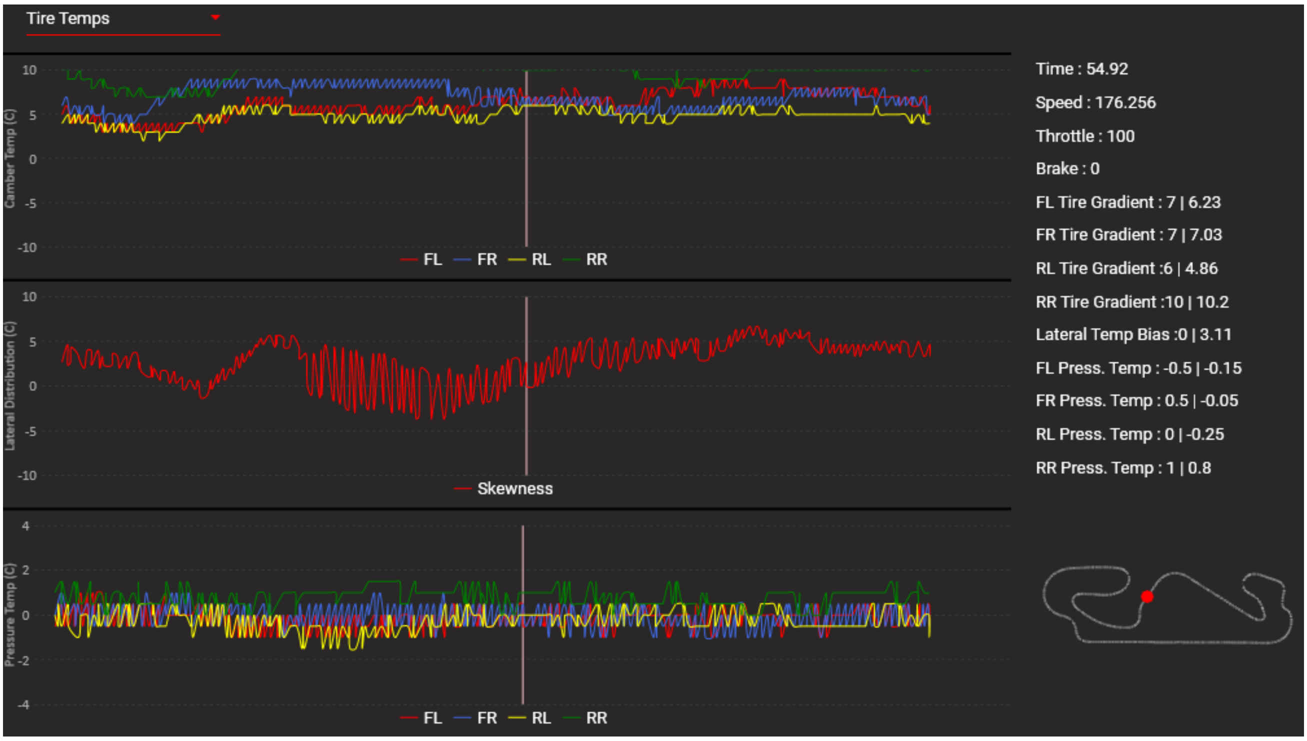

Figure 3.85: Tire Temperature Tab

This screen will help you adjust your tire pressures and camber angles to maximize the contact patch area in corners and analyze the cornering balance of your car through the Lateral Temperature Bias Chart.

<u>Camber Temperature Chart</u>

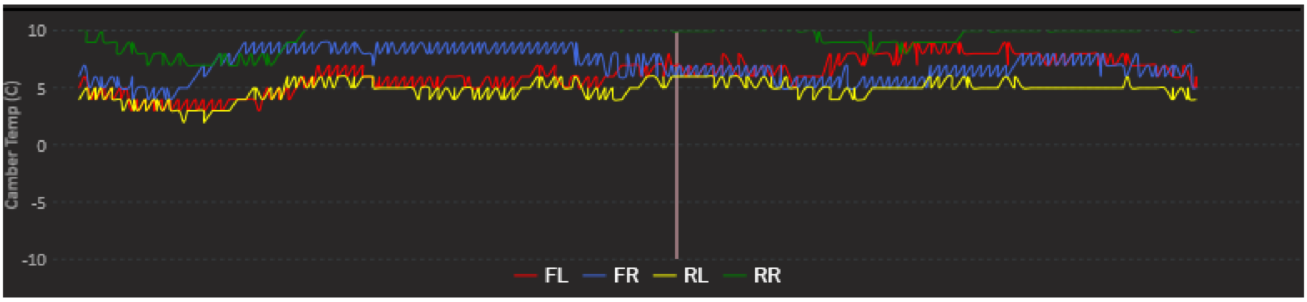

Figure 3.86: Camber Temperature Chart

This chart displays the temperature difference between the inside and outside shoulder of each tire.

The temperature difference is defined as: Positive → Inside hotter than outside

Negative → Outside hotter than inside

Your target should be to get the lap average values (right column in data table) between +5°C and +10°C to maximize the contact patch area in corners. You can use **asymmetric camber angles** to achieve this but that's **highly track dependent**.

Example 1: Autódromo do Algarve has multiple medium fast to fast right hand turns and basically only slow left-hand turns. For this track you should set a higher negative camber on the left wheels to increase cornering ability in those fast corners and a low negative camber on the right wheels for more mechanical grip in the slower corners.

Example 2: Spa Francorchamps has multiple fast and slow, left and right corners. Since you'd want to have similar cornering performance through all those turns you should stick to a more symmetrical camber setup at this track.

Another possibility to tweak your camber setup is to **lower rear camber angles**. This can **improve your acceleration** on corner exit because of the increased contact patch area.

Roll Stiffness vs. Camber Angle Change

When you increase your roll stiffness by installing stiffer springs or antiroll bars, the change of camber angle during cornering will decrease, which means you should adjust your camber angles with every suspension stiffness change.

Low Roll Stiffness: The lower your roll stiffness the higher your camber skewness will be. To compensate for this you'll have to increase your camber angles. If you choose to run asymmetric camber angles, the difference between left and right camber must be higher

High Roll Stiffness: With higher roll stiffness your camber angle will change less at the same lateral acceleration. On top of that, your camber skewness will be reduced, which means that you can run more symmetric camber angles.

Pressure Temperature Chart

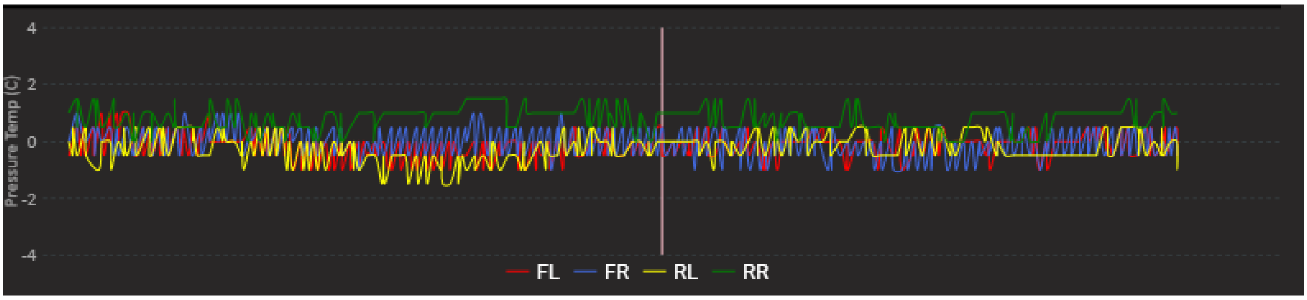

Figure 3.87: Pressure Temperature Chart

The goal with the Pressure Temperature chart is to get the lap average values (right column in data table) as close to zero as possible. This will guarantee that your pressures are evened out between all four tires and your contact patch area is maximized during cornering.

Be aware though that you're not seeing actual pressure but temperature differences here. A value of -1°C for example doesn't mean you should increase pressure by 1 BAR/PSI but that the middle temperature of your tire is too low compared to the outside and inside temperatures.

Note: Depending on the track you're driving on it might be beneficial to over- or under inflate your tires.

On **fast tracks** like Le Mans or Monza you should **increase your pressures** to profit from the **reduced rolling resistance, which will increase your top speed**.

On **slower tracks** like Long Beach you should **lower your pressures** to get **more mechanical grip in slow corners**.

Lateral Temperature Bias Chart

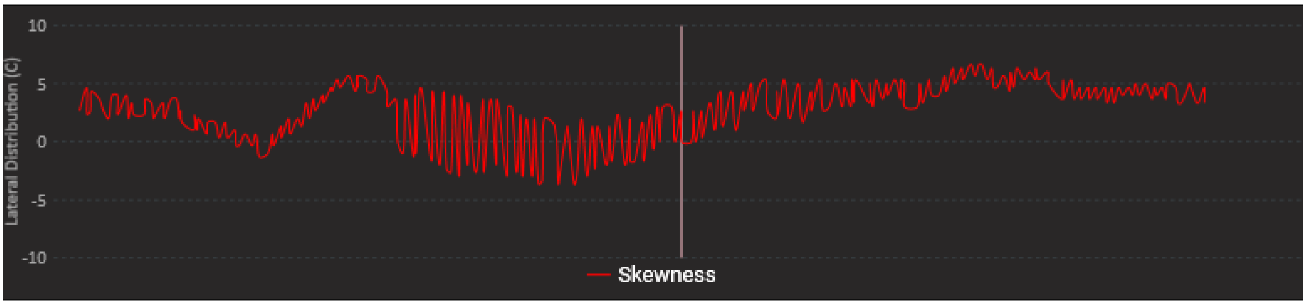

Figure 3.88: Lateral Temperature Bias Chart

This chart reflects the ratio between front and rear tire temperature delta. Since this temperature difference is an indicator of lateral load transfer you can evaluate lateral stiffness bias and therefore cornering balance of your car.

The temperature bias graph is defined as: Positive → Front temperature / stiffness bias

Negative → Rear temperature / stiffness bias

For balanced cornering performance you should **aim for a lateral temperature bias close to zero**.

Balancing Front/Rear Skewness

Balancing the skewness between your front and rear tires basically means fine tuning your car handling by changing the stiffness distribution between front and rear axle. In theory you can adjust a lot of things in your setup to achieve this: Spring bias, aero balance, differential locking, antiroll bars or rake angle.

Now, changing your well-balanced spring bias to even out your temperatures has negative side effects, so you probably don't want to touch that. Aero won't help you in slow corners so it's not an effective tool for this most of the time. And adjusting your differential locking doesn't work well either because its effect is torque dependent.

This basically leaves you with two options to fine tune your car handling: Antiroll bars and rake.

Antiroll Bars:

The two main functions of the antiroll bars (ARB) are increasing the overall roll stiffness of your suspension and balancing the lateral load transfer distribution between front and rear axle.

If you want to move your stiffness bias rearwards, you should either soften your front ARB or stiffen your rear ARB and vice versa.

The amount of lateral load transfer is constant, no matter how soft or stiff your ARB setup is. The reason for this is that **lateral load transfer is independent from your roll stiffness.**

Based on this fact you can conclude that your **ARBs can only balance the lateral load distribution between front and rear axle, but not reduce it overall.**

Reducing the overall lateral load transfer can be achieved by lowering your ride height, which moves the center of gravity closer to the track.

Rake Angle:

Another tool to adjust your temperature skewness (and therefore handling balance) is to change your rake angle. Increasing your rake will raise the roll center height on your rear axle, which will result in better turn in ability.

There's a downside though. Contrary to stiffer antiroll bars, a higher rake angle can increase the total lateral load transfer (because it slightly raises the center of gravity too) and therefore will lower your cornering grip.

Another downside is that a change of rake angle can alter your aero balance and even lower your overall aero efficiency. That's why this option should preferably be used in low downforce cars that are less aero dependent.

3.7.2. Brakes

Use the Brake Temperature chart to keep your front and rear brakes in the optimal temperature range.

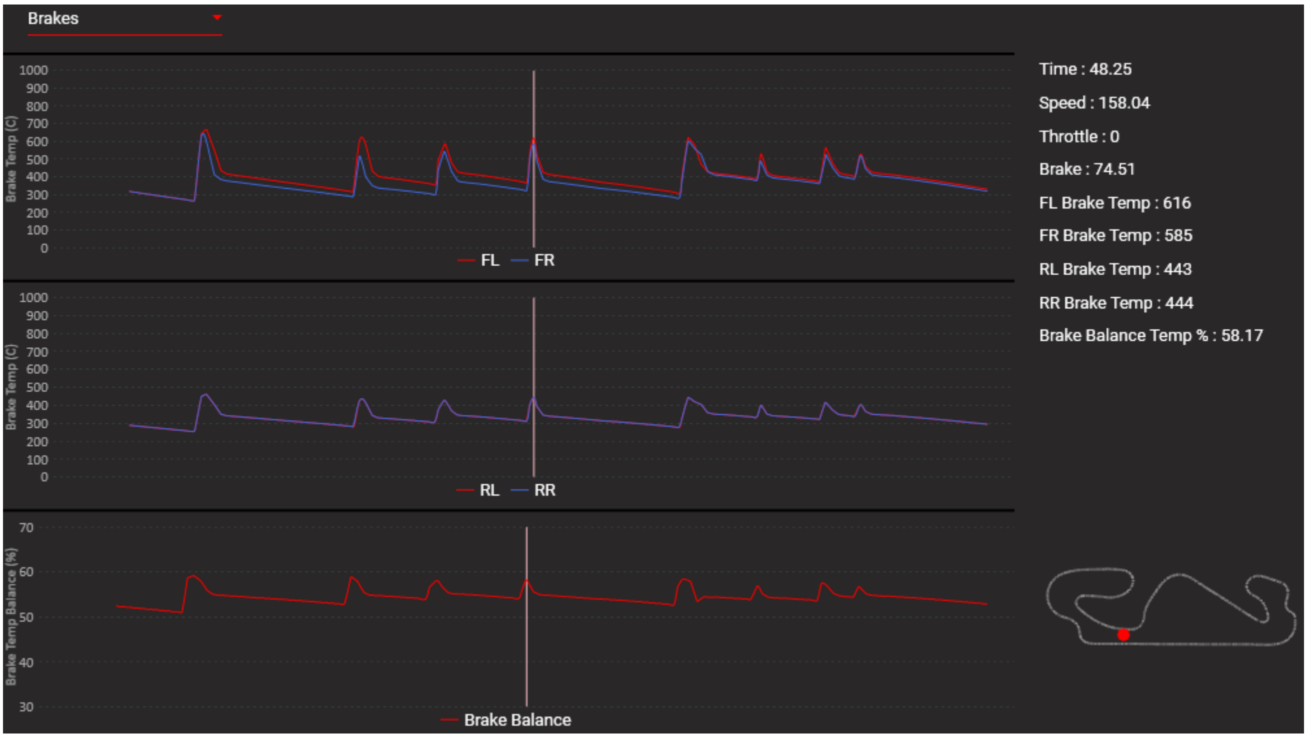

Figure 3.89: The Brake Temperature Chart

Optimal operating temperatures for iron brakes are between 350-650°C but you're still getting >95% brake performance at 750°C. Above 750°C their performance will basically fall off a cliff, so try to stay below that.

Carbon-carbon brakes work well for temperatures up to 1200°C.

The brake temperature balance graph displays the front / rear brake temperature ratio.

This ratio is defined as:	>50%	→	Hotter front brakes
	<50%	→	Hotter rear brakes

As a result of the brake balance tuning (see chapter 3.3.3) the front brakes will be loaded more in most cases, which results in a forward brake temperature bias. To counter this, you can close the rear brake ducts more. Be aware though that the increased temperature will raise your tire pressures.

3.7.3. Absolute Temps & Pressures

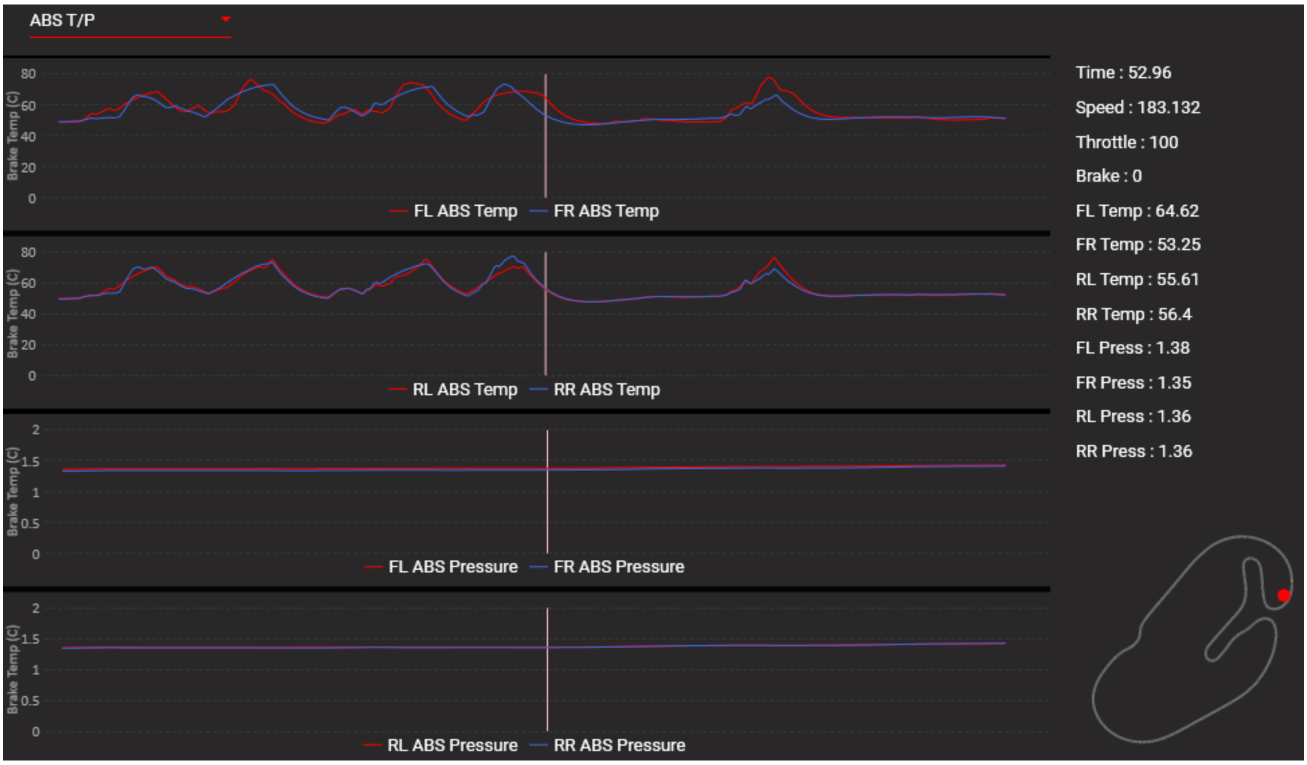

Figure 3.90: Absolute Temperatures and Pressures

On this screen you'll see the absolute tire temperatures and pressures and how they develop over the course of a lap.

The optimal temperature and pressure values can differ significantly between the various supported games, but the following recommendations should be a good starting point.

Basic tire temperature recommendations:

Soft Slicks:	~80-90°C
Hard Slicks:	~90-105°C
Rain Tires:	~60°C

To evaluate the optimal temperatures, analyze tire performance with the Optimal Tire Temp run chart (see chapter 3.9.5)

Basic tire pressure recommendations:

Formula Cars:	1.7bar front / 1.45bar rear (24psi / 21psi) at road circuits. Oval/speedway tires up to 45psi on the right side.
Modern GT & LMP:	~1.8bar front and rear. Down to 1.6bar for a very slow track like Long Beach. Up to 1.90-1.95bar at Le Mans for less rolling resistance.
Touring cars & V8 Supercar:	2.0-2.15bar front and rear
Ford Fusion:	2.4-2.6bar front and rear for road courses. On ovals up to 3.0bar+ (45-50psi) on the right side.
Light sportscars:	~1.6bar (24psi)
Road car tires:	All in the 2.1-2.2bar (29-32psi) range hot.
Vintage GT:	~1.8bar front and rear.
Vintage Group 6:	~1.7bar (25psi) up to 2.0bar (29psi) or
Vintage Formula:	~1.7bar (25psi) down to 1.2bar (17psi).

To evaluate the optimal pressures, analyze the Pressure Temperature chart (see chapter 3.7.1).

3.7.4. Engine Temps

The Engine Temperature chart displays the oil and water temperatures of your engine.

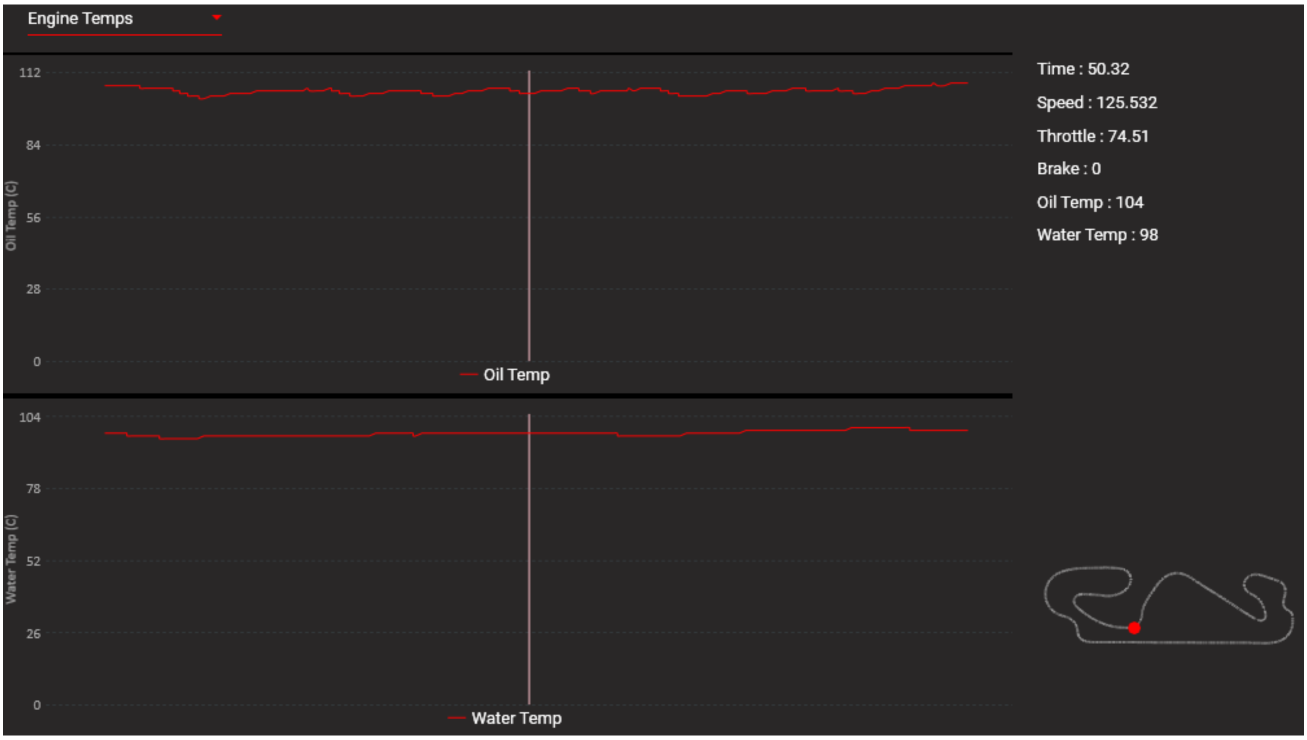

Figure 3.91: Oil and Water Temperature Charts

Keep the oil temperature below 120°C and water temperature below 105°C to prevent engine damage over time. You can control the engine temperatures with the radiator opening in your car setup.

3.7.5. Environmental

The Environmental chart shows track and ambient temperatures and the air density of the current track.

