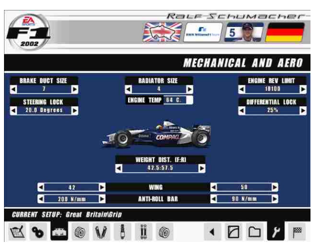
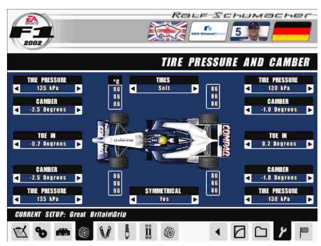
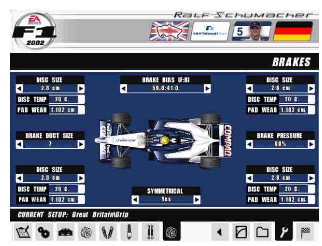
Advanced Formula 1 Setup Guide

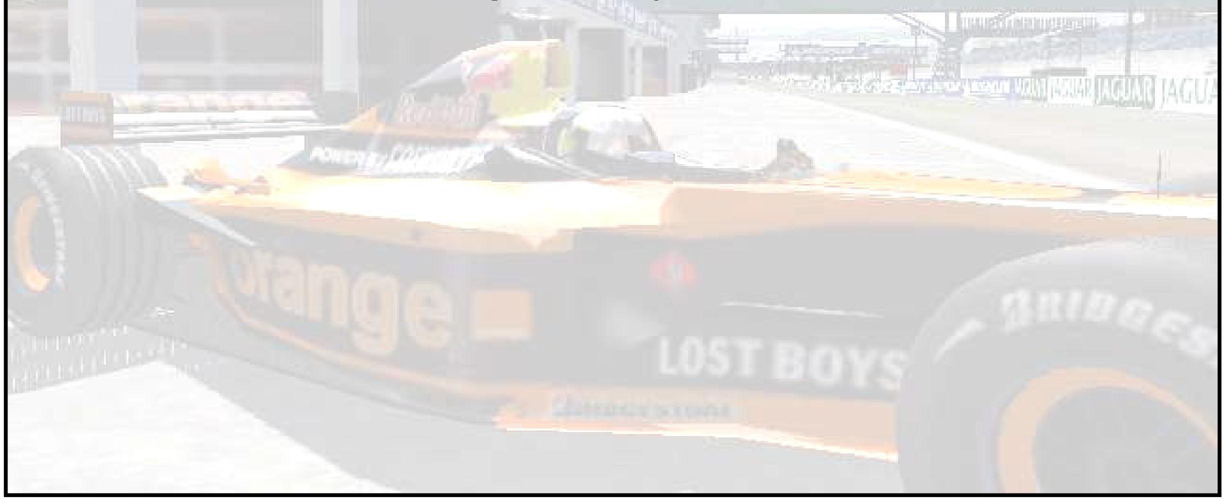






"To start with, the first thing a beginner should do, as far as setting up his car is concerned, is complete as many possible laps without worrying about other drivers. He must try to learn all about the car, systematically changing key components to see how they affect it: try a different anti-roll bar, softer then harder springs, adjust aerodynamic downforce, that sort of thing. Even in the junior formulae, driving skill alone is not enough, so you must know how to get the most out of your chassis. At that skill level, you can probably gain a second per lap through skillful driving, but lose three times as much by setting up the car incorrectly."

Alain Prost from his book "*Competition Driving*"



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Forward

First off: this guide will not make you a faster driver! Unfortunately, there is no quick fix for that. There is no substitute for logging the laps that make your reactions to the car become second nature. There is no quick way to learn a new circuit so you can concentrate totally on what the car is doing at any given point in time. The only way to be faster is to practice, read, learn, and practice some more.

What this guide can help you with, is understanding the various components involved in car setup, and why their adjustments affect what they do. In other words, the guide will give you the knowledge with which to create a faster car. After that, you still must drive the car to its limit!