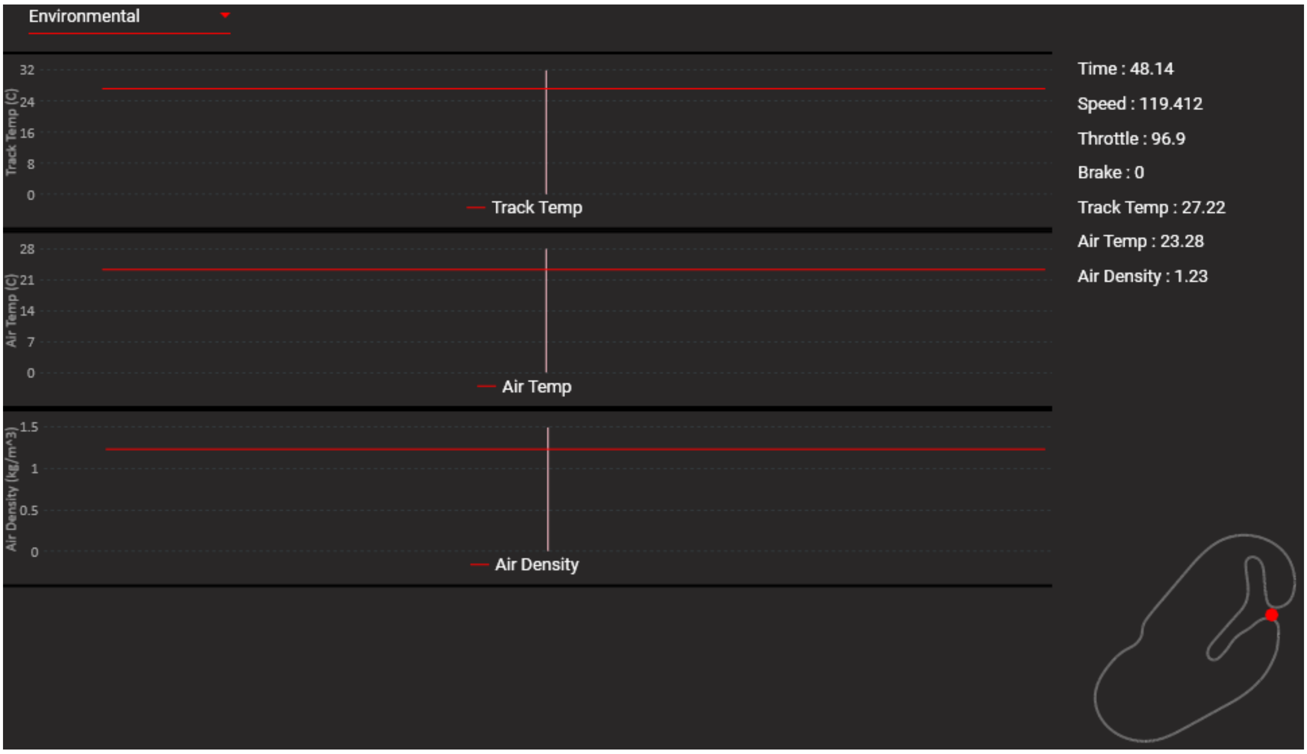

Figure 3.92: Environmental Temperature and Air Density Charts

Track and ambient temperatures are mostly dependent on race date, time of day and weather. They can have a significant impact on engine, brake and tire temperatures so make sure to choose the correct tire compound and radiator / brake duct openings for the current ambient conditions.

Air density is mainly affected track altitude. The higher the altitude the lower air density will be. Lower air density can reduce your aero efficiency, so it’s possible that you need a more aggressive aero setup at Red Bull Ring compared to Long Beach for example.

3.8. Track

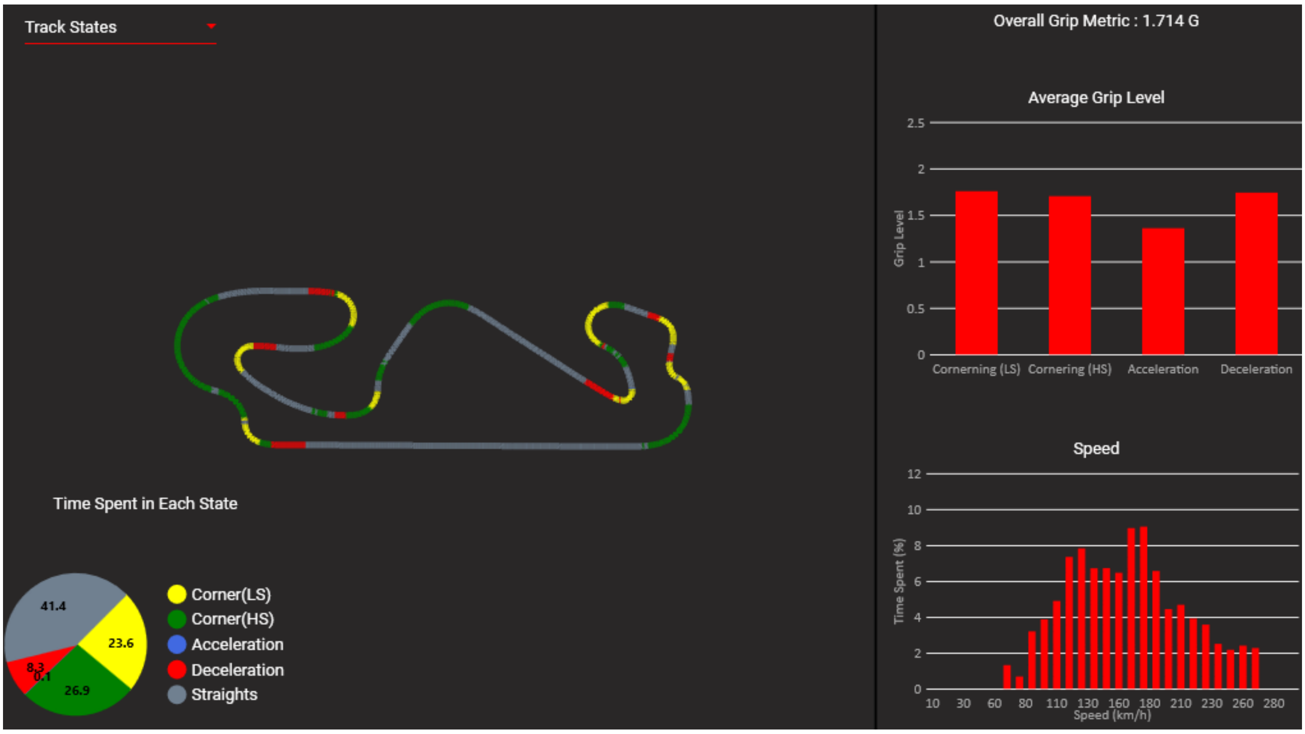

Figure 3.93: The Track Chart

The Track chart is mainly used to evaluate the track profile and tells you if a high or low downforce configuration should be preferable or if you're lacking mechanical grip.

Track Map

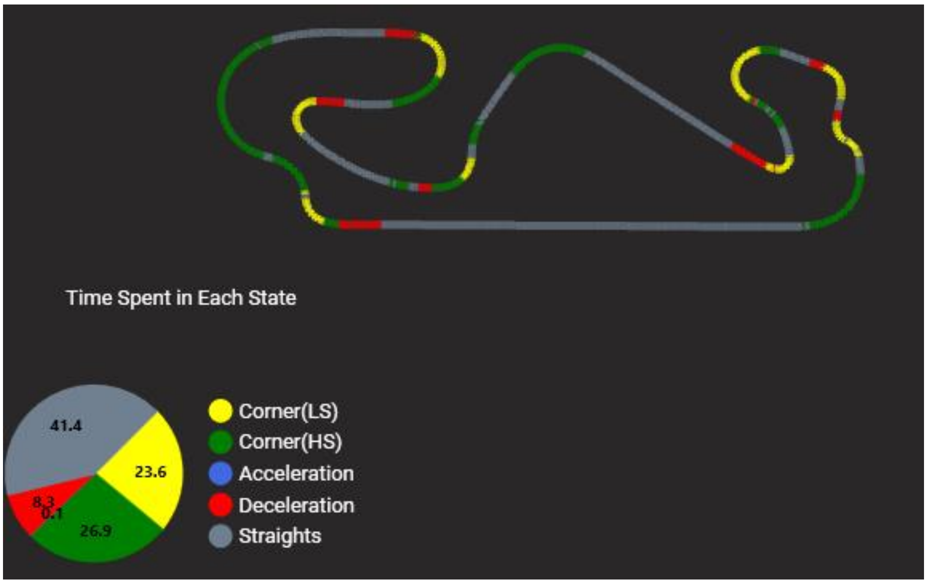

Figure 3.94: Track Map

The track map itself comes with multiple functions to evaluate track profile, bumpiness brake and throttle application and many more. Those functions will be explained in the following chapters.

You can pan the track map by moving the mouse while holding down the RMB and zoom in and out with the mouse wheel.

Average Grip Level Chart

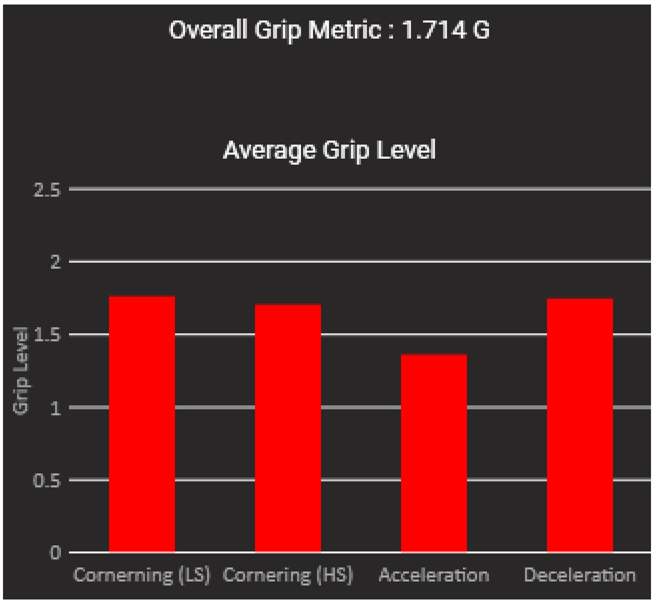

Figure 3.95: Average Grip Level Chart

This chart shows the average grip potential of your car for the various states (slow corners, fast corners, acceleration and braking) and an overall grip metric, which defines the average grip level of all the aforementioned states.
Your goal should be to maximize the overall grip metric by raising your car's grip level on the most important states, based on the track profile (see chapter 3.8.1).

Speed Histogram

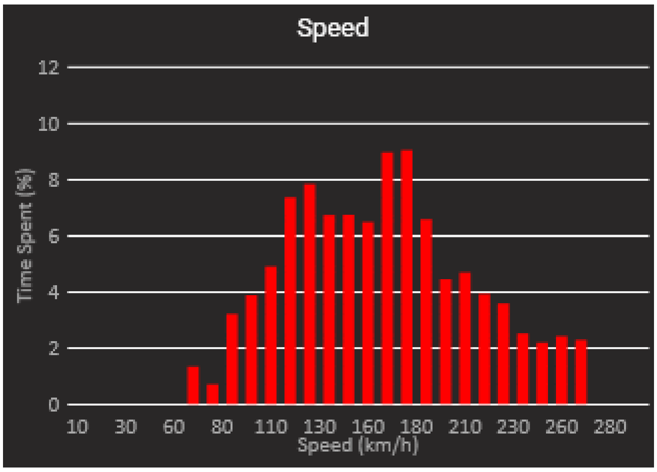

Figure 3.96: Speed Histogram

The speed histogram tells you how much time your car spends in a specific speed range. You should use it to determine if you need a longer or shorter gearing setup and (partly) how important your aero setup will be on this specific track.

Lap Comparison

For better driver and setup analysis you can compare the track maps of two different laps. To compare laps, you just need to select a base lap by ticking the box in the lap tree and then select the lap you want to analyze, as shown in the image below:

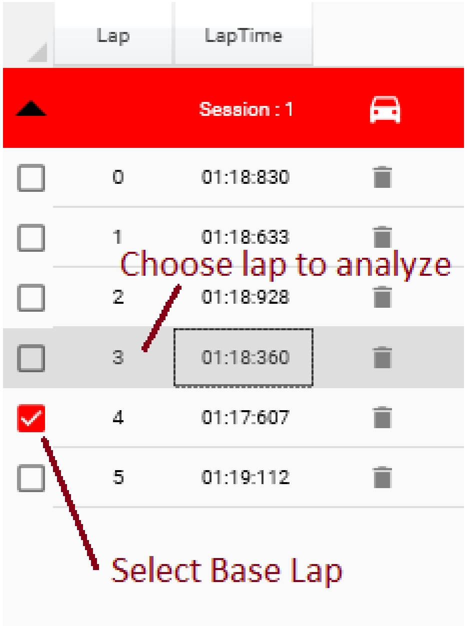

Figure 3.97: Lap Selection

Once both laps are selected, you can compare the data of the base lap (outside) and the currently selected one (inside), as shown in the example image below.

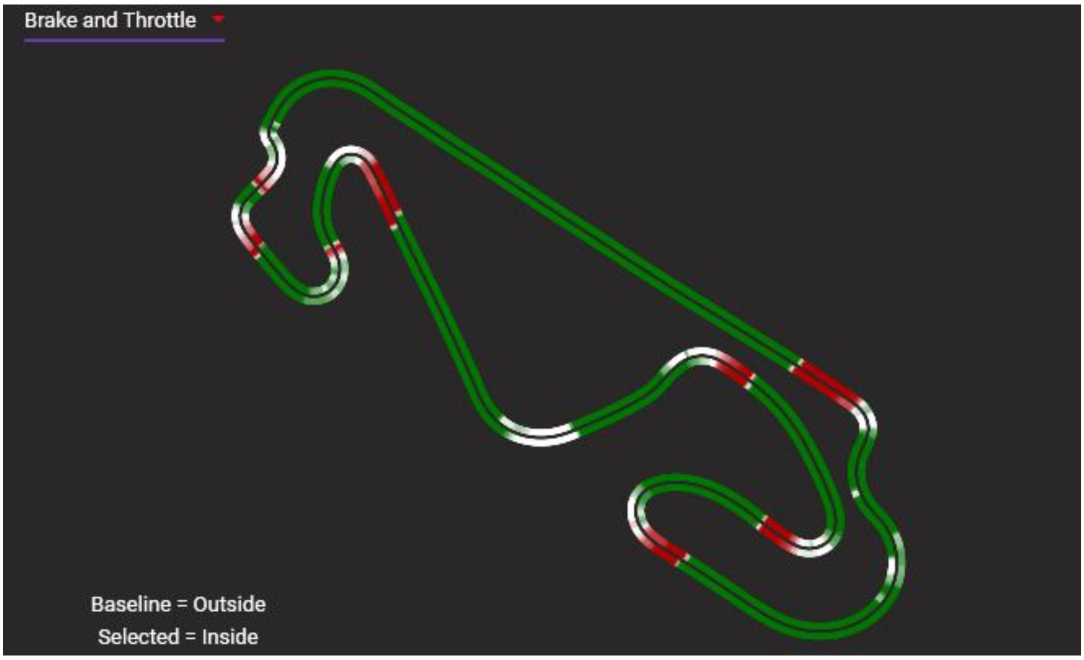

Figure 3.98: Track Map Comparison Example

3.8.1. Track States

The Track States map is one of your main tools to analyze the track profile. It'll tell you how much time the car spends in low speed and high-speed corners, on straights and on acceleration and braking.

Let's look at the track map of Catalunya GP, a typical high downforce track:

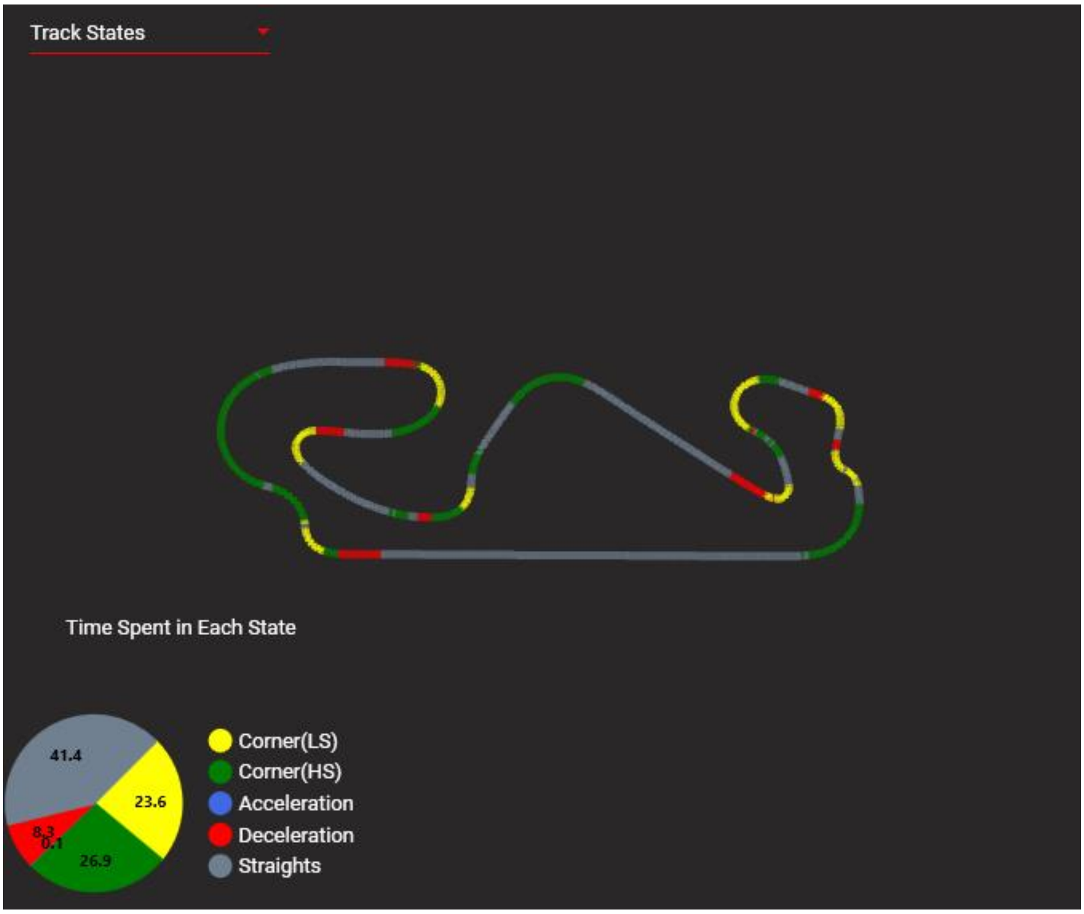

Figure 3.99: Track States of a High Downforce Track

As you can see there are quite a lot of high-speed corners on this track (>25%) which means your aero setup will be playing a big factor in overall performance. The time spent in straight line driving is relatively low, so additional drag from higher downforce will not slow you down too much.

On the other hand, you'll need good mechanical grip for all those slow corners, so you'll need to find a compromise between a stable, high DF aero setup (stiff suspension) and mechanical grip (soft suspension).

Now let's compare this to a low downforce track like Daytone Roadcourse:

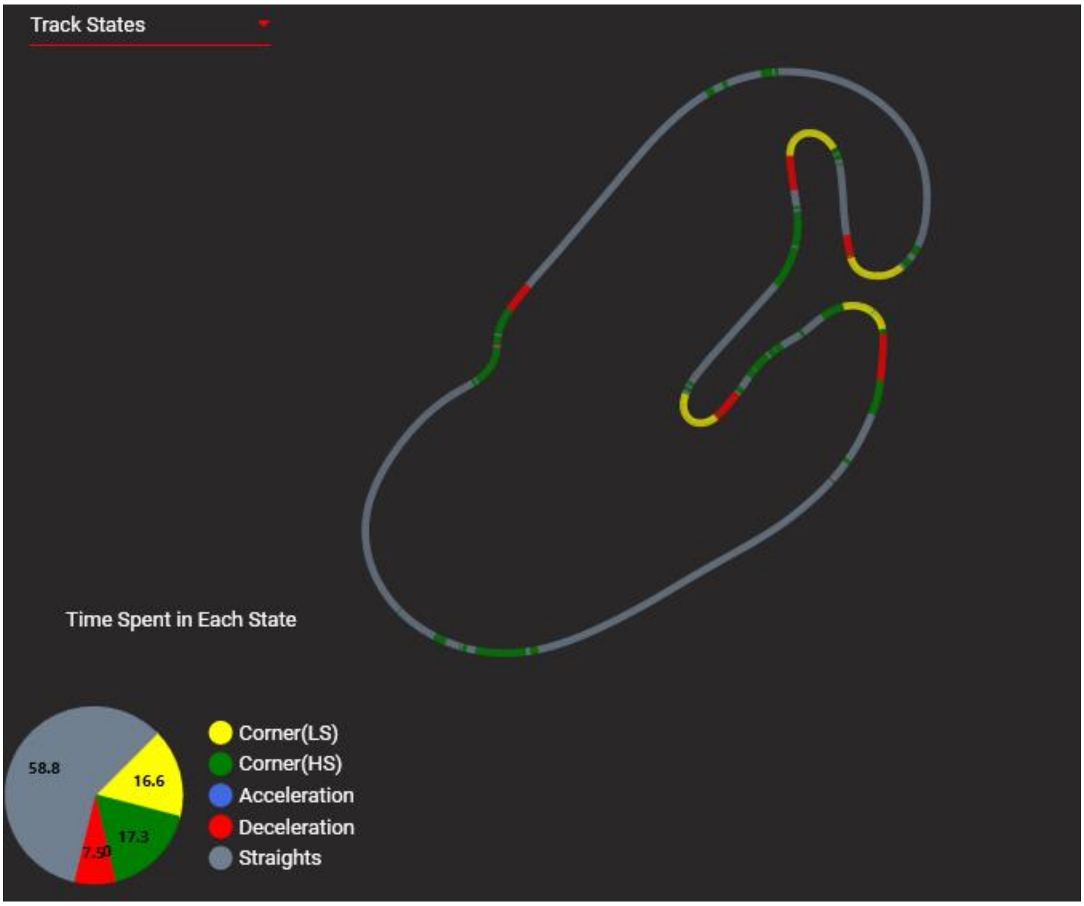

Figure 3.100: Track States of a Low Downforce Track

Compared to Catalunya, the rate of straight-line driving is significantly higher (58.8% > 41.4%) and time spent cornering is reduced. On top of that it could be argued that some high-speed corners displayed on the map can easily be taken flat out and therefore could count as straights too.

In conclusion, you should focus on reducing drag for higher top speed and good mechanical grip in the slower infield section.

3.8.2. Brake and Throttle

As the title indicates, you can analyze brake and throttle application in this map mode to spot setup and driving style issues like early braking points or too long coasting phases and to judge driver consistency.