And what makes a car fast? Well that depends on the driver and his technique. Some drivers prefer a lightly understeering car that reminds them gently where the limit is. Others have a more aggressive style and prefers to use oversteer to steer the car from both ends. And here is what's tricky: there is not one defining setup that is faster than any other setup for everyone. It's whatever gives a particular driver the confidence to drive a particular car at its limit. One thing is for sure, as you learn what settings work well for your style, you can generally apply those setup philosophies to most cars with desirable results.

This guide will refer to weight transfer over and over again. An F1 car has a minimum weight limit of 600Kg. That weight is subject to the laws of physics, and manipulating that weight is the science… no, make that *voodoo*, of car setup. The ultimate goal is to load that weight into the cars contact with earth, its tires, as evenly as possible at all times thus generating the tire temperatures that are deemed optimum for grip. As the car pitches (movement forward and backward) and rolls (movement from side to side) under acceleration, braking and cornering, this weight transfer must be manipulated to your advantage. Keep this in mind at all times because it is the name of the game.

This guide will not get into hotlapping. We will instead, focus on setting up the car for good solid, consistent performance. However, it shouldn't be too hard to push the principles outlined here to their limits and learn how and why those hotlap setups work.

The guide is divided into two basic parts: Part 1 will focus on all the various parts and pieces of the car, explain their principle roles and what they do, and give a brief setup guideline for each. It is the goal of the first part of this guide to give you a better understanding of what these components are, so you can better understand how and why to adjust them. Part 2 will be a testing session at Silverstone featuring the Arrows A-23 where we'll go over, in detail, all things discussed in the 1st part, while charting the effects and laptimes while we sort out the car and develop a well balanced, competitive setup.

Let's begin…

Aerodynamics

Aerodynamics is the single most important aspect of a modern day Formula 1 car. Much of the design budget is devoted towards shaping airflow over, under and around the car. Not only is airflow crucial in generating downforce with the lowest possible drag coefficient, but also serves to cool several systems including brakes, engine and transmission. The most often adjusted aerodynamic aids (at a Grand Prix circuit) are the front and rear wings and car ride-height.

Wings

The wings on an F1 car are not truly wings, as they do not achieve their downforce from purely airfoil low-pressure principles (United States CART and IRL series cars do in fact use airfoil wings in super-speedway trim). Wings on an F1 car are more like spoilers, in that they spoil the airflow in order to create downforce. This spoiled airflow therefore creates its downforce at the cost of aerodynamic friction, or drag.


The rear wing is always a compromise of rear downforce vs. top speed. High downforce settings produce serious drag, therefore greatly hindering the cars top speed. When setting rear wing angles, you should always try to obtain maximum rear downforce without impacting the cars ability to reach a competitive top speed.


The front wings do not impact drag much, even at their highest downforce settings. Therefore, the rule of thumb is to use as great a front wing angle as possible without upsetting the cars rear-end balance. While not done often, the front wings are adjustable during a Grand Prix pit stop.

Brake and engine cooling

Brakes and radiators require air at the cost of upsetting the airflow around the car and creating drag. Inside and slightly ahead of each hub/wheel assembly, are the brakes cooling ducts. These ducts are necessary to force cool air over the brake discs. They come in seven variations in size. We'll cover brake temperatures in the later section on brake wear.

The car also sports twin radiators whose airflow entry is at the front of the sidepods. These openings can be made larger or smaller depending on the circuit and radiator size. The smaller the inlet, the less friction is created as airflow is allowed to pass along the cars slippery sculptured body pieces. As a side note: The engine runs the most efficiently at its optimum temperature of 107.3 °C. Overheating begins at 110.6 °C and, by 113.9 °C the engine life expectancy is cut to 50%

Ride height (rear diffuser)

Airflow underneath the car is another source of downforce, particularly at the rear of the car. The airflow close to the ground is meticulously channeled under and around the plank. This airflow, due to the small gap between the car and road is highly pressurized from its "venturi" effect. From here, the air is accelerated by means of the rear diffuser. The diffuser design calculates the amount of space underneath the car, then sculpts an exit of increasing spatial volume. Much like an aircraft wing creates lift from low-pressure by accelerating airflow over its tapered surface, the diffuser creates this low-pressure acceleration at the rear of the car, and in the opposite direction, as the undercar airflow is literally pulled out from underneath. This suction causes downforce *without any drag penalty*. Therefore it's very, very efficient.

This low-pressure downforce increases as the ride height decreases. This is why we want to run the car as low to the ground as possible without drastically affecting plank wear. Ride height is initially dictated by spring rates, which themselves are selected for handling characteristics. Then the cars ride-height is fine-tuned by the ride-height adjustments on the suspension push rods (see picture on following page).

General principles:

Wing (rear): As high a degree as possible without effecting the car's competitive, straight-line speed.
Wing (front): As high a degree as possible to balance the rear downforce.

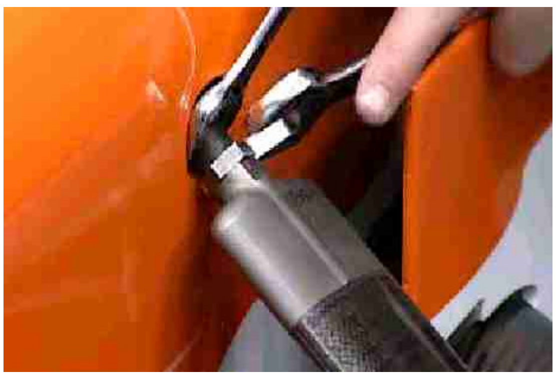
Ride height: Should be setup as low as possible without adversely effecting plank wear.

Suspension (overview)

The suspension of an F1 car is comprised of a complex set of hardware components. First there's the upper and lower control A-arms, or wishbones. These are the triangular, black carbon/fiber or steel pieces, which attach the wheel/hub assembly to the chassis. These are hinged both at the chassis and the wheel/hub assembly and provide the radius on which the wheel travels up and down. Usually by design, the wishbones run roughly parallel to the track surface and are aerodynamically shaped.

The push rods run diagonally from the bottom of either wheel/hub/lower wishbone, up to the chassis where through a complex pivotal rocker arm, it interfaces with the springs, dampers and anti-roll bar (see below right). The push rod transfers the weight of the car into the spring and damper assemblies. The push rod is also the point at which ride height is fine-tuned. Height adjustments are made via an adjustment nut where the push rod penetrates the body.

Also running parallel to the front edge of the upper wishbones are the steering arms. These connect the upper front section of the wheel/hub assembly to the steering box located in the nose of the car, which houses the steering ratio gear. The gearing of this unit dictates the steering lock. This point also allows the setting of the front wheels toe adjustments.



Altering the front ride height

Push rod, dampers and packers

The front springs and dampers reside under a cover-plate located on the nose of the car, just ahead of the driver's cockpit opening. When this panel is removed, crew can access the all hardware including front springs, dampers and packers.

"In motor racing, including Formula 1, you must always reach a compromise between the various settings which affect the performance of the car. There is no clearly defined procedure that will allow you to find the most effective setup in a scientific and dependable way"

Ayrton Senna from his book "*Principles of Race Driving*"

It's vital to make a point at this time. When adjusting suspension components, more so than at any other time, you really are balancing understeer and oversteer from all 4 corners of the car. Because the springs and dampers affect weight transfer, it is possible to dramatically, and directly affect the front of the car by adjusting the rear. And vise versa. In other instances, such as wings for example, even though understeer and oversteer are used as descriptors, you're actually only affecting the specific end of the car where the adjustment is being made. It's because of the complexity of the suspension, it's important that you fully understand all the components and their specific purposes.

Springs

Springs store energy by absorbing or deflecting force. That is, when weight is transferred, the resulting energy is stored temporarily within the springs of the car until the weight is returned to its static state. At this point, the springs merely store the energy resulting from the car's weight under the force of gravity.