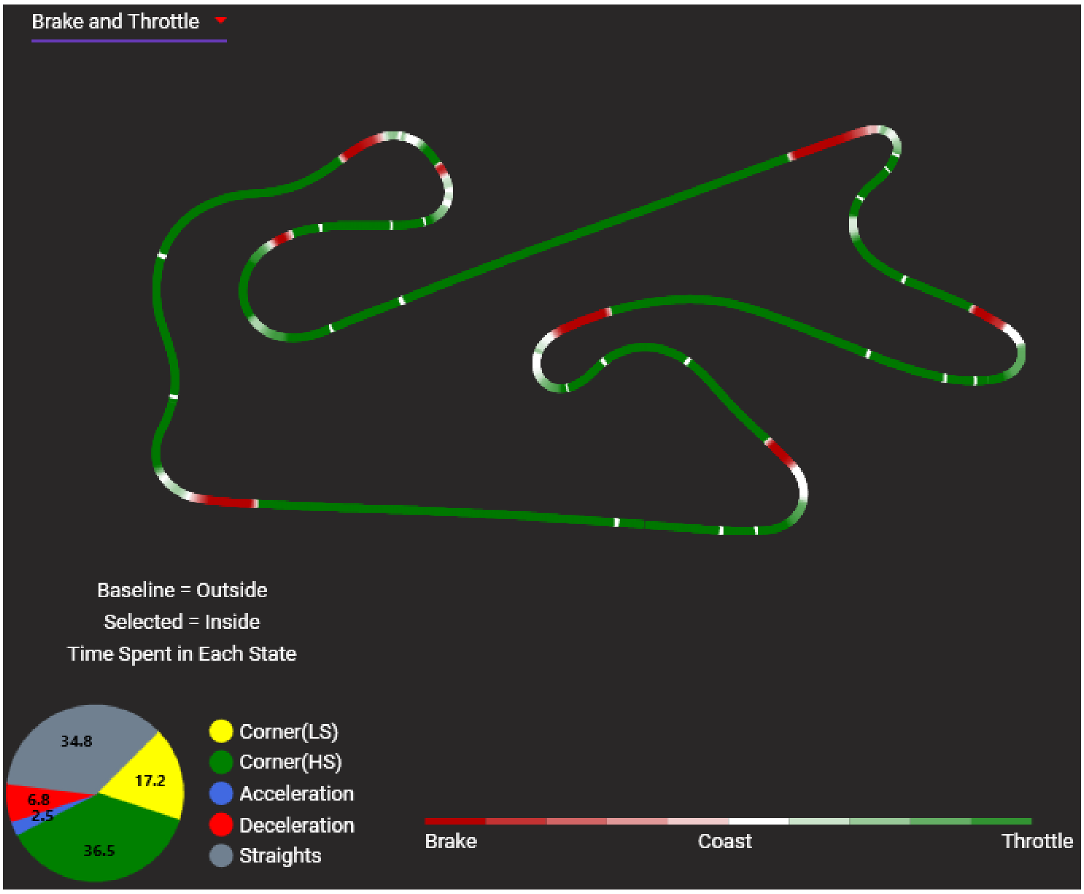

Figure 3.101: Brake and Throttle Application Track Map

The color code for this track map is:

Red	→	Braking
White	→	Coasting
Green	→	Throttle

The lap comparison tool is especially useful in this map mode to locate points on the track where you're losing time. It's essentially a visualization of the Time Slip chart (see chapter 3.10.1).

In the following example, the baseline lap was significantly faster than the selected lap and the reasons for this can be spotted easily.

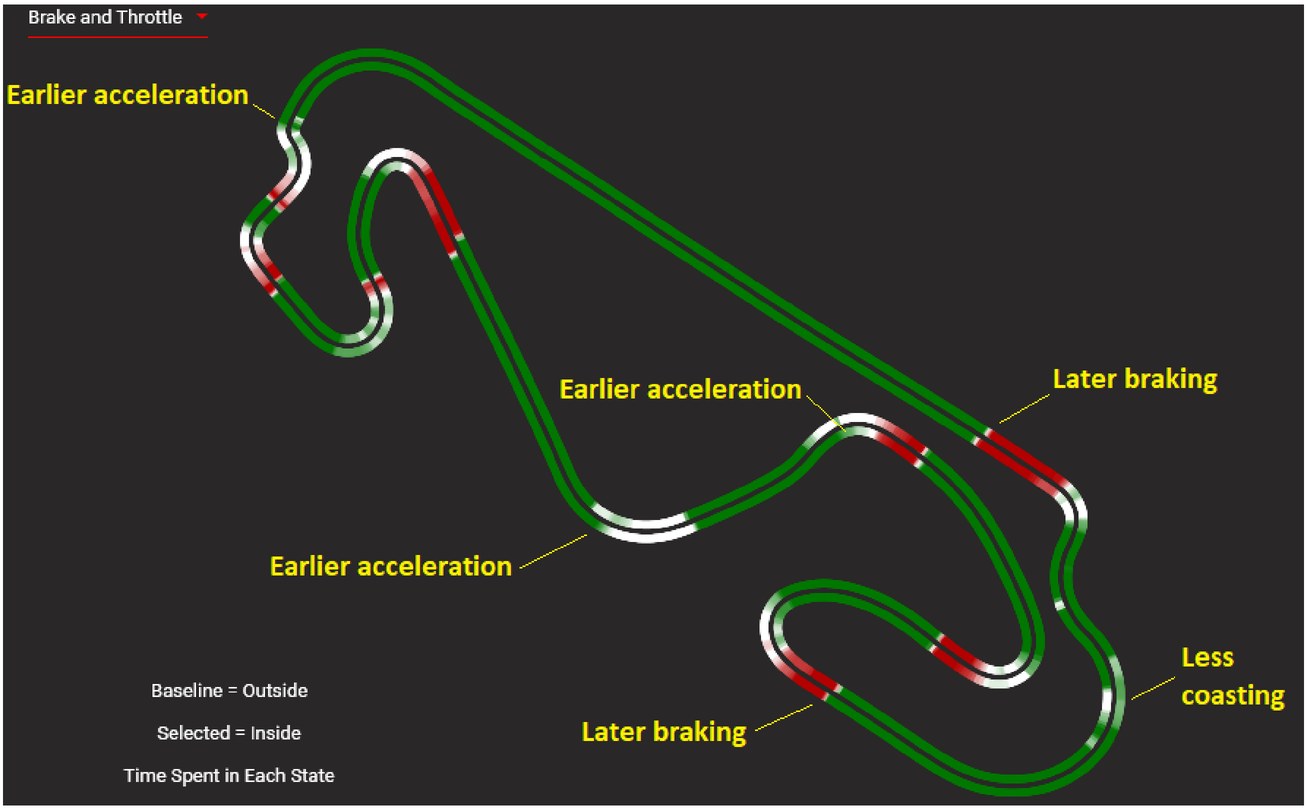

Figure 3.102: Comparing Brake and Throttle Application

There are even more corners where the driver is gaining time in the baseline lap that aren't marked here. You can confirm those through the Time Slip chart (see chapter 3.10.1).

3.8.3. Differential Locking / Unlocking

The Differential Locking map mode shows the sections of the track where there's a wheel slip difference in the driven wheels, indicating that the differential is unlocked.

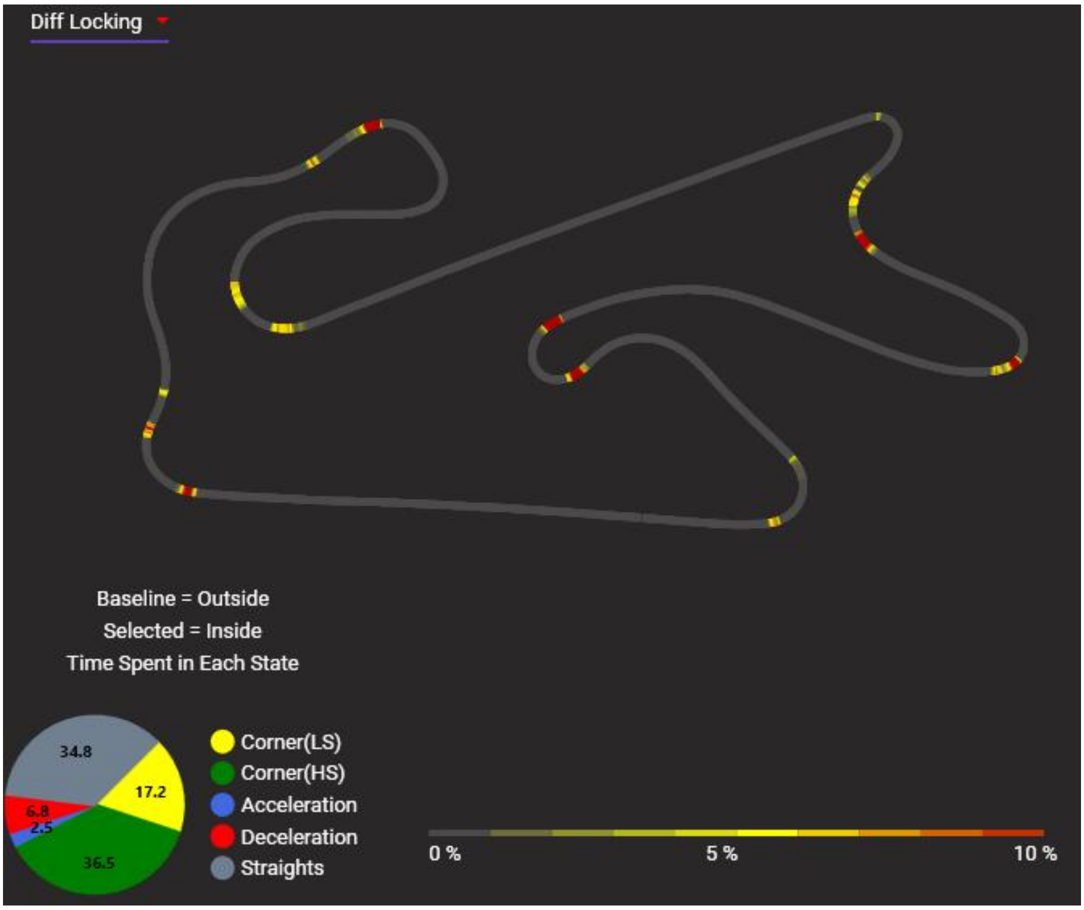

Figure 3.103: Differential Locking Track Map

This map is a visual representation of the Wheel Slip Diff. Graph from the Differential tab (see chapter 3.3.3) and can be used to analyze and tune the differential, especially (but not exclusively) in corners.

For more info about differential tuning, please check out the Differential Locking Analysis section in chapter 3.3.3 (pages 92 – 99).

3.8.4. Track Bumpiness

With this map you can evaluate the bumpiness of the track surface. It is a visual representation of the damper speeds that you can analyze with the Damper Speed chart, as mentioned in chapter 3.3.4.

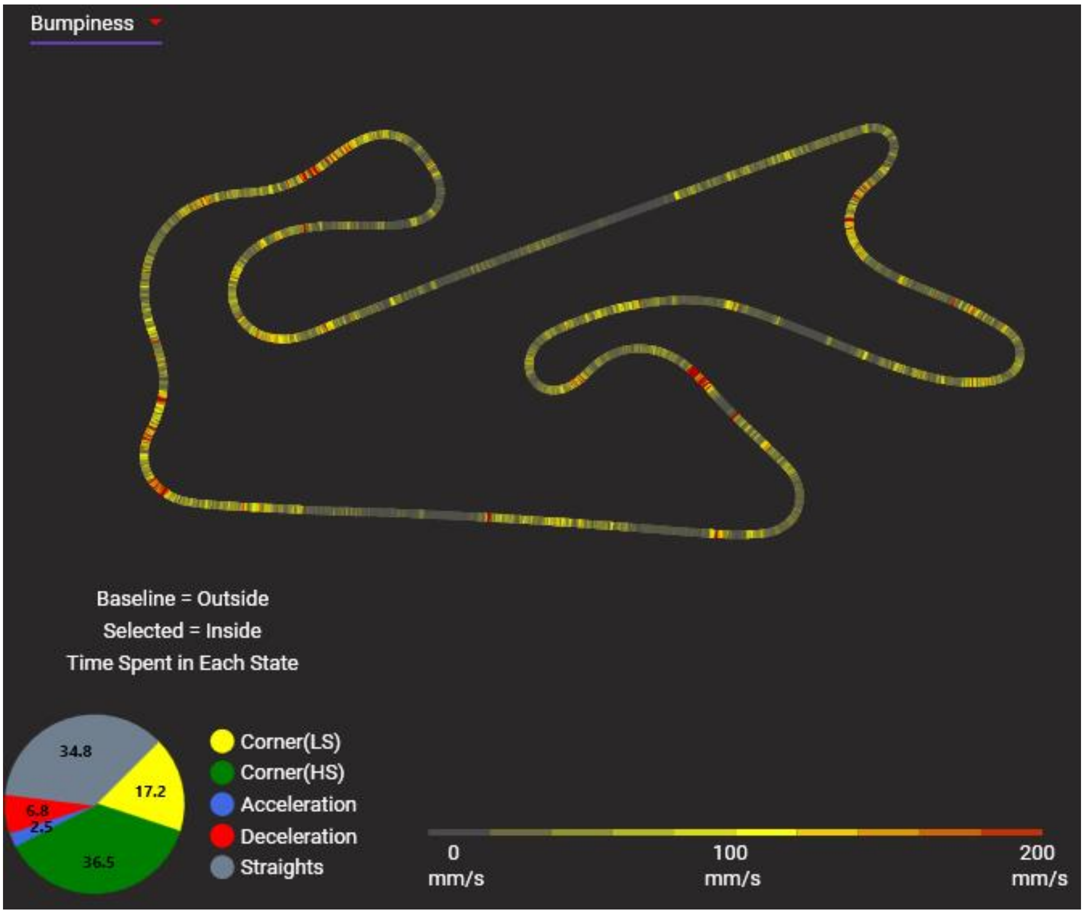

Figure 3.104: Visualization of Track Bumpiness

Use this map for spring and damper setup tuning.

The bumpier a track is the softer your suspension and the more refined your high-speed damping setup should be.

In addition to determining the general track bumpiness, you can use this map to spot where you're hitting the curbs aggressively, on purpose or by accident.

In the following example image, you can see how the driver gains and loses time by attacking the curbs:

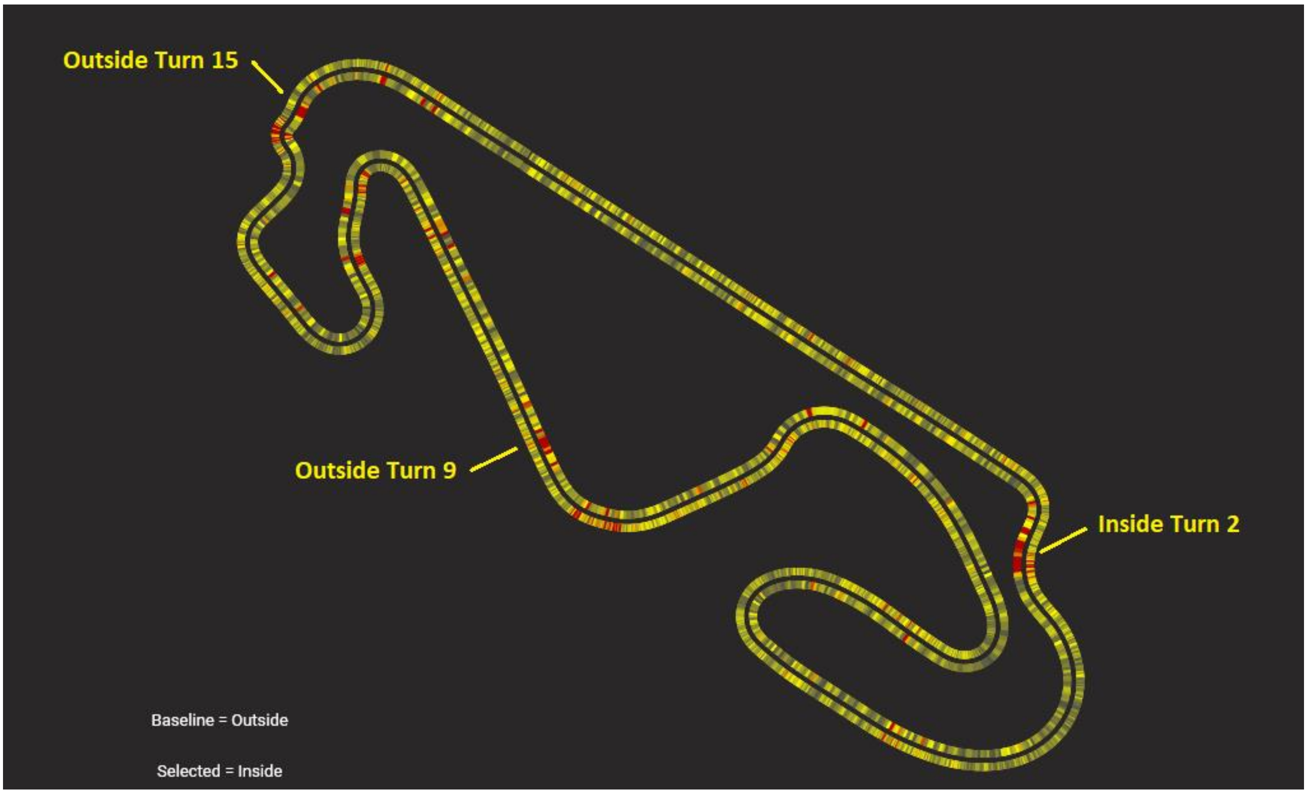

Figure 3.105: Cornering Analysis by Spotting Attacked Curbs

Inside Turn 2:	In this turn the car hits the inside curb hard which unsettles the suspension and forces the driver to back off the throttle and therefore lose time compared to the baseline lap.
Outside Turn 9:	Here the driver uses the whole track width by driving over the outside curb and gains time thanks to the higher corner exit speed.
Outside Turn 15:	Once again the driver uses the outside curbs at the exit of this turn to achieve a higher corner exit speed for the long start-finish straight.

3.8.5. Lateral Acceleration

This map mode expresses the car's cornering performance by showing the lateral acceleration at every point of the track.

The example image below displays the cornering performance of an Audi R18 running a high downforce setup at the Dubai Grand Prix track:

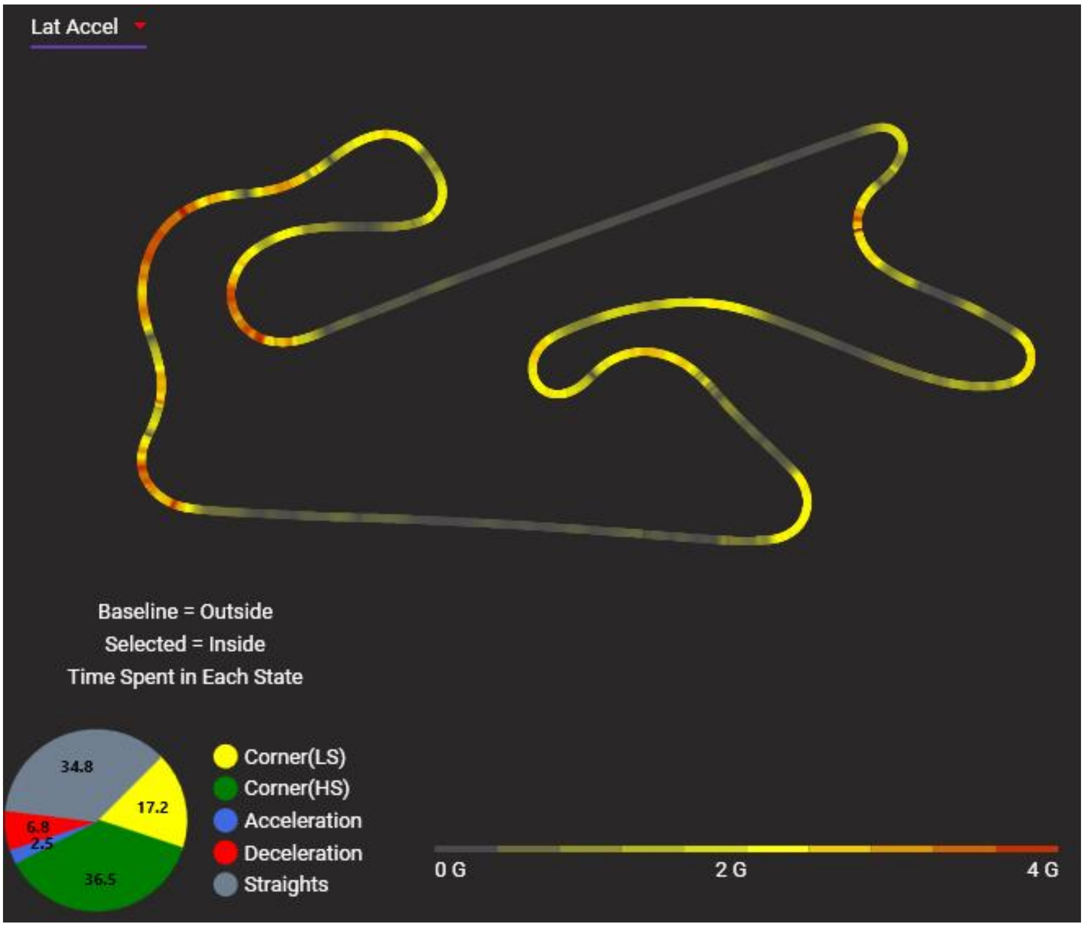

Figure 3.106: Lateral Acceleration Track Map

As you can see, the car negotiates the high-speed corners at up to 4 G which is quite impressive.

This map mode is mainly used to optimize your aero setup for high speed corners and should be analyzed in conjunction with the traction circle (see chapter 3.4.5) to increase the car's lateral grip potential.

3.8.6. Speed

The Speed track map displays the car's velocity at any given point on the track and is a visualization of the Speed Trace chart (see chapter 0).

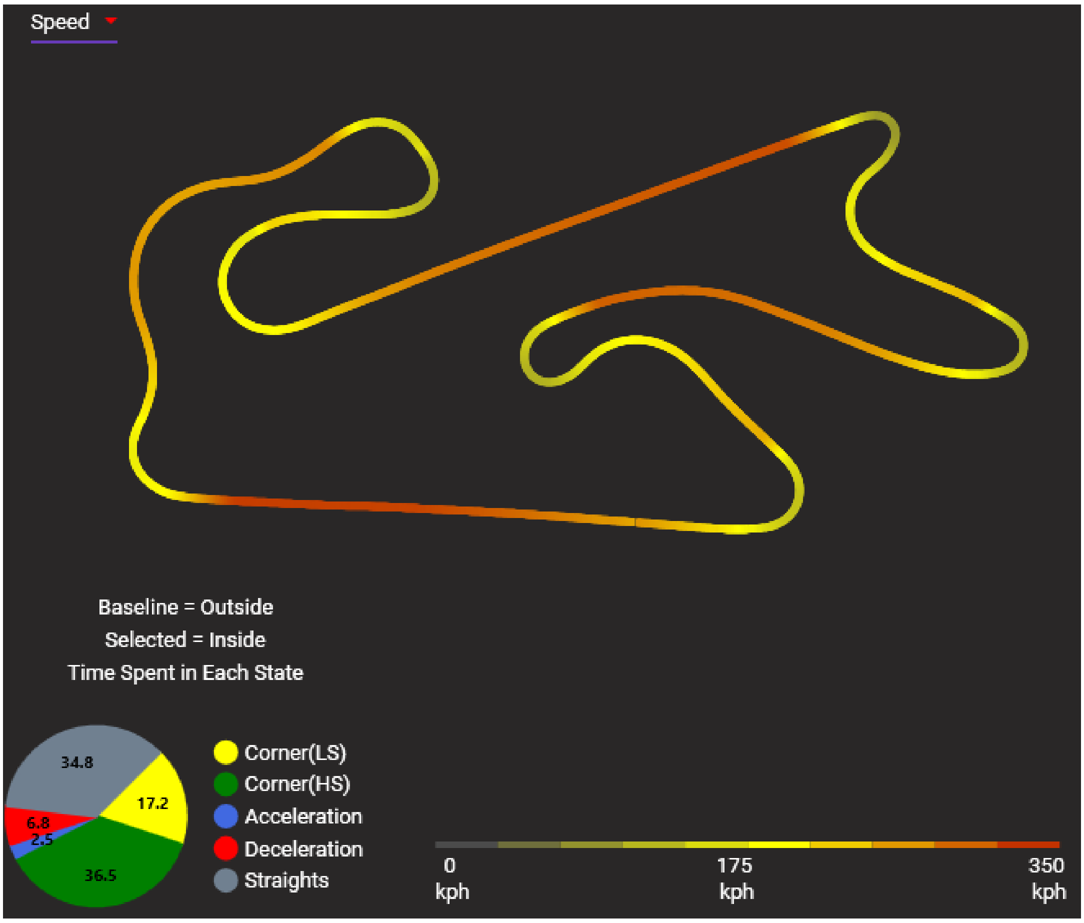

Figure 3.107: The Speed Track Map

This map mode is mainly used to optimize your aero (by minimizing drag) and gear ratios.