2 sizes of torsion springs

Top of installed spring and spring pivot

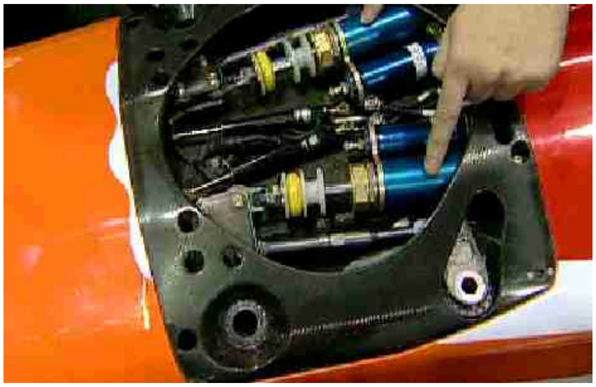
The springs on a typical F1 car are not springs in the tradition coil sense, but rather "torsion bars" (see picture above left). Rather than dissipate energy through a coil, the torsion bar spring twists while absorbing energy. The diameter of the spring indicates its torsion strength and therefore how much energy it can store. In general, the spring's strength ranges from 100 N/mm to 250 N/mm (a conversion table is located in the "References and Resources" pages for conversion into imperial lbs.). The bottom of the spring is fixed to the chassis, while the top is attached to the push rod rocker arm (above picture on right) via a short connecting arm. In the rear of the car, the springs are enclosed on either side of the gearbox/differential. From the pictures, you can imagine exactly how easily the springs can be changed on a modern F1 car.

The spring's main function is to suspend the cars mass (thus being called "sprung mass") while establishing a basic ride height, absorbing bumps and undulations, and controlling the motion of the vehicle under weight transfer during acceleration, braking, and cornering. These are critical functions, as due to the increasing influence of modern aerodynamics, any drastic changes to the car's pitch and attitude will disrupt the aerodynamic downforce and overall efficiency.

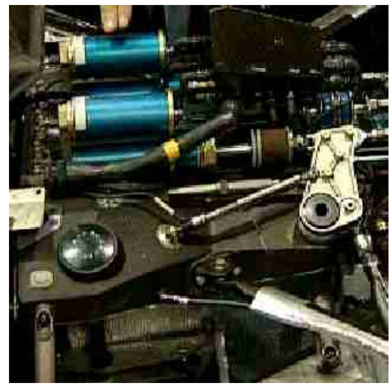
Here's the basic principle: "***Softer" springs generally absorb more weight, therefore when the weight is unloaded away from that corner of the car, the spring unloads slower. This allows for better grip because under weight transfer, by allowing the sprung weight to roll while less energy is transferred from the tires. This however, comes at the cost of lower response time to driver input. "Stiffer" springs deflect weight because they load weight slower and unload it quicker. This increases driver response time, but due to higher deflection under weight transfer can overload the tire quicker, thus producing less grip.*** And remember; softer and stiffer are relative. In a modern F1 car, even the softest springs are stiff by road car standards.

Dampers

Dampers, or shock absorbers, are oil-filled cylinders which control the movement of the springs travel. In it’s basic form a damper consists of a piston, piston rod, and the oil cylinder. The kinetic energy from the piston movement is damped into the oil, resulting in increased heat. Therefore, the damper placement needs some form of cooling, since excessive heat can effect the performance.



Front dampers (blue) and packers (white)



Rear dampers

In above left picture, note the layout of the suspension. The lower left, larger “hole” marks the pivot point around which the push rod connection interfaces with the spring and damper (via the rocker arm that originates from the pivot-point and connects to the damper piston rod and spring connecting rod). Note how the travel of the damper and the spring connecting rod runs parallel to one other.

Basically, the internal workings of the damper are as follows: The piston forces the oil to flow through small holes in both the inner cylinder wall and through the “shim stacks” (which are diffusers above and below the piston). When adjustments are made to the dampers, it affects the size of the holes, thereby regulating the oil resistance during piston travel. Adjustments to the “slow response” are made to the shim stacks, while adjustments made to the various inner cylinder holes alter the damper “fast response”. Since the fluid in the damper is hydraulic oil (and allows for no compression), an inert gas, nitrogen is used to allow slight compression as the damper piston travels.

Dampers control the way the springs react in the transition of loading and unloading energy. Example: under severe braking, the front-end pitches down, and front ride height decreases under weight transfer. ***While the springs dictate the amount that the nose pitches down, the dampers control the rate at which the pitch occurs***. And of course, this applies to all transfer of weight during acceleration, braking and cornering.