Similar to the Track States map (see chapter 3.8.1) it's also very useful to analyze the track profile and determine if a low or high downforce setup should be preferred.

3.9. Run

Run charts are a great tool to examine the car's (and driver's) performance and consistency over a whole session. Having a quick hotlap setup for qualifying is great but it won't help you win the race if it overheats and wears out your tires after just a few laps. Run charts allow you to look at the data from a wider angle and help recognizing trends (deteriorating tire performance) and anomalies (driving errors). To judge your car's performance, consistent driving is important. If you're not familiar enough with a car/track combination, the run chart data will be skewed and therefore less useful.

For this chapter we'll be comparing two different sessions of identical cars (including setup) but with different tires (soft and hard slicks).

3.9.1. Total Grip

The Total Grip run chart is one of the key indicators for car performance and how it changes over the course of a session and reflects the Total Grip Metric displayed in the Track tab in chapter 3.8.

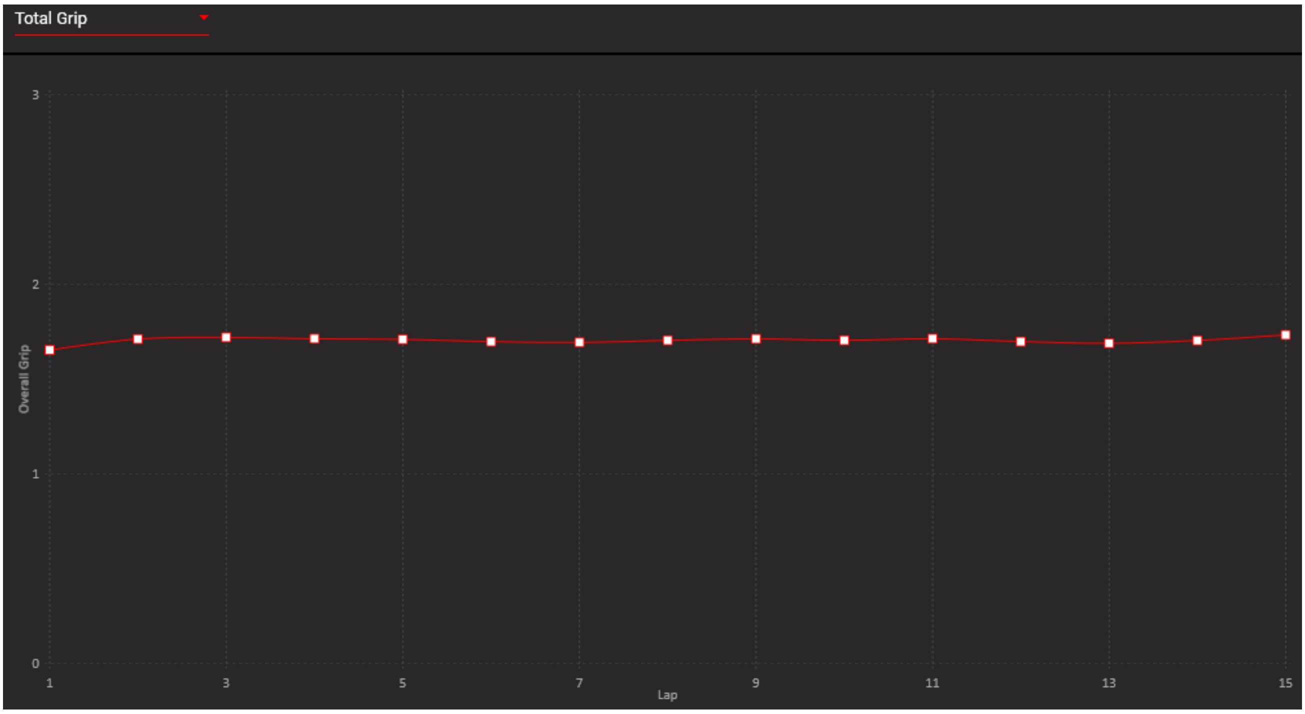

Figure 3.108: Total Grip Run Chart for Hard Slick Session

In the hard slicks example above, you can see that the overall grip variation is rather low, thanks to the hard slicks and relatively constant driver performance:

Figure 3.109: Constant Total Grip on Hard Slicks

There only seems to be a very slight dip in performance on lap 13. Since this is a unique event, it was most likely caused by a driving error.

Now let's move on to the soft slick session data:

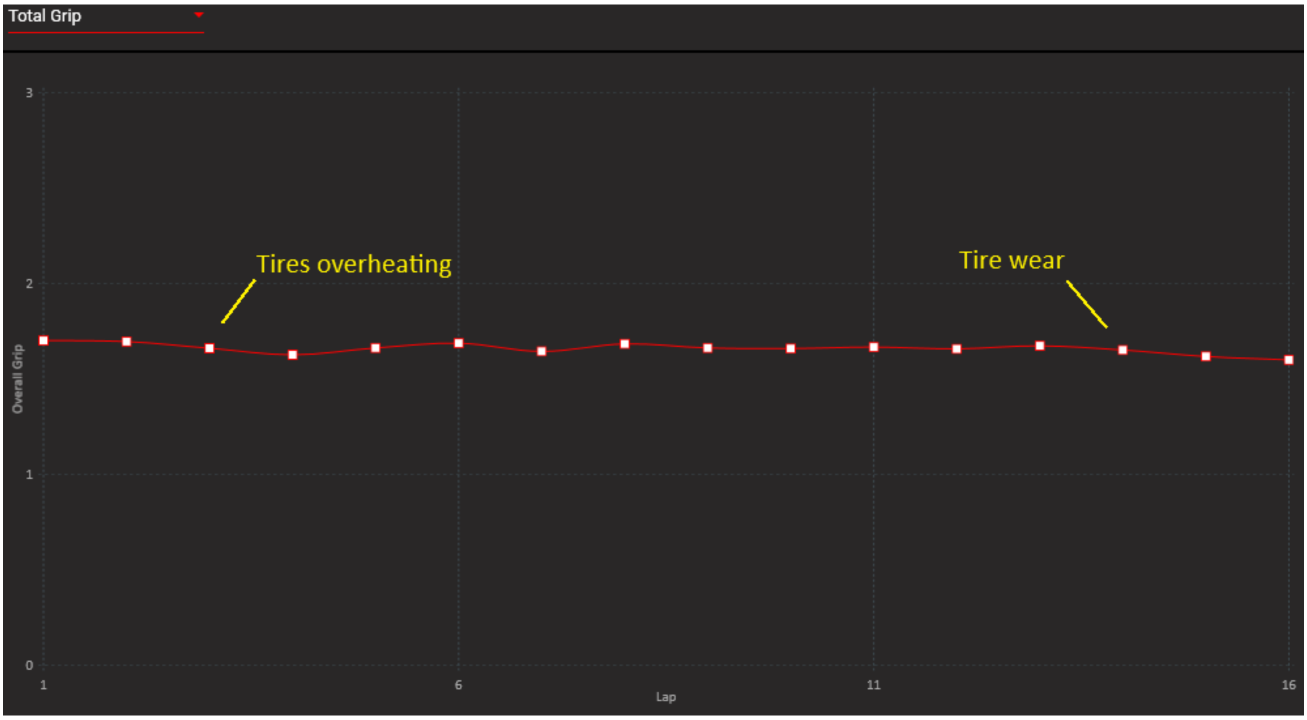

Figure 3.110: Total Grip Run Chart for Soft Slick Session

As you can see the overall grip variation is higher, caused by quickly overheating tires in the beginning and tire wear at the end of the session.

It is also quite clear that the overall grip constantly deteriorates over time:

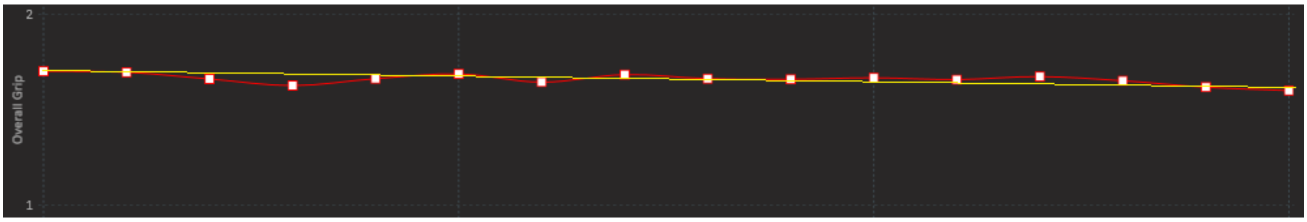

Figure 3.111: Total Grip Deterioration on Soft Slicks

This is also reflected in overall higher lap times.

As a first, quick conclusion, the hard slicks seem to be the better choice for this car / track combination.

3.9.2. Max Throttle %

Like the Total Grip run chart, the Max Throttle % chart is a performance indicator (indirectly) representing the overall grip of your car. The higher your grip, the earlier you can hit the throttle pedal and the higher your maximal throttle time will be.

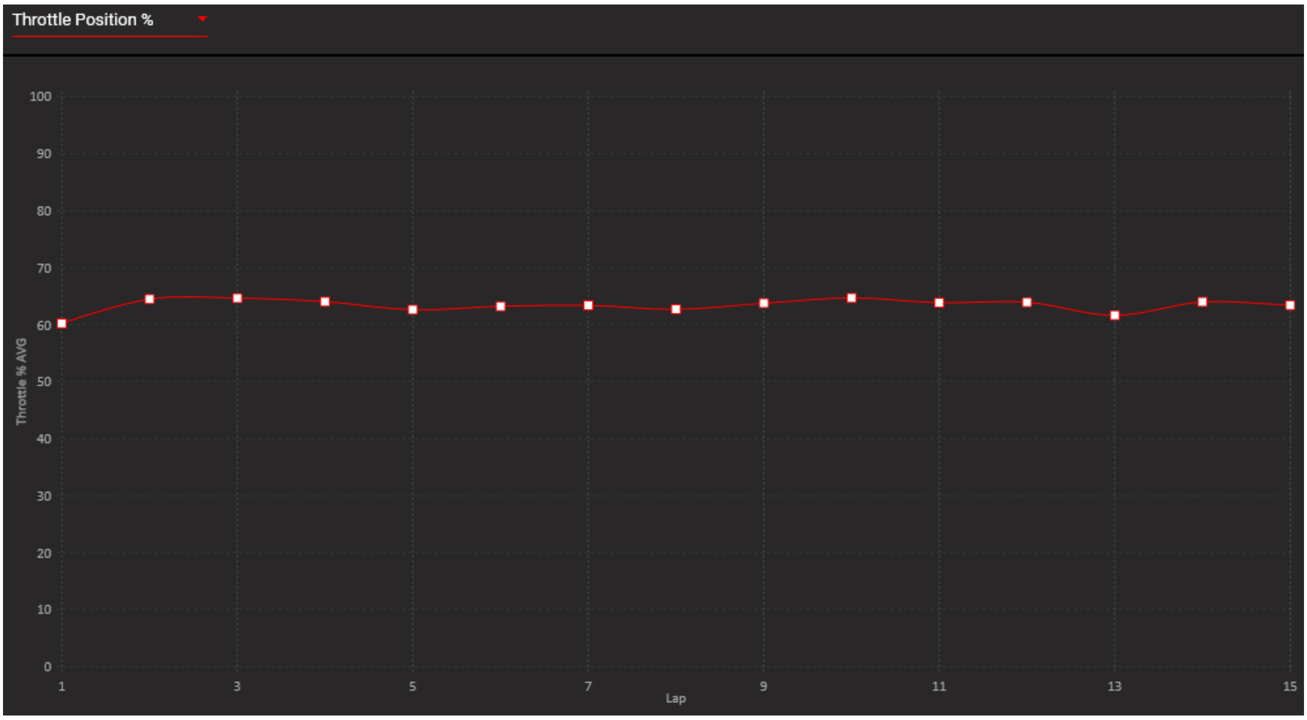

Figure 3.112 Run Chart of Max Throttle % per Lap

Again, the variation is quite low in the hard slicks example above, with a slight dip caused by a driving error on lap 13.

The average percentage stays roughly between 60 – 65% over the whole session and confirms the constant performance of the hard slicks, established in chapter 3.9.1.

The data of the soft slick session paints a different picture again:

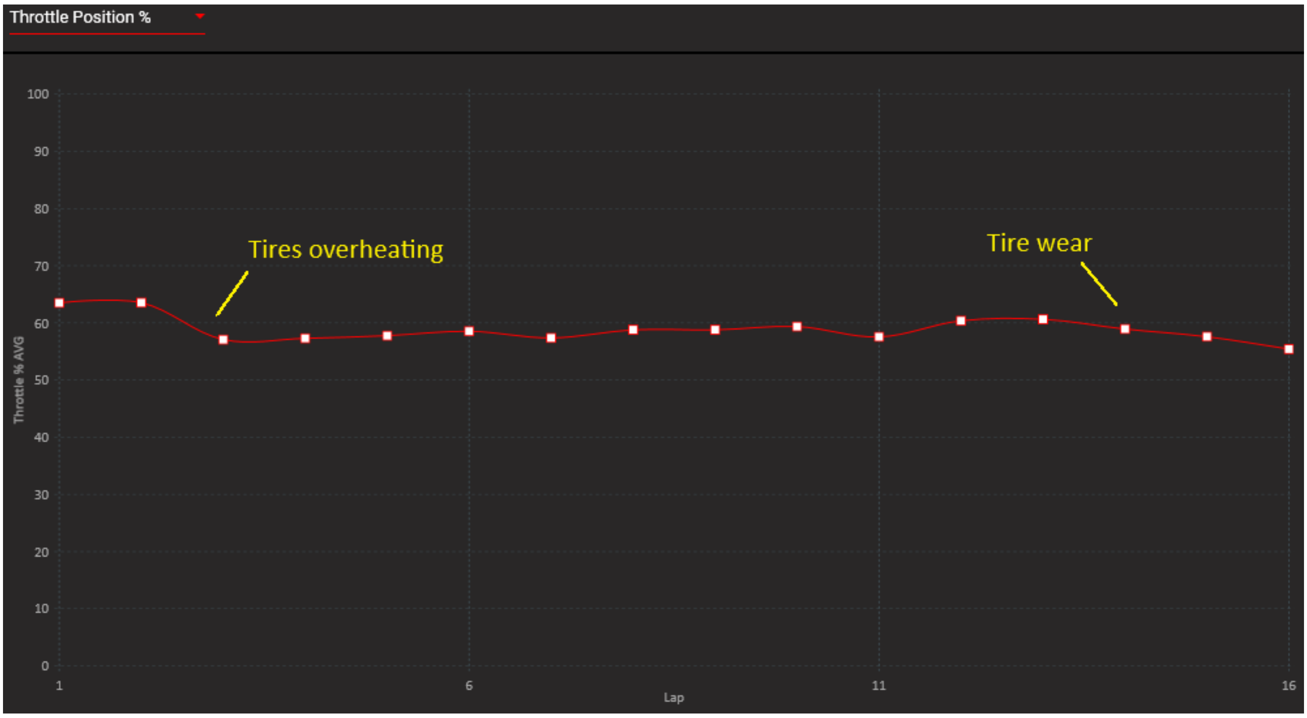

Figure 3.113: Performance Drop on Lap 5

1) The decreased grip level is lower, which is confirmed by the lower max throttle % that's below 60% almost all the time.
2) While the performance is similar on the first two laps compared to hard slicks, it drops quickly as the tires start to overheat
3) There's a second performance drop after lap 13 as the tires are reaching their end of life (high tire wear).

Once again it is confirmed that soft slicks are not the right choice for this particular car / track combination.

3.9.3. Understeer Angle

The Understeer Angle Chart displays the relationship between your car's understeer or oversteer tendency and the achieved lap time. It shows the average neutral steer angle per lap from the Neutral Steer Channel, located in the Lateral Stiffness Distribution chart (see chapter 3.4.6). Since tires degrade over time and the car gets lighter because of fuel consumption, the driving characteristics change slightly (and sometimes significantly) over the course of a session.

The understeer angle in this graph is defined as followed:

Negative value → Oversteer tendency

Positive value → Understeer tendency

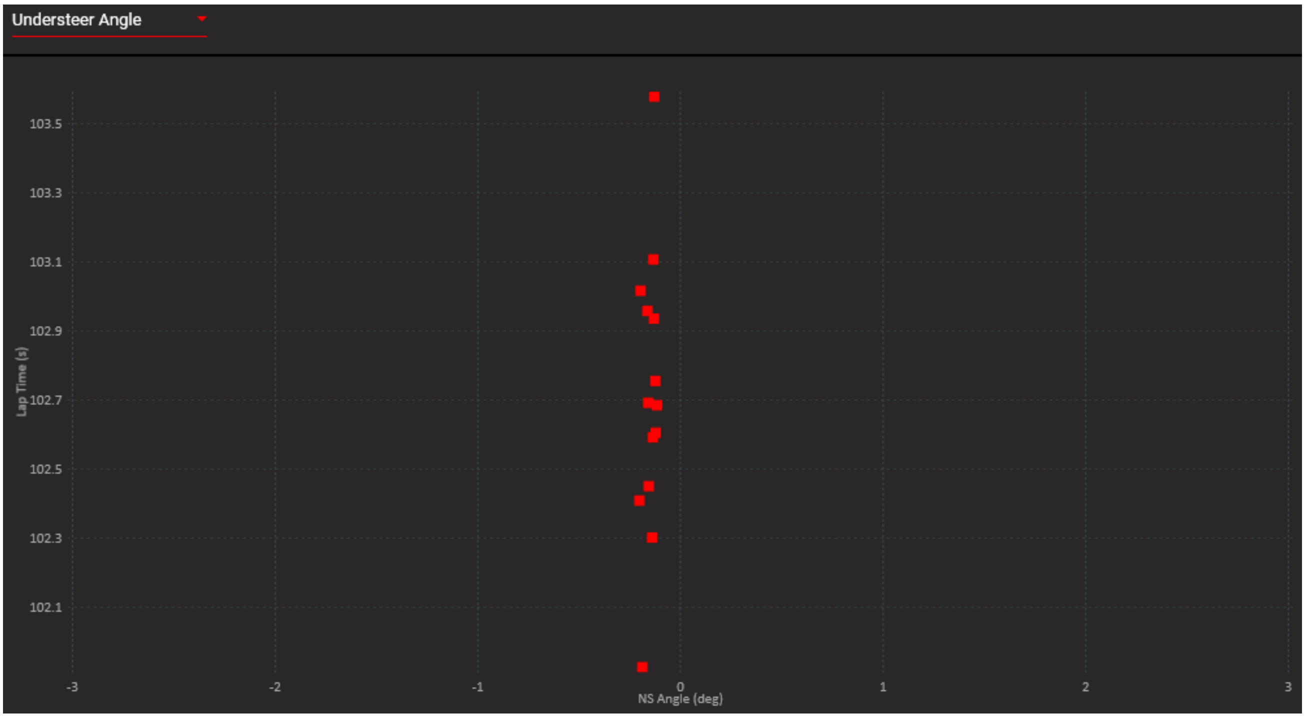

Figure 3.114: Neutral Steer Angle to Lap Time Run Chart

The desired understeer angle is highly dependent on driving style. Some drivers may prefer a neutral or slightly understeering car while others prefer the agility of an oversteering car.

Additionally, to determining the change in your car's driving characteristics, you can also use this chart to find out what suits your driving style and as reference when tuning different cars.

Let's analyze the chart of our hard slicks session:

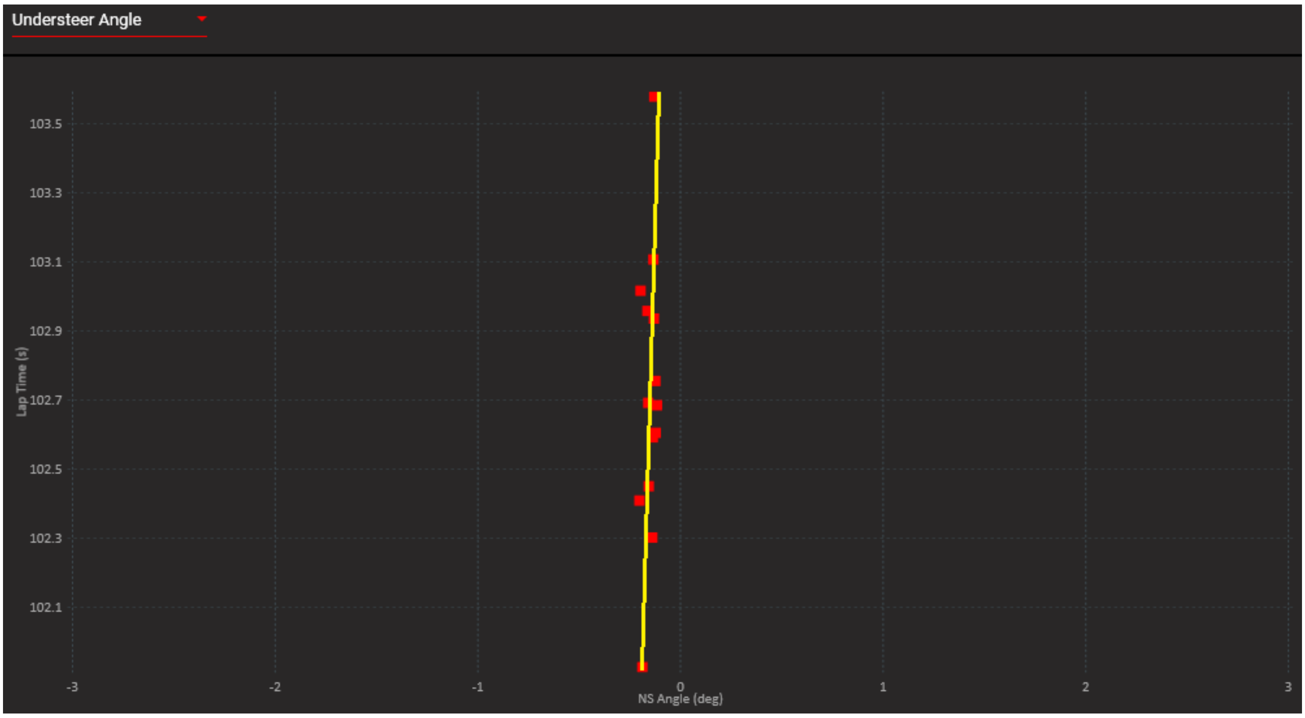

Figure 3.115: Understeer Angle Run Chart for Hard Slicks

From the data we can draw three conclusions:

1) The car has a slight oversteer tendency (small negative NS Angle).
2) As we've already established, the car's performance on hard slicks is quite constant, which is confirmed here by the extremely low NS Angle variation.
3) The higher the oversteer tendency, the lower the lap time. This is an indicator that the driver prefers a slightly oversteering car and it might be beneficial to adjust the setup even more towards oversteer.

Now let's take a look on our soft slick session:

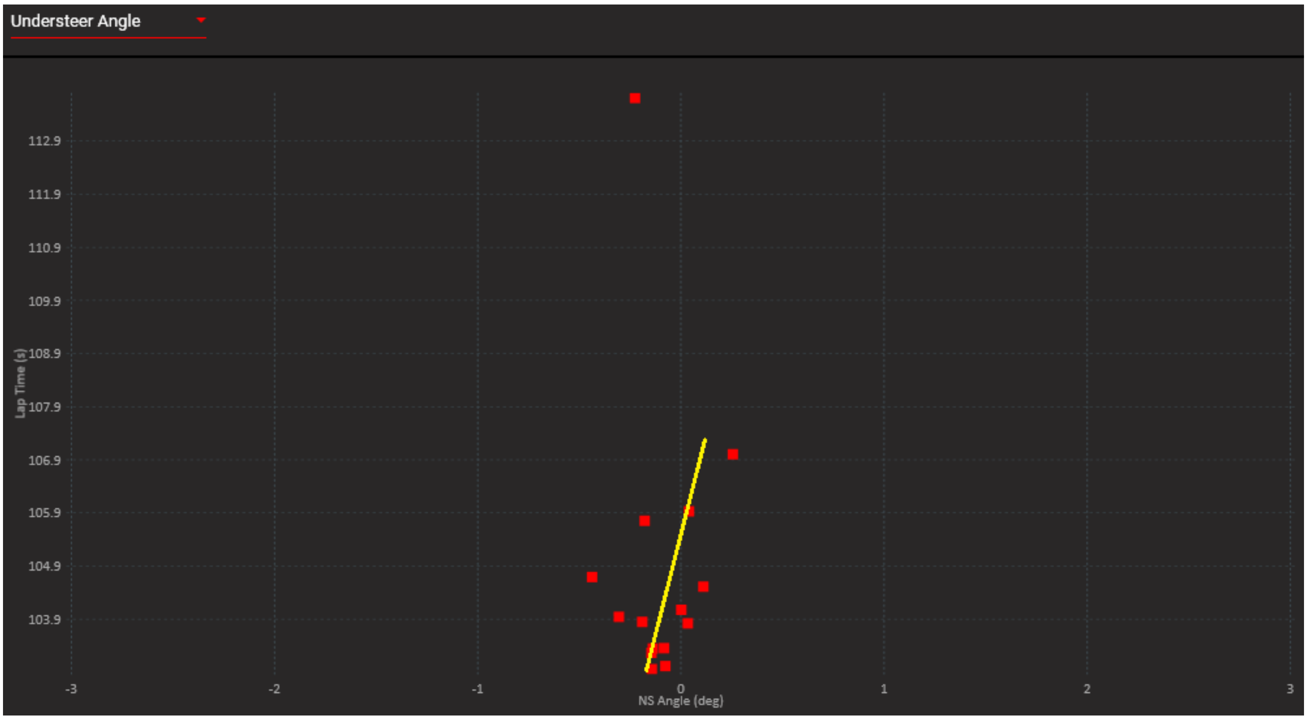

Figure 3.116: Understeer Angle Run Chart for Soft Slicks

Ignoring the outlier at the top (huge driving error) we can again draw multiple conclusions:

1) The car feels tighter compared to hard slicks (some laps with positive NS Angle).
2) The car's performance is much more inconsistent (higher variation), which is most likely caused by overheating tires and increased wear.
3) The higher the oversteer tendency, the lower the lap time. This is an indicator that the driver prefers a slightly oversteering car and it might be beneficial to adjust the setup even more towards oversteer.

3.9.4. Understeer Angle 2

The Understeer Angle 2 Chart is very similar to the first Understeer Angle 2 Chart, with the difference that it displays how your average understeer angle changes over the course of a session.

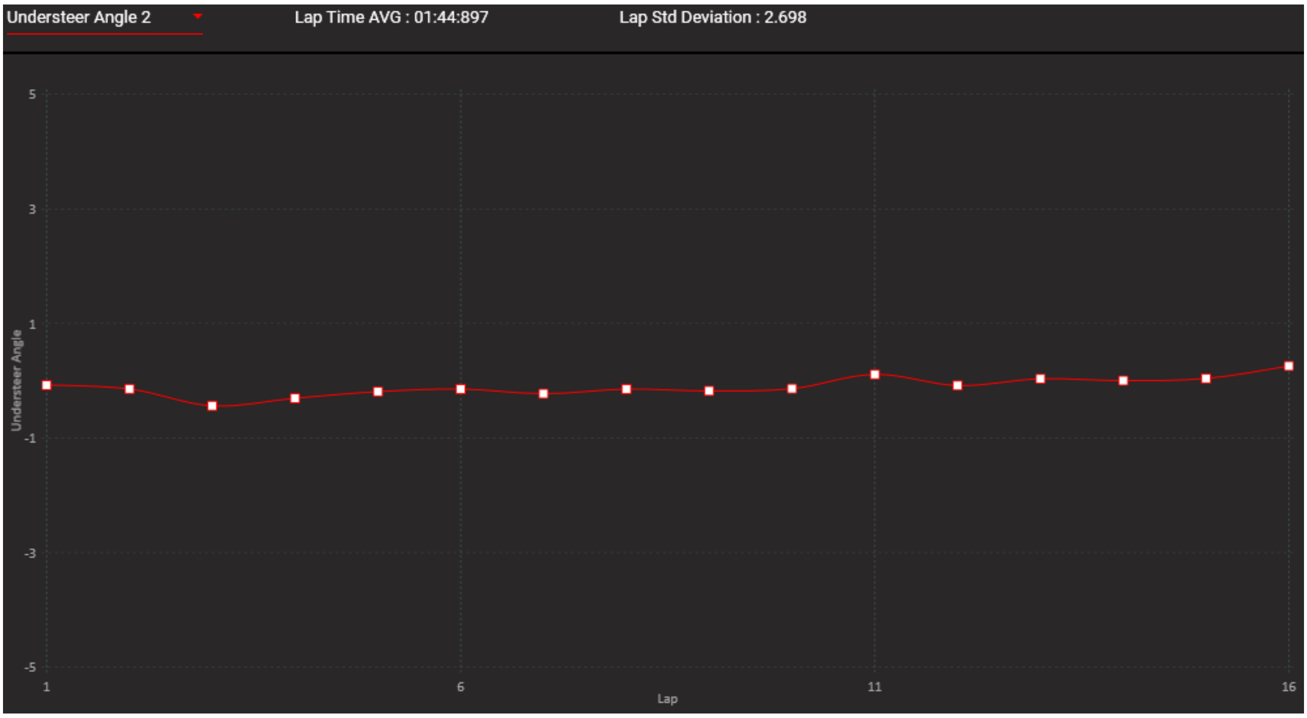

Figure 3.117: Neutral Steer Angle to Lap # Run Chart

The understeer angle in this graph is defined as followed:

Negative value → Oversteer tendency

Positive value → Understeer tendency

As already mentioned in chapter 3.9.3, the understeer angle can change over the course of a session since tires degrade over time and the car will get lighter because of fuel consumption.

In most cars you can compensate for this by adjusting brake balance and ARBs while on track.

Use this tool for testing sessions to be prepared for any changes in driving characteristics in your upcoming race.

As a quick example, let's compare two different (hard and soft slick) practice sessions:

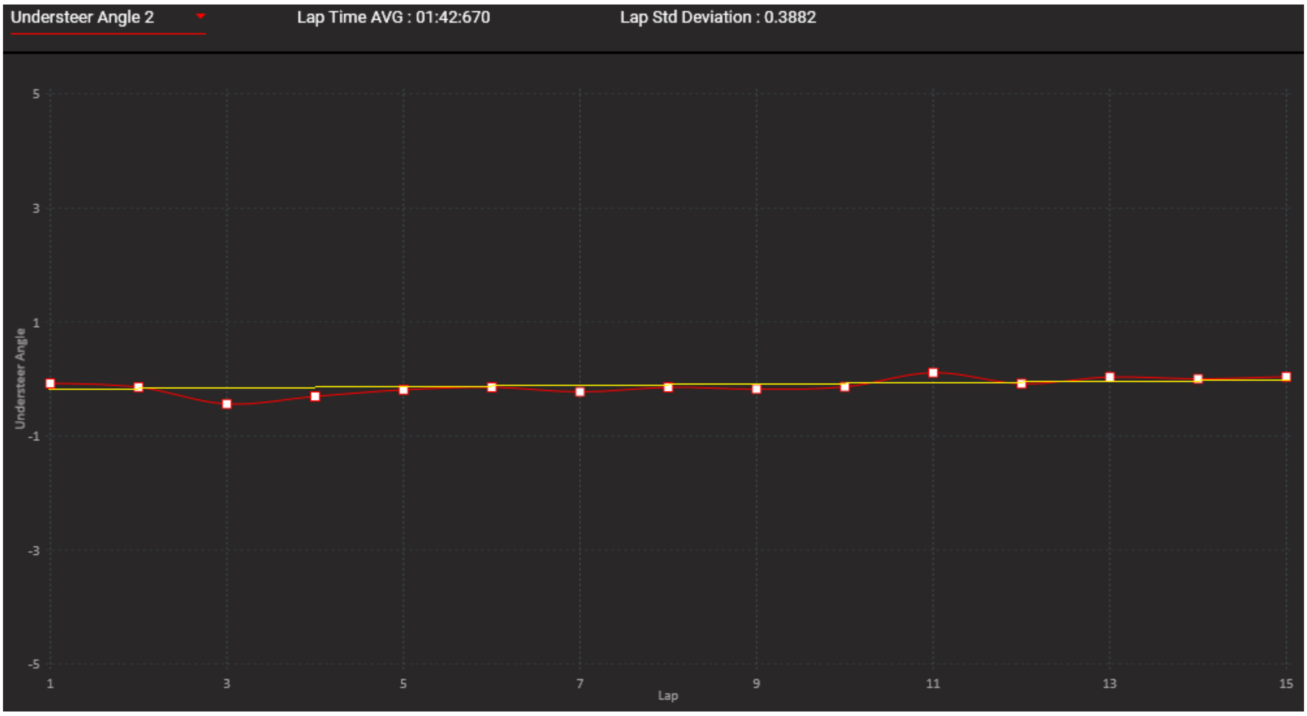

Figure 3.118: Understeer Angle 2 Run Chart for Hard Slicks

As you can see, the understeer angle doesn't really change because the hard slicks haven't degraded much yet. The result is quite different for soft slicks though:

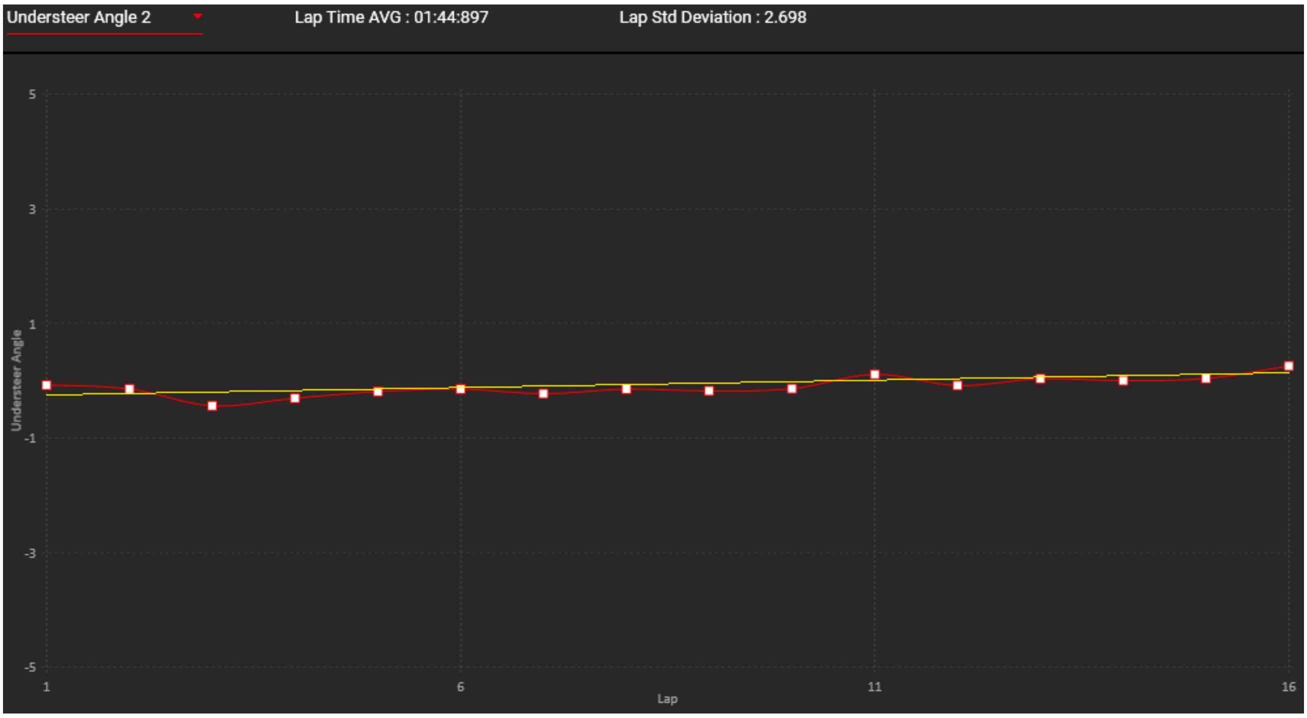

Figure 3.119: Understeer Angle 2 Run Chart for Soft Slicks

You can clearly see a tendency towards understeer over the course of the session.

3.9.5. Optimal Tire Temperatures

The Optimal Tire Temperature Charts help you find the temperature range in which the tires are developing their highest grip potential. It shows the average temperature of both front and rear tires respectively and how it relates to the acceleration that is achieved.

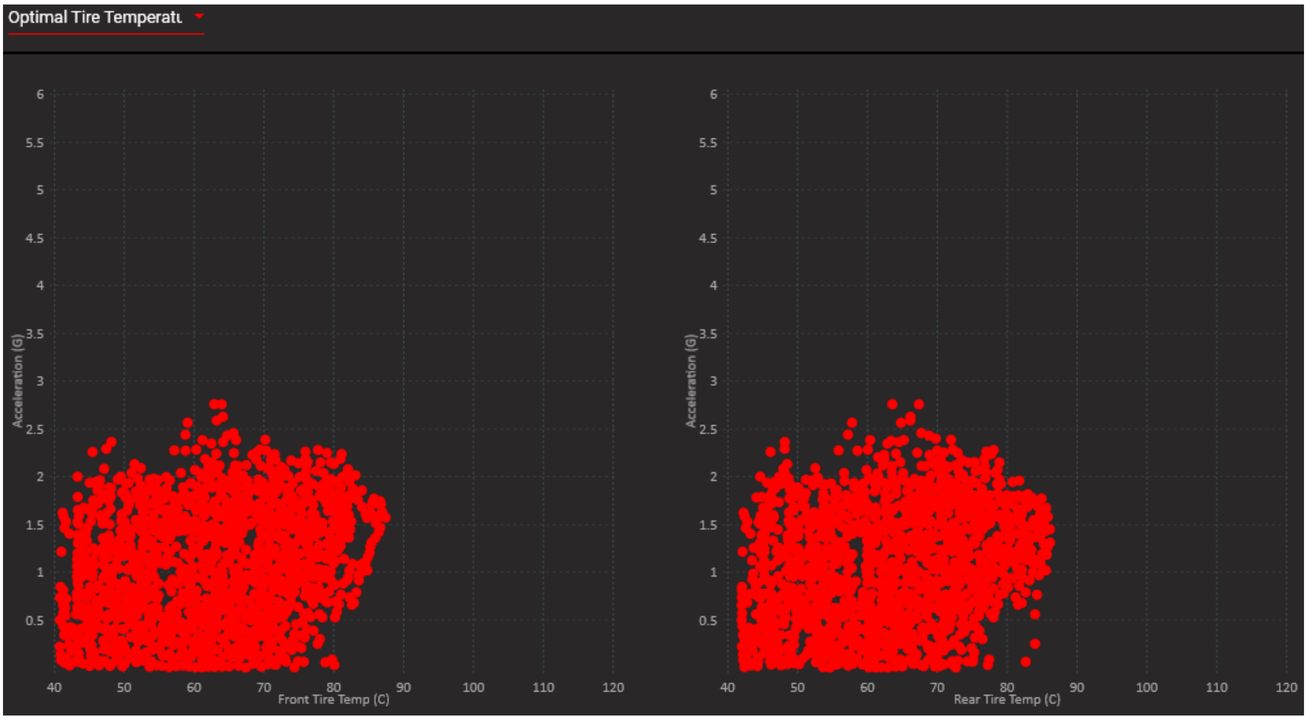

Figure 3.120: Tire Temperature to Combined Acceleration Run Chart

Taking a closer look on the above example reveals that those specific tires have their peak performance between 60 – 75°C and start to drop off significantly above that:

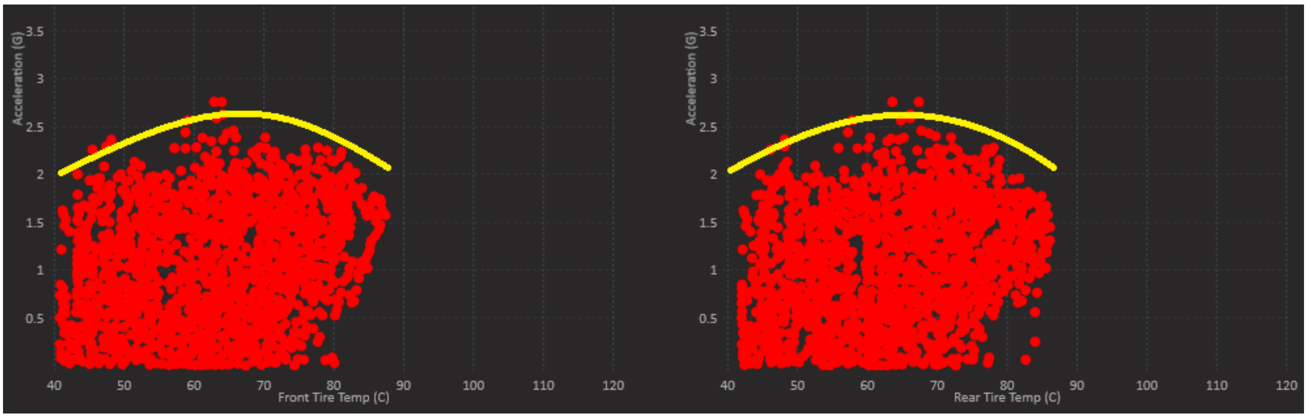

Figure 3.121: Determining Peak Performance to Tire Temp Relationship

Peak performance can defer between front and rear tires, which means, you should always check both ends of the car.

Now let's compare our hard and soft slick sessions again.

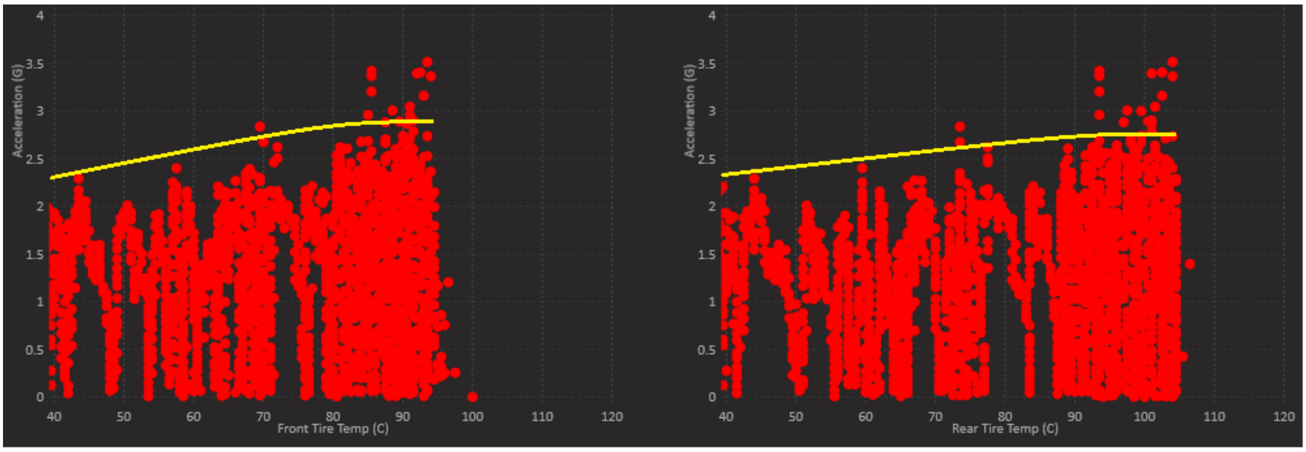

Figure 3.122: Optimal Tire Temp Chart for Hard Slicks

We can see how the performance of the hard slicks increases and stays relatively constant from ~85°C / 95°C (front / rear) on, telling us that they're not overheating. The data density is also the highest in this range, which means the tires are spending most of the time in their optimal performance range.

The results for our soft slick stint are looking quite differently though:

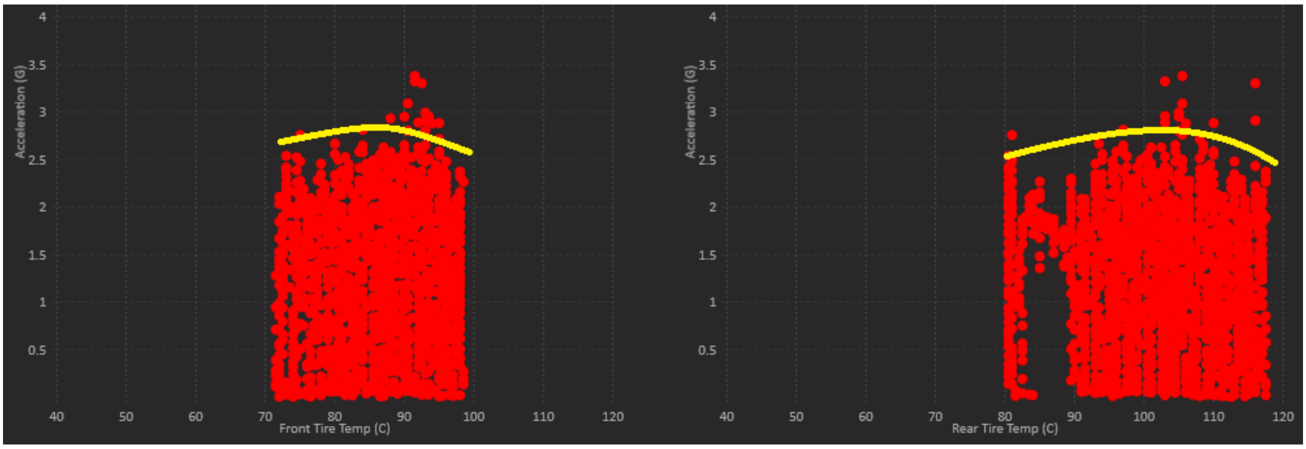

Figure 3.123: Optimal Tire Temp Chart for Soft Slicks

While peak performance is similar (~2.8G) and is reached at comparable temperatures of ~85°C / 100°C (front / rear), it starts to drop quickly again at higher temperatures, indicating that the tires are overheating.

3.9.6. Fuel

The Fuel Run Chart displays the change in fuel load over the course of a stint and lets you recognize trends in fuel consumption.

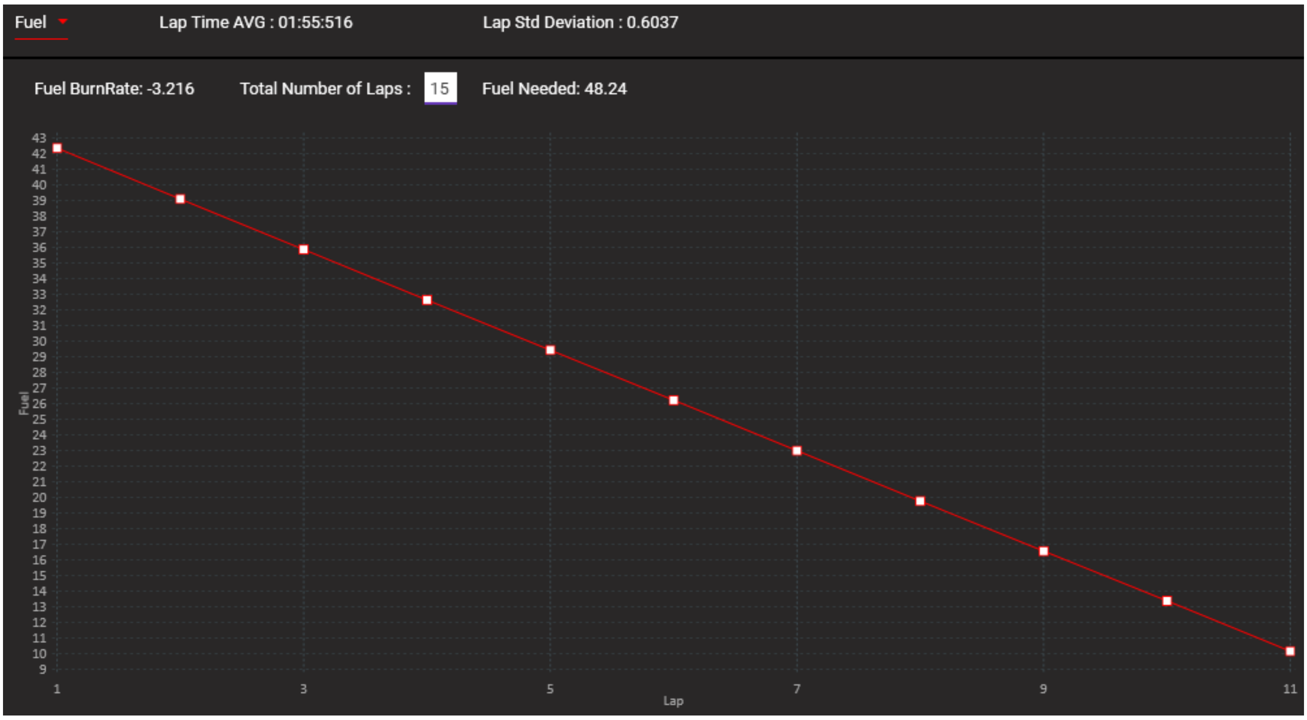

Figure 3.124: The Fuel Run Chart

Since fuel load has a big impact on the car's performance you can easily analyze the relation between lap times, fuel load and consumption.

It also shows the amount of fuel currently left, so you estimate your total stint length and use the data to analyze various pit strategies (see chapter 4.1).

3.9.7. Fuel vs. Time

With the Fuel vs. Time Run Chart you can analyze the fuel load's impact on your car's performance. Keep in mind though that this is only one part of many that is affecting lap time. And the impact of it varies a lot, depending on the type of car, as you can see in the example image below. It displays the fuel load over a practice stint of a GTE car at Brno.

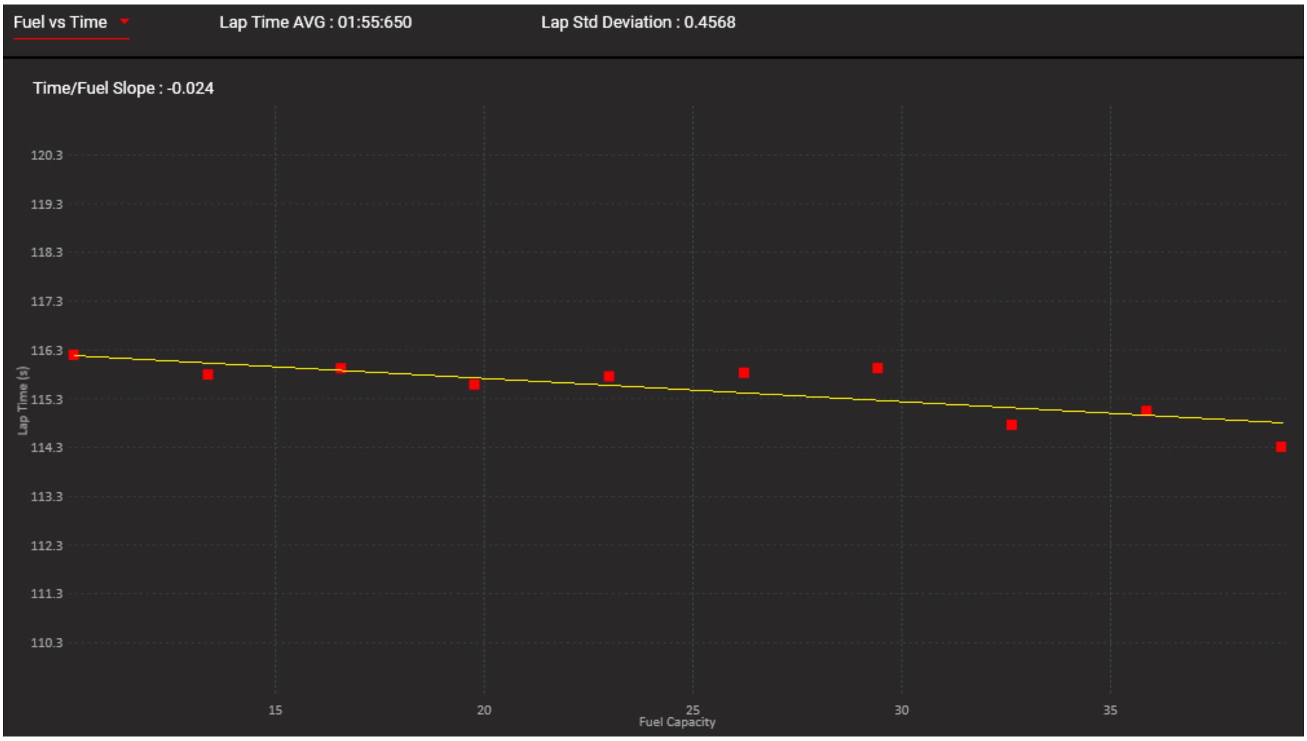

Figure 3.125: The Fuel vs. Time Run Chart

Contrary to what you would expect, the trendline indicates that lap times are higher with low fuel load in this specific case. The reason for this is that fuel load isn't such a big factor in GT cars compared to, for example, open wheelers.

The lap time increase was caused by excessive tire wear, which overweighed the benefit of a lower fuel load significantly.

3.9.8. Camber and Pressure Temperatures

This Run Chart is an extension of the Tire Temps Chart (see chapter 3.7.1) and lets you analyze how the camber and pressure temperatures develop over the course of a stint.

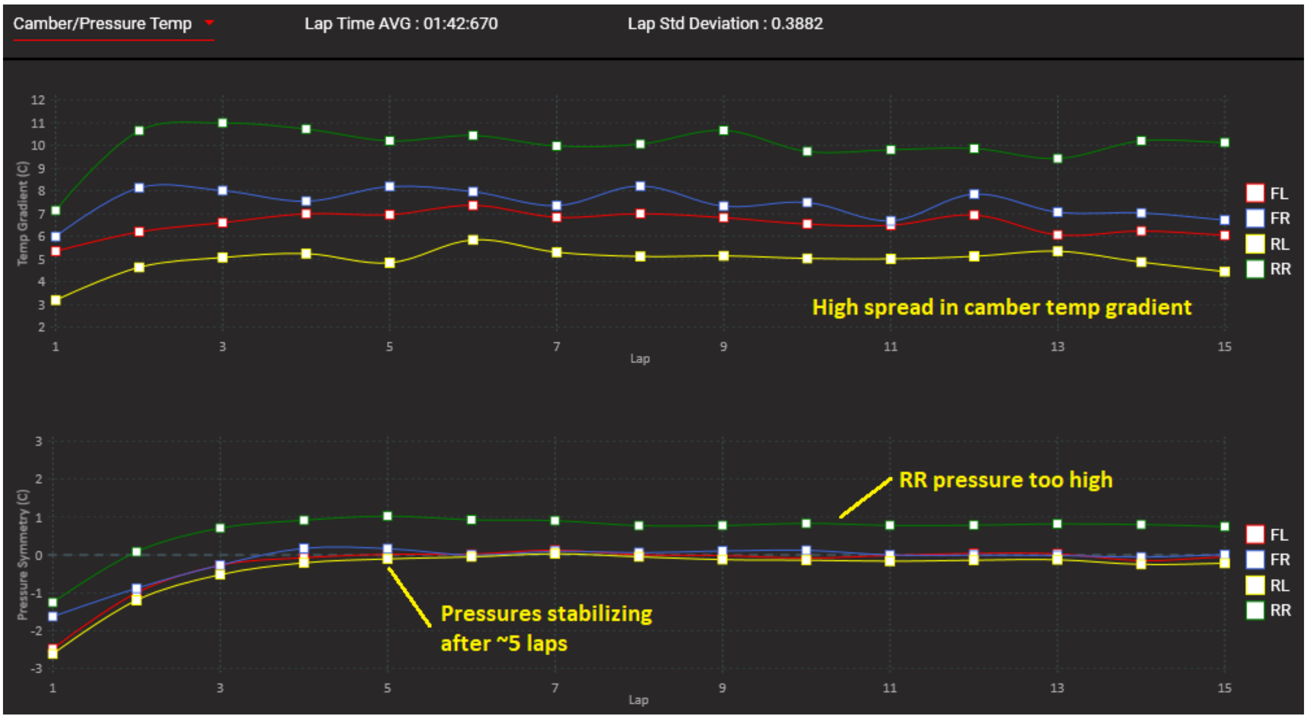

Figure 3.126: The Camber and Pressure Temperature Run Chart

The above run chart was recorded in a practice session with a GTE car. You can clearly see that pressures are only stabilizing after ~5 laps, once the tires (and the air inside them) are up to operating temperatures. That's why it's important to do longer stints if you want reliable data for analysis.

There are multiple issues with this base setup. The rear right tire pressure is too high and there's a significant variance between the camber temperature profiles of all tires.

The following chart displays what camber and pressure temps you should aim for in most (not all) cases:

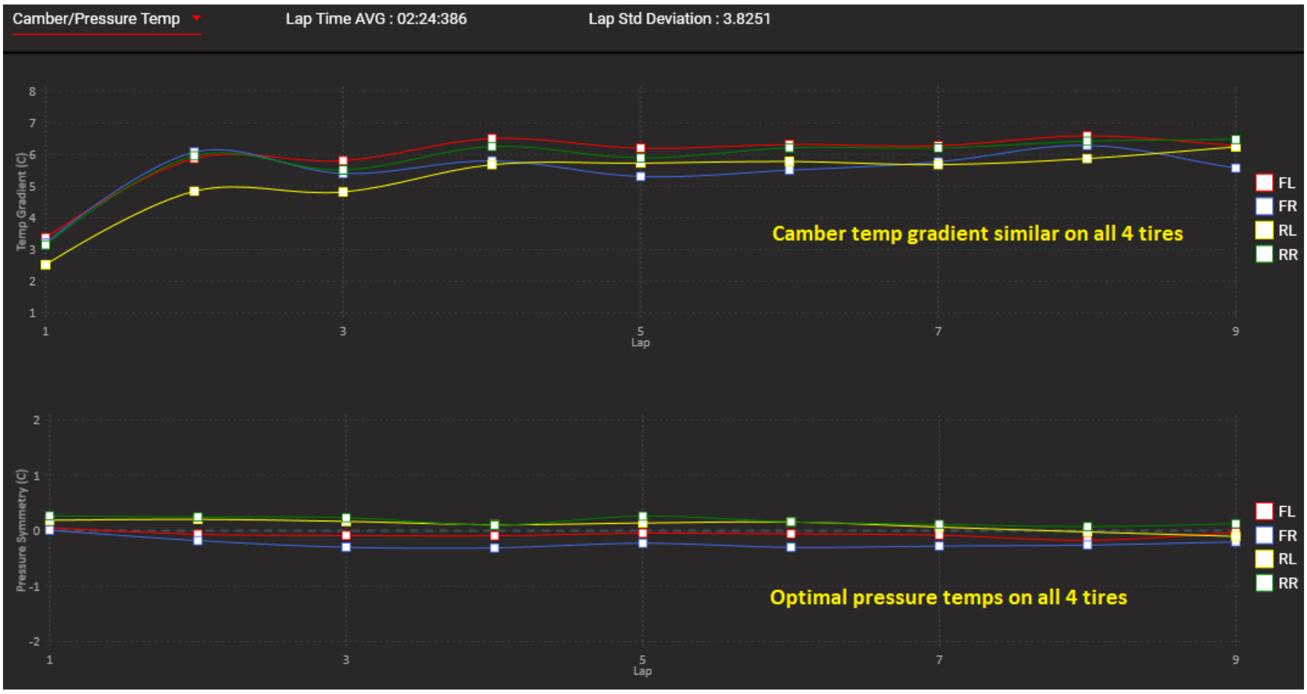

Figure 3.127: Optimized Camber and Pressure Temperatures

For more information about camber and pressure temperatures check out chapter 3.7.1.

3.10. Driver

Although the app's focus lies on car tuning there are a few powerful tools available to evaluate your driving style and performance.

With the Time Slip and Driving Line charts you can compare two different laps and find out where you're losing time and why.

To compare laps, you just need to select a base lap by ticking the box in the lap tree and then select the lap you want to analyze, as shown in the image below:

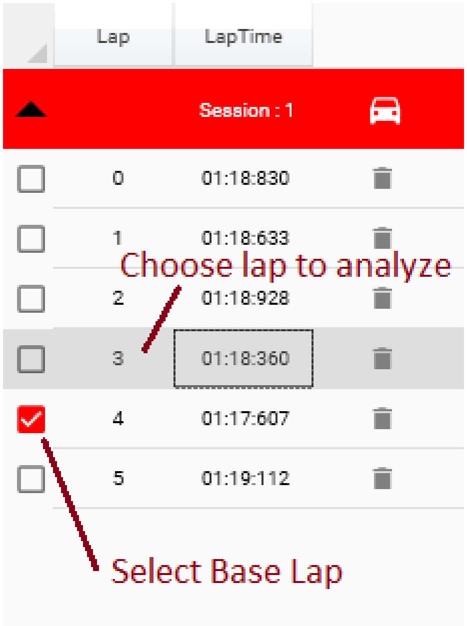

Figure 3.128: Lap Selection

Note: When overlaying telemetry data of two laps in the Driver tab, you need to select **Distance Mode**. Using Time Mode will create an offset in the charts, caused by the lap time delta, making it impossible to compare the data in a meaningful way.

3.10.1. Time Slip

With the Time Slip and Speed Comparison charts you can instantly spot where you're losing or gaining time compared to your base lap and how to improve your driving style for a more consistent performance.

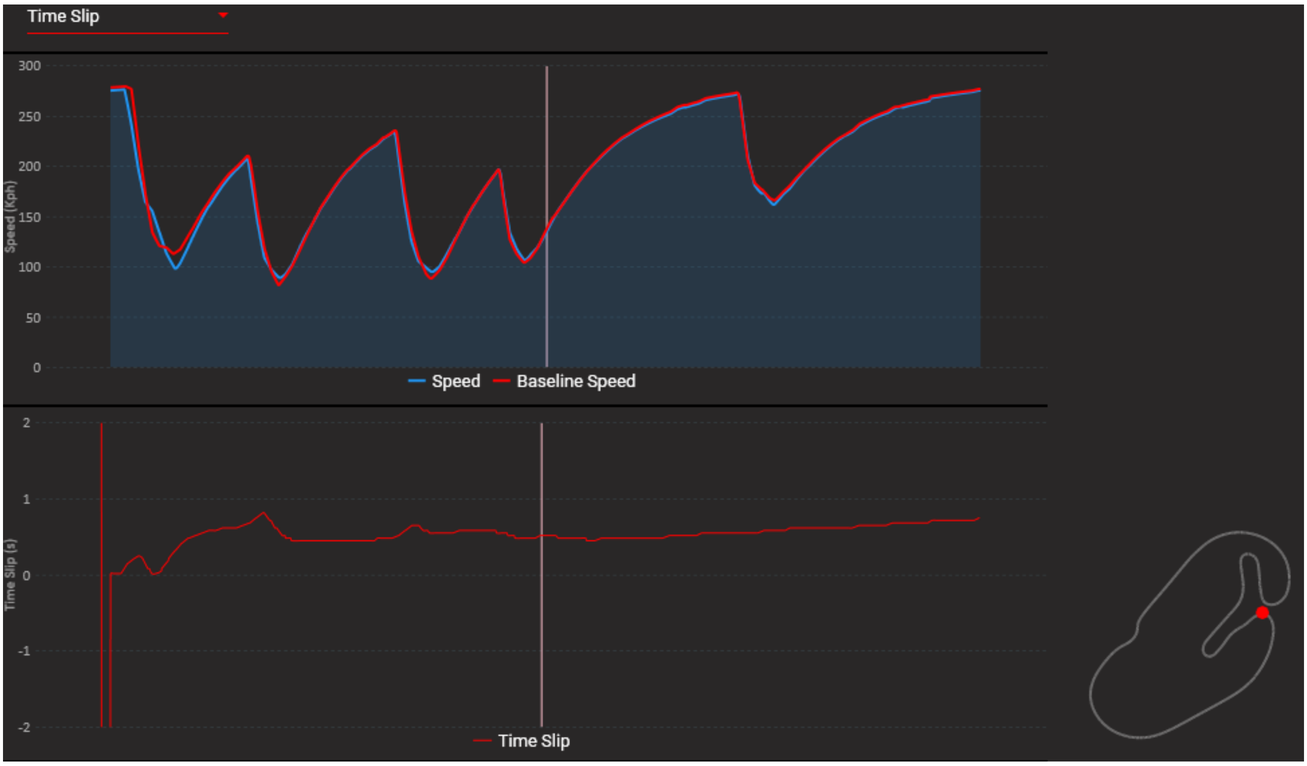

Figure 3.129: Time Slip and Speed Comparison Charts

The time slip graph is defined as:	Positive values	→	Losing time
	Negative values	→	Gaining time

Let's analyze an example corner and find out why time is lost here:

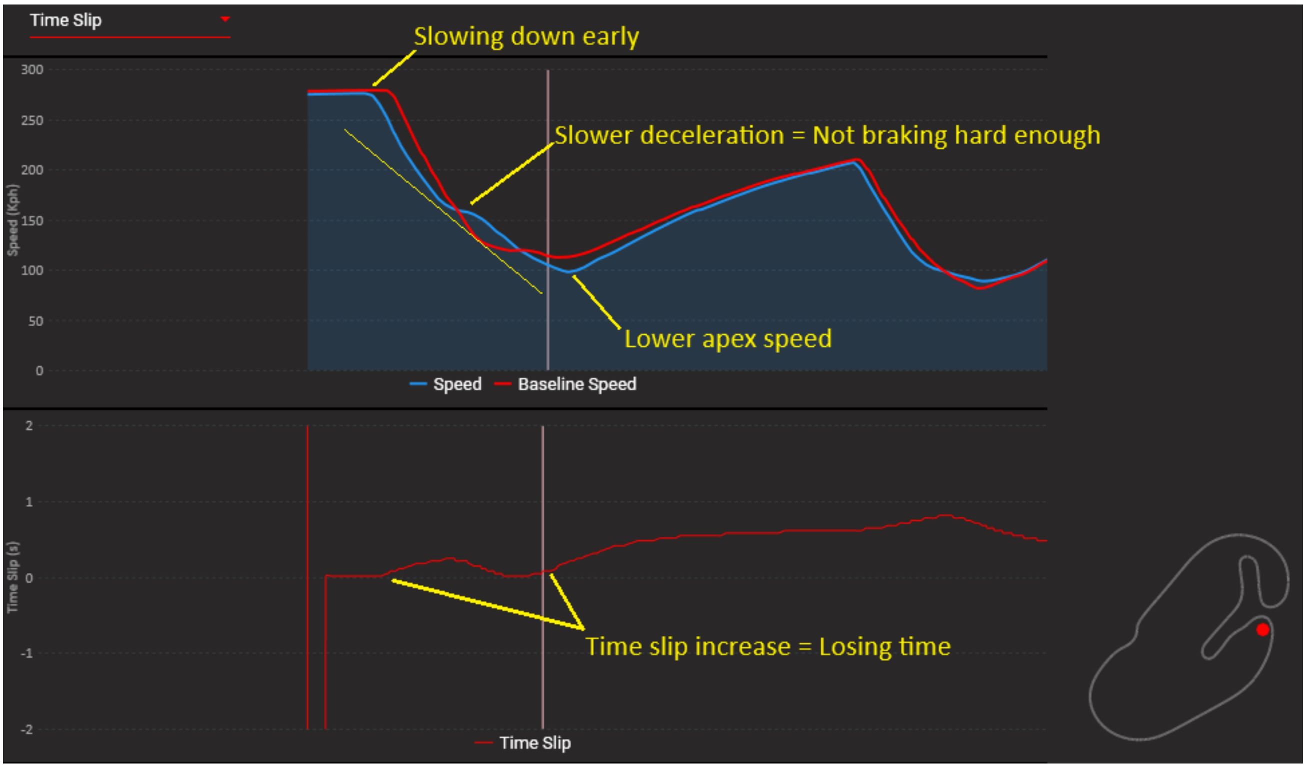

Figure 3.130: Time Slip Analysis Example

Obviously, there are multiple indicators on why the driver is losing time in this corner:

1) The braking maneuver starts too early, that's why some time is already lost in the braking zone.
2) The slope of the graph in the braking section is not as steep, which indicates that the driver is not braking hard enough.
3) The apex speed is slower, which is most likely caused by a late apex (see chapter 3.10.2 for corner apex analysis of this example) and compromises performance on the following straight.

You can see in the time slip graph how important constant braking points and a correct driving line are as the driver is losing more than half a second in this corner alone.

3.10.2. Driving Line

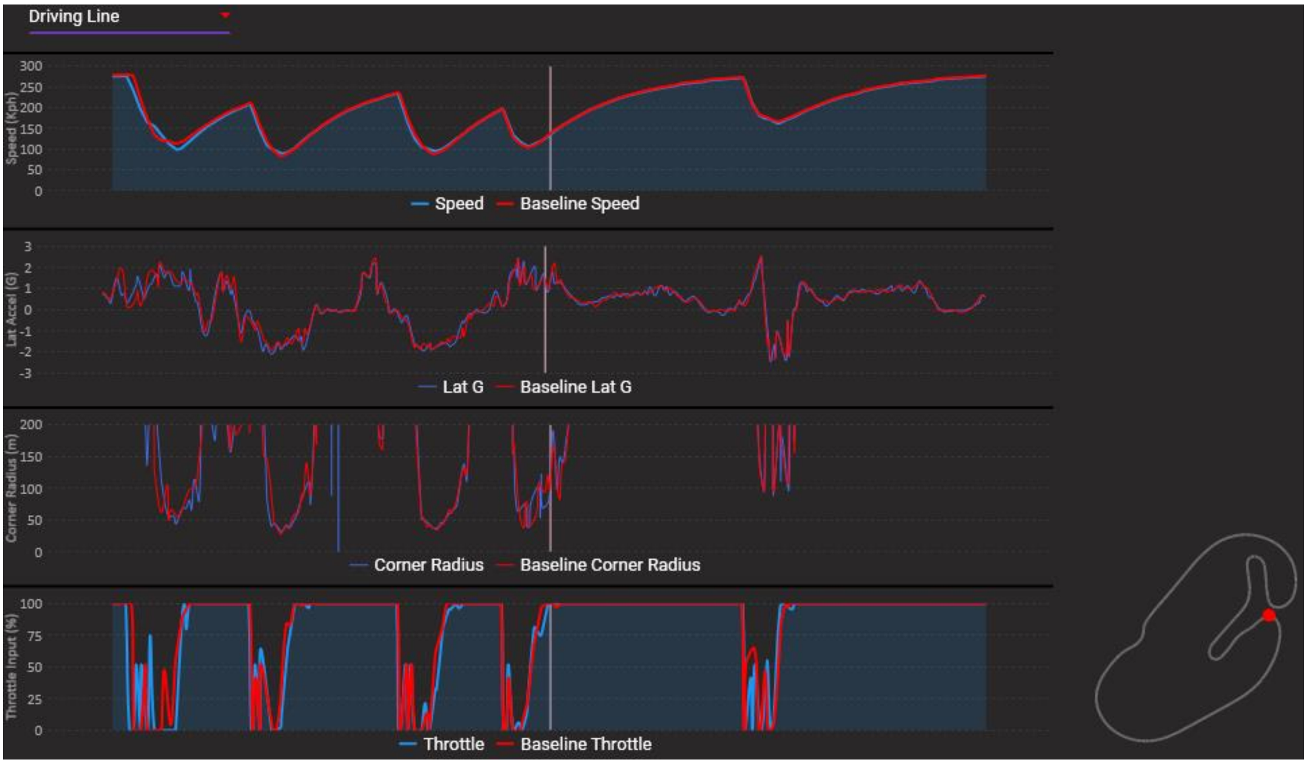

Figure 3.131: Driving Line Comparison Screen

Together with the Time Slip chart the Driving Line screen is used to analyze driver and car performance in various ways.

Use it to analyze throttle application, driving line, apex shape and speed, and the car's lateral performance.

Speed Comparison Graph

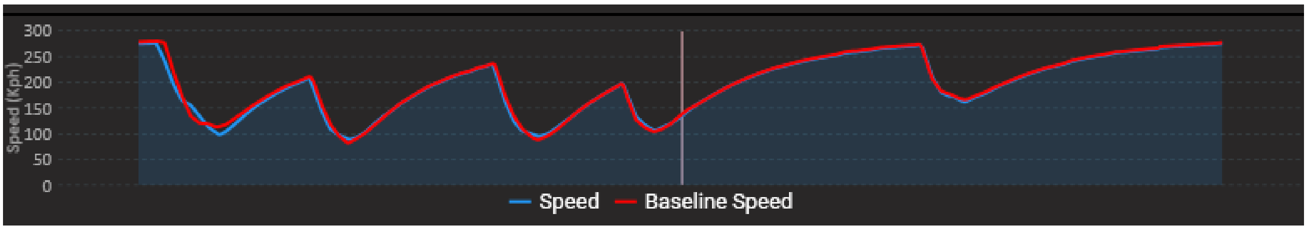

Figure 3.132: Speed Comparison Graph

The Speed Comparison graph doesn't just let you compare top speed, but also braking points, braking power, cornering speeds and throttle application.

Lateral Acceleration Comparison Graph

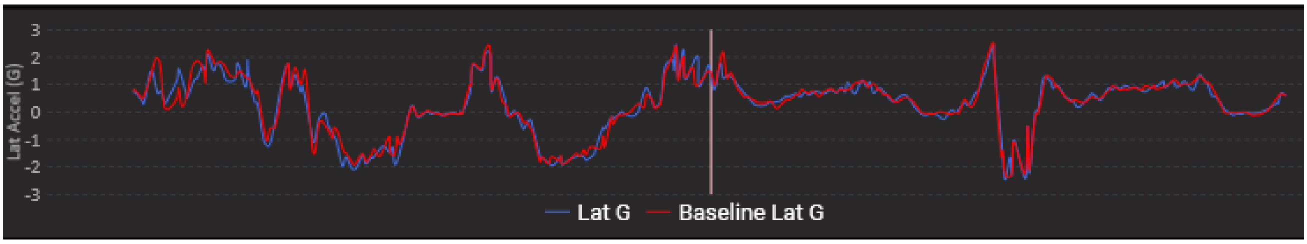

Figure 3.133: Lateral Acceleration Comparison Graph

With this graph you can compare cornering performance. The higher and the more consistent your lateral acceleration in corners is, the better your performance will be.

Corner Radius Comparison Graph

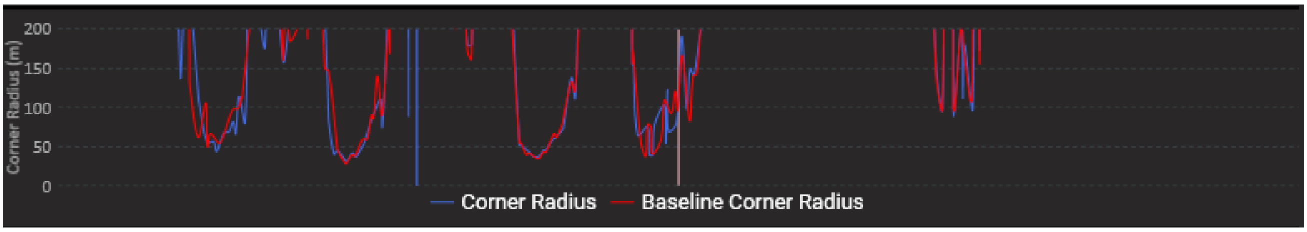

Figure 3.134: Corner Radius Comparison Graph

The Corner Radius Comparison graph is used to evaluate the driving line by detecting early or late apexes. Use this graph to optimize your driving line.

Throttle Application Comparison Graph

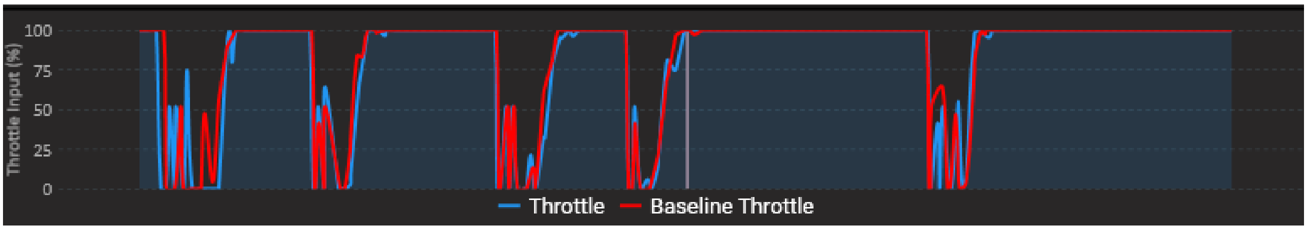

Figure 3.135: Throttle Application Comparison Graph

Here you can compare throttle application, throttle duration and manual blipping.

Let's start with driving line analysis through the shape of the corner radius graph.

The following image shows an early apex caused by the driver's too early steering input:

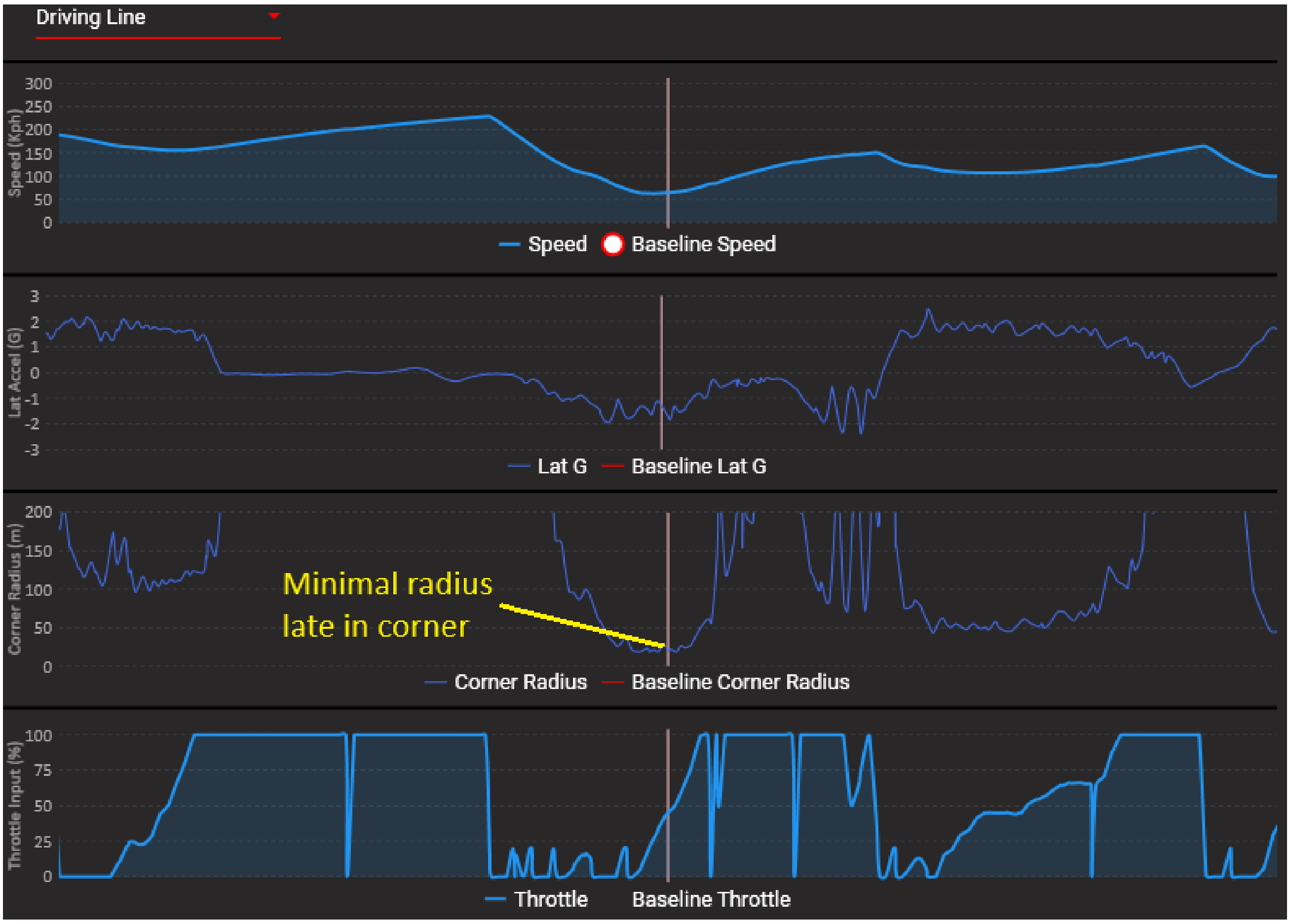

Figure 3.136: Early Apex Example

An early apex can be recognized by a late minimal cornering radius (maximal steering input). This will compromise corner exit speed and therefore time loss on the following straight most of the time.

Exceptions are corners with increasing radius where an early apex is preferable.

Now let's check out a typical mid corner apex graph:

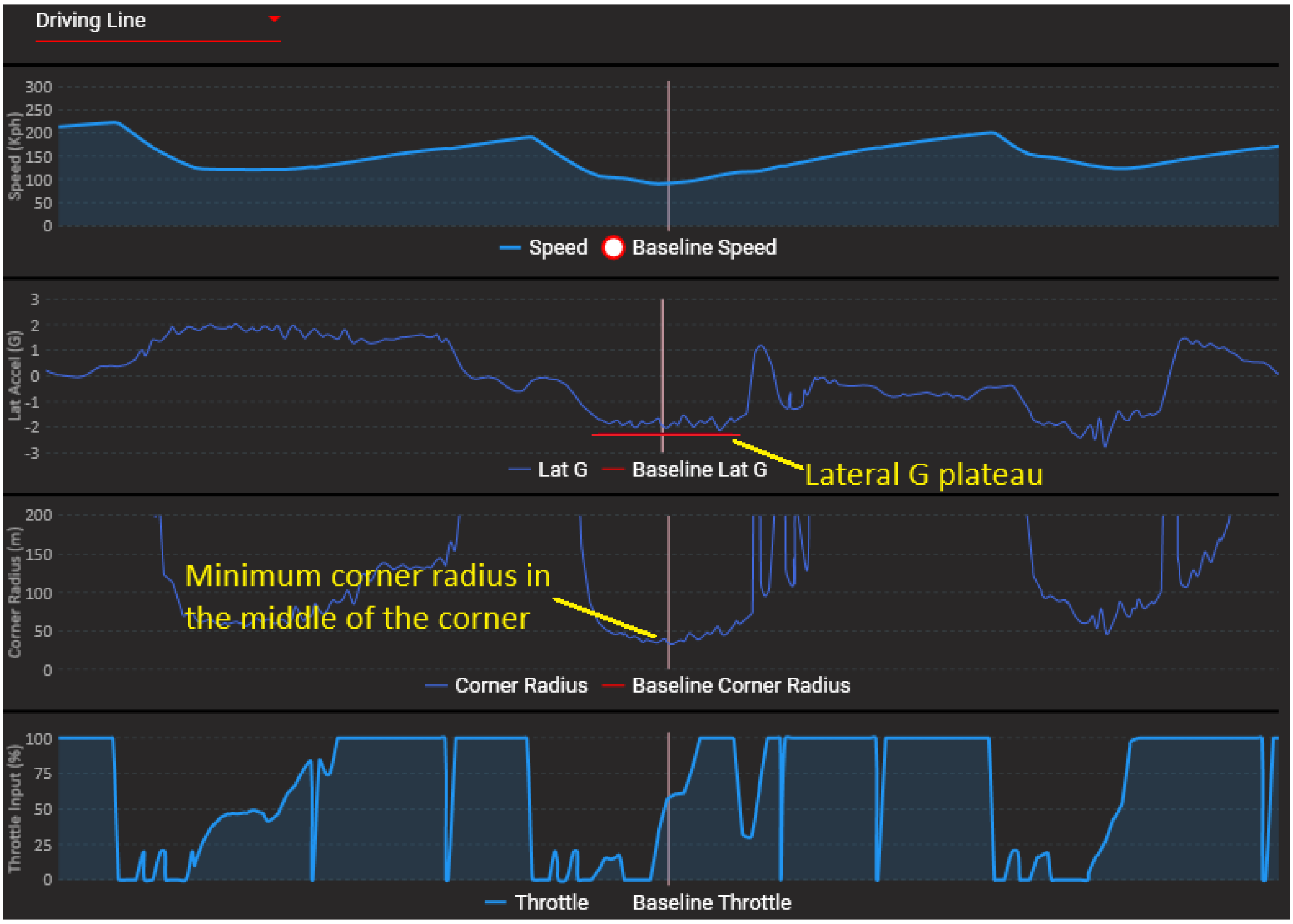

Figure 3.137: Mid Corner Apex Example

Most race track corners are taken with a mid corner apex because the car's performance is fully utilized during the whole cornering sequence (lateral acceleration plateau). You can recognize it by the centered minimum corner radius and the aforementioned lateral G plateau.

This is the preferred driving line for corners with a constant radius.

Last but not least, this is what a late apex graph looks like:

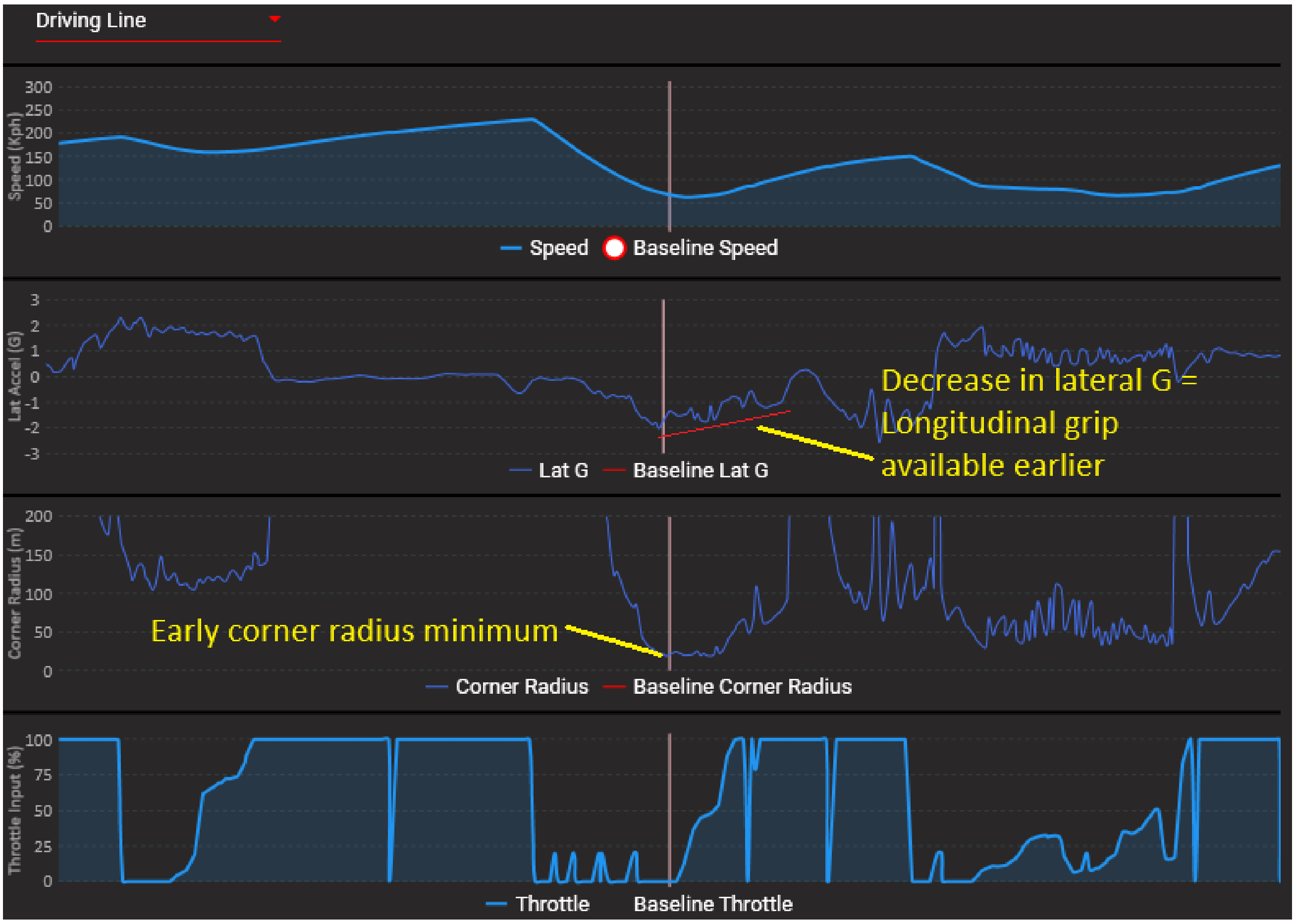

Figure 3.138: Late Apex Example

As you can see, because of the late turn in the minimal corner radius is reached earlier. The downside of this is a lower corner entry speed causing a loss of time during the cornering sequence. On the other hand, the decrease in lateral acceleration caused by the unwinding of the steering wheel results in more longitudinal grip potential availability.

Use this driving line for hairpins and corners with a decreasing radius.

Now let's compare the two cornering sequences we already analyzed in chapter 3.10.1:

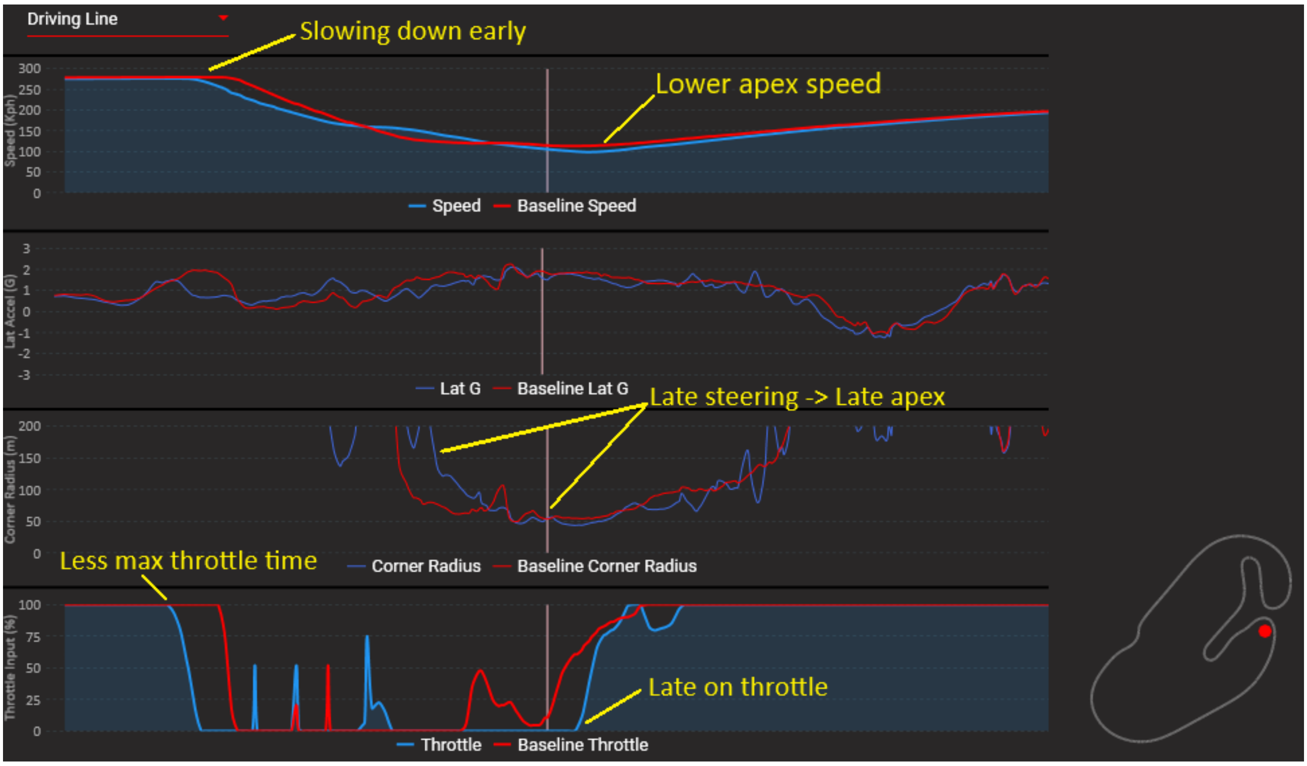

Figure 3.139: Driving Line Comparison Example

Once again, we can recognize the same issues (and more) compared to the base lap:

1) The driver slows down too early which can be seen in the speed and throttle input graphs.
2) The slope of the speed graph in the braking section is less steep, which indicates that the driver is not braking hard enough.
3) The early minimal corner radius indicates a late apex which results in a lower apex speed and significant time loss
4) The driver is late on throttle, causing further time loss on corner exit and the following straight.

3.11.Race Engineer

The Race Engineer is another powerful tool for car setup and driver performance evaluation. The Engineer automatically detects corners and will analyze the car's balance and the driver's input and will give advice on possible improvements in both areas.

The Race Engineer is in an early development stage right now and its functionality will be expanded significantly with future updates.

3.11.1. Driver Analysis

In this screen the Race Engineer analyzes the driver inputs to help improving your driving performance.

Figure 3.140: The Race Engineer's Driver Analysis Screen

The Driver Analysis screen displays the minimum speed and maximum lateral acceleration the car is experiencing while negotiating a corner.

It also analyzes the following parameters:

<u>Steering Smoothness</u>

Steering Smoothness describes how smoothly you're turning the steering wheel. You should try to keep this value below 0.2.

Too quick and erratic steering inputs can upset the car's suspension and compromise your cornering performance or even result in a spin. They're not always a sign of bad driving though. Very often a lack of steering smoothness is a result of an unbalanced car which requires a lot of correctional inputs.

Throttle Acceptance

Throttle acceptance reflects the percentage of lateral acceleration at which your throttle input is 100%, compared to the maximum lateral acceleration for a specific corner.

For example, if the maximum lateral acceleration through a corner is 2.0 G and throttle input reaches 100% at 1.5 G the throttle acceptance of the driver will be for this corner:

$$\frac{1.5\ G}{2.0\ G} \cdot 100 = 75\%$$

The table below offers target values for throttle acceptance relative the available engine power output:

Target Values for Lateral G % at Full Throttle [B-1]	
Power Output	**% Lateral G at 100% Throttle**
< 150 HP	95%
150 – 250 HP	90%
250 – 400 HP	85%
> 400 HP	80%

Keep in mind that those values are recommendations for professional drivers. Currently the app is more lenient and only tells you when your throttle acceptance is below 60%.

The following image displays an example of the Race Engineer's driver analysis with a low throttle acceptance and erratic steering inputs:

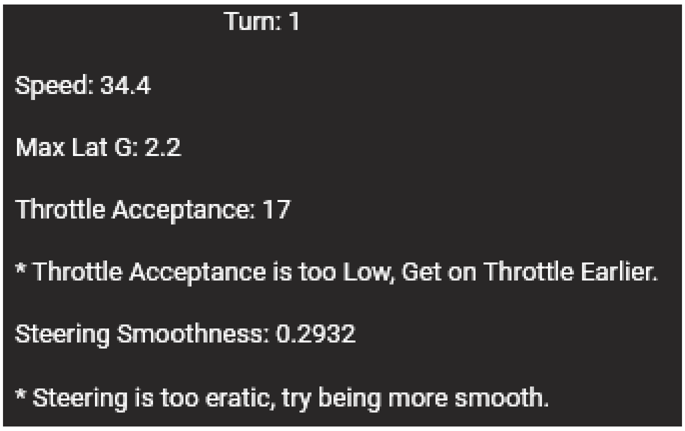

Figure 3.141: Race Engineer Driver Analysis Example

As already mentioned, those issues can also be symptoms for a badly set up car and are not necessarily an indicator for poor driving.

3.11.2. Car Setup Analysis

In the Car Setup Analysis screen, the Race Engineer will analyze the balance of your car.

Figure 3.142: The Race Engineer's Car Setup Analysis Screen

Together with the Driver Analysis screen the Car Setup Analysis screen will help you spot various possible issues in your car's setup.

On this screen the Race Engineer analyzes the following parameters:

<u>Diff Unlocking Factor (Coast and Power)</u>

As the title says, the coast and diff unlocking factors tell you if your differential unlock during coasting into or accelerating out of a specific corner.

If the factor is 0 the differential stays locked while values above 0 indicate that it's slipping. Use this info in combination with the wheel slip % graphs (chapter 3.3.3) to adjust the car's differential.

<u>Lat Load Transfer</u>

This value represents the average Load Bias % (see chapter 3.4.6) for every corner, indicating the mechanical vehicle's balance. As you already know a value above 50% reflects a forward bias (understeer) while a value lower than 50% means rearward bias (oversteer).

Let’s check out the car setup analysis data for an example corner:

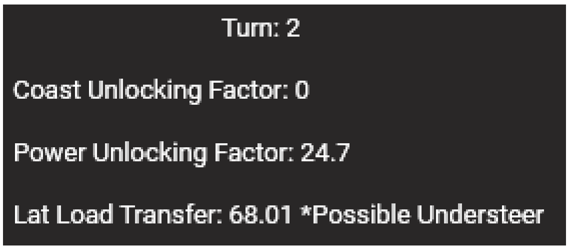

Figure 3.143: Race Engineer Car Setup Analysis Example

As you can see, the differential is unlocking on acceleration out of this corner. You should increase your differential locking if this is happening regularly (and not on purpose) to improve your acceleration out of corners.

The lateral load transfer data shows significant (mechanical) understeer. As already established in chapter 3.4.6, this value should be closer to 55% on a balanced suspension setup. You should move the mechanical balance rearward by adjusting ARBs and springs for a neutral turning behavior.

4. Additional Tools and Functions

4.1. Strategy

The Race Strategy Analysis Tool allows you to optimize your pit strategy for your upcoming race.

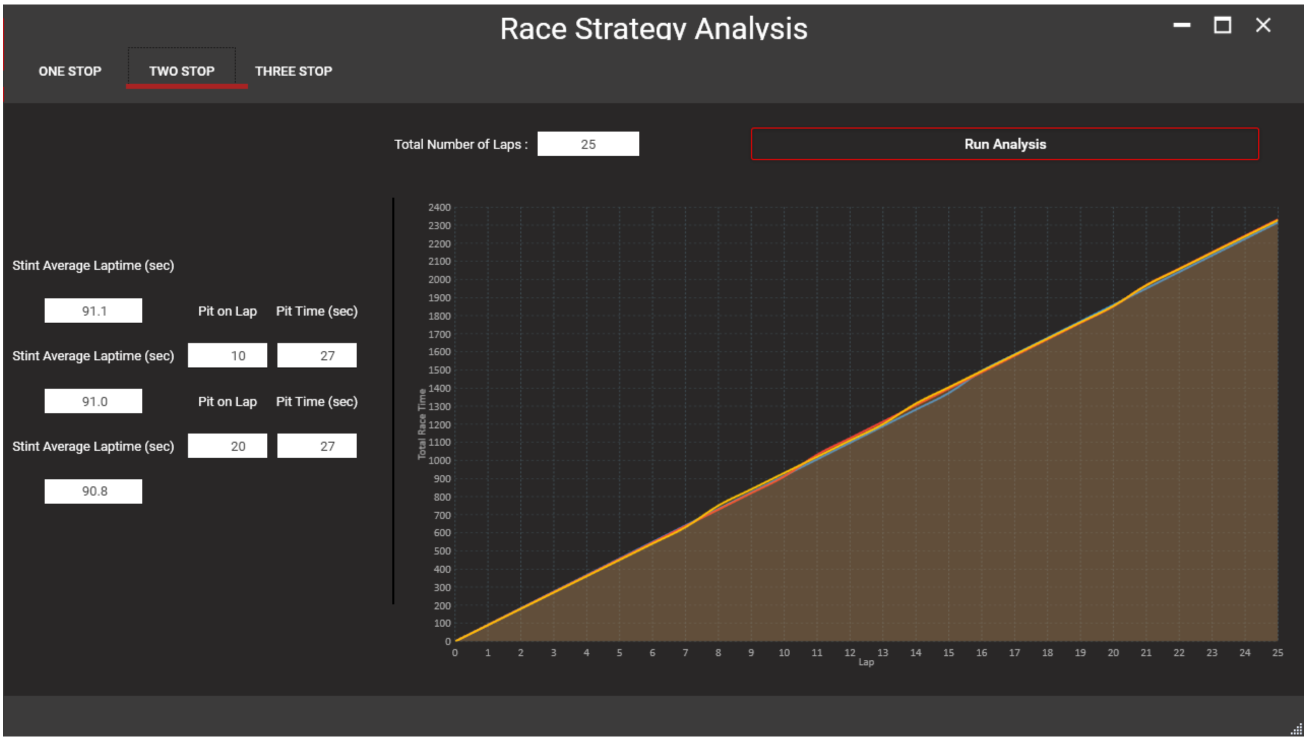

Figure 4.1: The Race Strategy Analysis Tool

To find the optimal pit strategy for your race, take the following steps:

1) Define the total race length by entering the total number of laps at the top of the graph.
2) Enter the average lap time per stint, the lap(s) in which you're planning to pit and the estimated time you'll lose per pit stop for the strategies you want to compare.
3) Click the "Run Analysis" button and the tool will calculate to total race time.
4) Move the mouse cursor over the final lap on the chart and observe the different race times for the various pit strategies (see Figure 4.2).

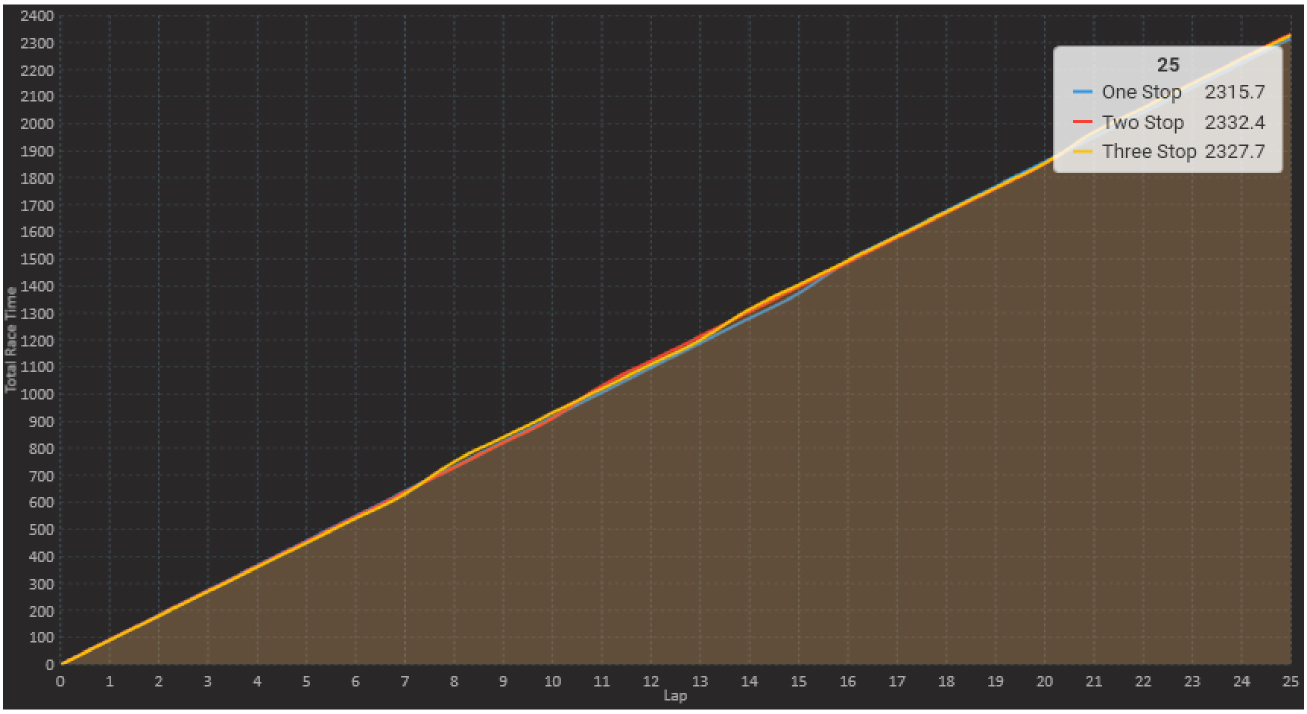

Figure 4.2: Race Strategy Analysis Example Results

As you can see, the one stop strategy is the fastest one in the above example, followed by the three stop one.

Another way to use the tool is to find out target lap times for your stints. If two pit strategies offer an equal race performance, simply adjust the estimated average lap times to find out how much quicker you need to be to compensate for an additional pit stop for example.

4.2. Preferences

In the Preferences you can adjust various app settings like the volume of the "New Lap" sound, default save locations for car parameter and session files or hotkeys for in-app navigation.

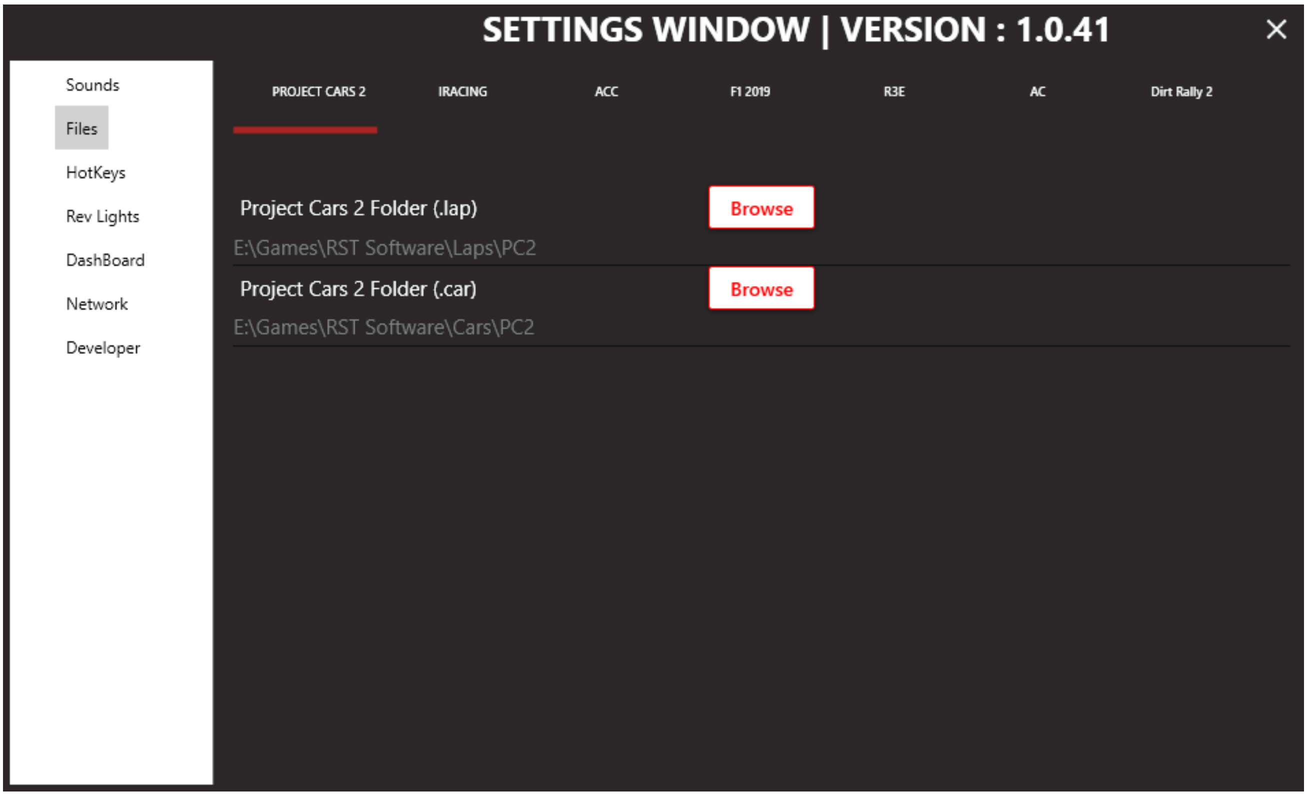

Figure 4.3: The Settings Window

4.3. License Store

Via the License Store you can purchase additional licenses for all games supported by the RST Software.

4.4. Help

The Help section is currently in development. Right now, it'll redirect you to the manual document you're currently reading.

4.5. Contact

If you're having technical issues with the app you can click the Contact button at the top right to submit a ticket to RST:

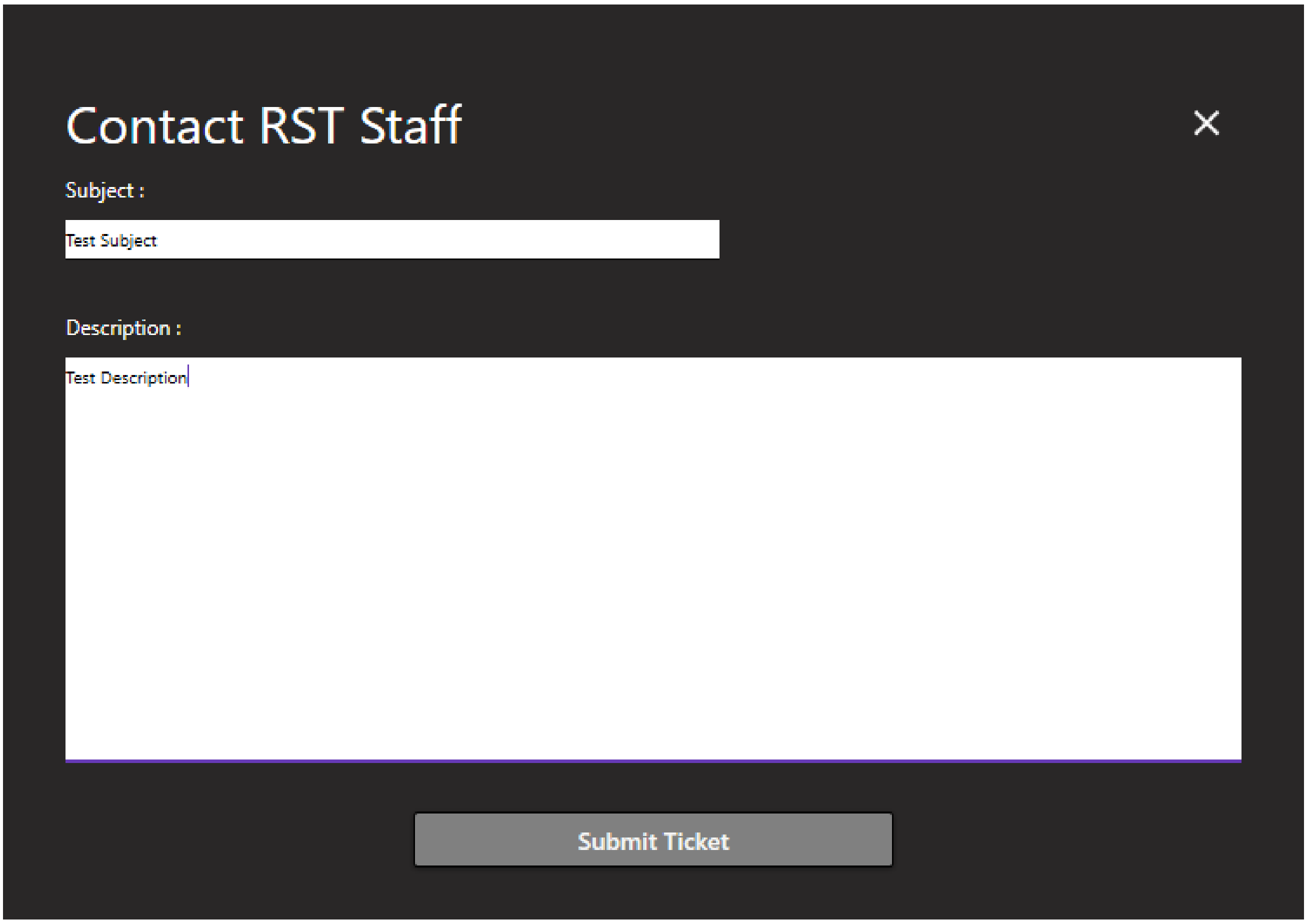

Figure 4.4: Submitting a Ticket

4.6. User Profile

Clicking on your profile name at the top right will allow you to view and edit your account information:

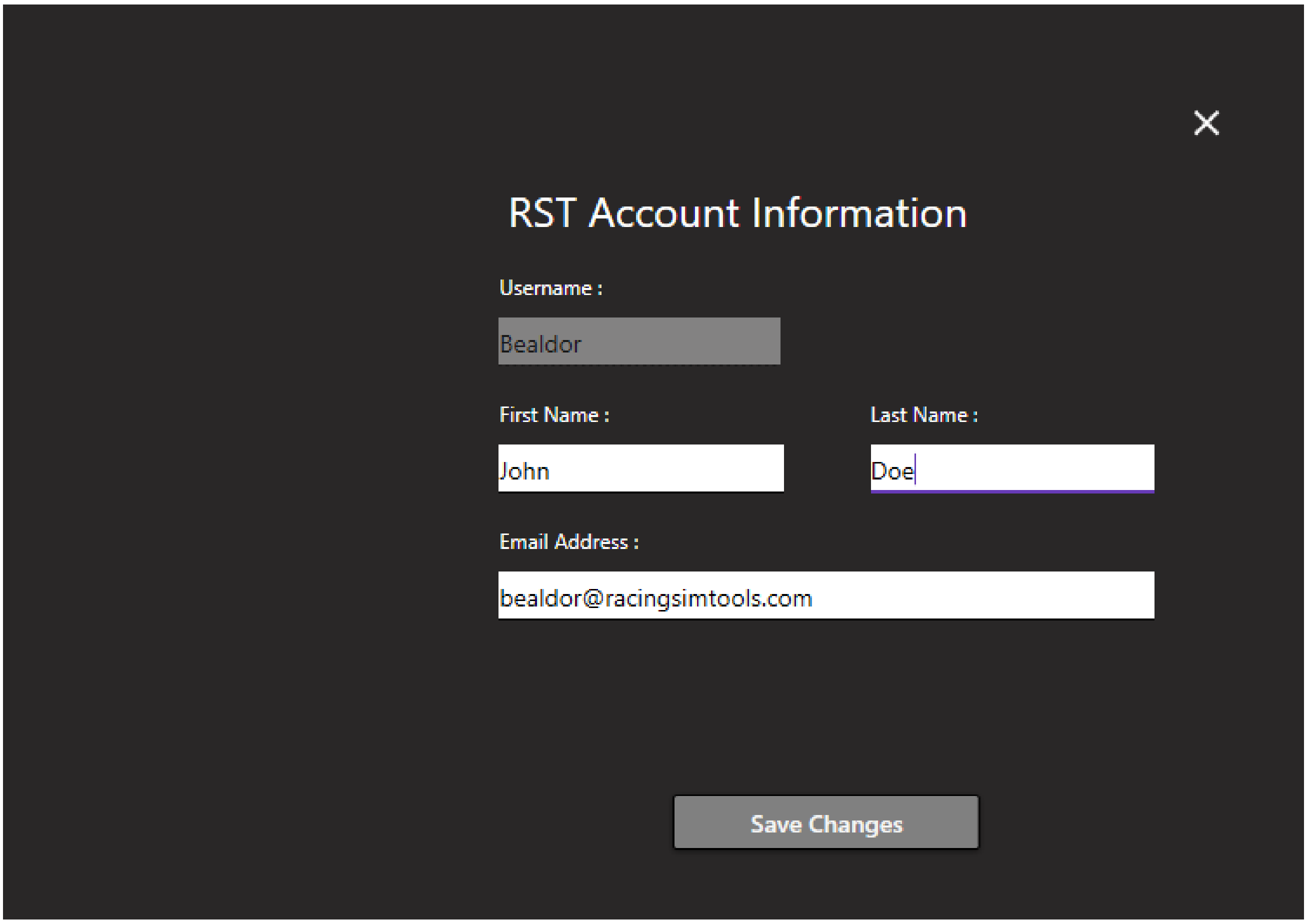

Figure 4.5: User Profile Editing

5. Useful Links and Literature

Books

[B-1] Analysis Techniques for Racecar Data Acquisition (2nd Edition); Jörge Segers

[B-2] Race Car Vehicle Dynamics (RCVD); William F. Milliken Douglas L. Milliken

[B-3] Race Car Vehicle Dynamics and Data Acquisition, Seminar binder; Claude Rouelle

[B-4] Making Sense of Squiggly Lines; Christopher Brown

[B-5] Vehicle Dynamics: Theory and Application; Reza N. Jazar

Online Articles, Videos and Technical Papers

[O-1] The Insider's Guide to Project CARS 2
https://www.youtube.com/playlist?list=PLwngKHZDy-rqLXf6oeOQ6O1rOrGfc2LNT

[O-2] OptimumG’s Technical Papers
http://www.optimumg.com/technical/technical-papers/

[O-3] NASA Speed News article on tire temperatures
https://nasaspeed.news/tech/wheels-tyres/tuning-tyres-tracking-tyre-temperatures-and-tuning-your-setup-accordingly-can-pay-dividends-on-the-racetrack/

[O-4] Collection of SAE Papers on Formula SAE
http://www.fsae.com/forums/showthread.php?658-SAE-papers-on-Formula-SAE

[O-5] ChassisSim’s YouTube Channel
https://www.youtube.com/user/ChassisSim

[O-6] Intothered talking about LSD
http://www.intothered.dk/simracing/differential.html

[O-7] MUR Motorsports on the topic of differentials, part one
https://murmotorsports.eng.unimelb.edu.au/news-and-events/news-and-events/mur-blog-differentialswhats-the-difference

[O-8] MUR Motorsports on the topic of differentials, part two
https://murmotorsports.eng.unimelb.edu.au/news-and-events/news-and-events/mur-blog-differentialswhats-the-difference-part-two

[O-9] Multibody modeling of a Limited Slip Differential
http://www.multibody.net/teaching/msms/students-projects-2012/limited-slip-differential/

[O-10] Brian Beckman's The Physics of Racing
http://phors.locost7.info/contents.htm

[O-11] Discussion on steady state lateral weight transfer
http://racingcardynamics.com/weight-transfer/