Dampers on an F1 car are 4-way adjustable. You may adjust the slow and fast response of the “bump” movement (energy loading into the springs), and the slow and fast response to the “rebound” movement (energy unloading out of the springs). The terms fast and slow do not correlate to the speed of the car, but rather the speed of the piston’s travel within the cylinder under the force of the push rod’s energy transfer. An easy method to analyze this is as follows: ***slow damping affects the weight transfer of the cars sprung mass (chassis pitch and roll) on the springs; fast damping controls the springs response to the deflection of the cars unsprung weight (the tire/wheel/hub assembly reaction to bumps).*** In other words, slow fine-tunes the cornering balance, fast fine-tunes the cars ability to handle over bumpy surfaces.

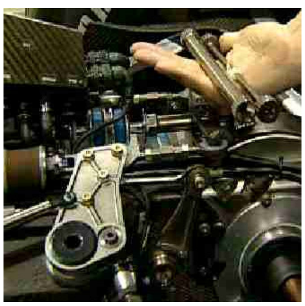
Dampers are the most finely tuned adjustments made to the suspension. The dampers should be the finishing touches to a well-crafted car setup. Because the nature of the dampers is so critical to the ultimate performance of the racecar, I suggest reading as much as possible on this topic. A great resource for this and other technical topics is the website “Technical F1”. It is listed (along with many more) in the chapter titled “References and Resources”.

Packers

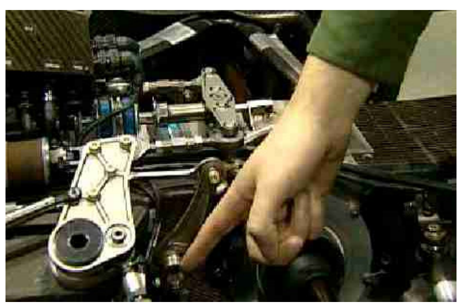
Packers are composite "spacers" placed on the piston rod of the dampers. The packers are a last ditch effort to keep the plank underneath the car from being damaged. When the suspension push rod moves up with extreme force, compressing the spring and dampers to their maximum, the packer stops the travel of the suspension by impacting the damper cylinder body and the bump rubber (yellow rubber seals in previous picture on the left). If you look closely at the picture on the previous page, you'll see the packers are free to move along the damper piston rods. Packers range from 0.0 cm to 4.0 cm in the front and 0.0 cm to 8.0 cm at the rear. The packers on the previous page appear to be about 2.0 cm.

Anti-roll bars

So far, the springs, dampers, and packers are grouped where each wheel/tire has independent control. And even though all 4 corners of the car are completely independent, most adjustments to these components are made symmetrically, with both left and right front spring/damper settings adjusted the same and both left and right rear spring/damper settings adjusted the same. This way, they handle the transfer of weight from front to back very efficiently, and handle bumps at each wheel extremely well. But, weight transfer from inside to outside during steady state cornering is not yet at maximum efficiency. The inside tires lose traction while the outside tires load-up during cornering. This is where anti-roll bars come into play.



2 sizes of anti-roll bars



The rear bar couples here

The front bar is in the nose

Anti-roll bars, like springs, are torsion bars on today's F1 machines. Here is how they work: the anti-roll bar ties the left and right side springs and dampers together laterally. Remember the picture of the front springs and dampers where I pointed out how they traveled parallel to each other? Each end of the anti-roll bar attaches via a connecting rod to the same rocker arm as the damper and springs; one end to the left side, the other to the right. When the car hits a dip in the road, both wheels reaction is roughly the same (travelling up…then returning down), so the bar merely "rolls" equally in the same direction with little to no effect. However in a turn, the weight transfer is from inside to outside. The inside wheels travels down (losing sprung weight) as the inside springs releases energy under weight transfer and the outside wheels travels up (remember the car weight is rolling inside to outside) as the outside springs absorbs more energy. This causes the anti-roll bar to twist its ends in opposite directions. This in turn limits the chassis roll and suspension travel due to the anti-roll bar limiting the amount of opposing spring/damper energy loading/unloading, thus transferring some grip back towards the inside of the turn and the inside wheels.

Like springs, anti-roll bar strength is size depended. The range of anti-roll bars are 100 N/mm to 200 N/mm in 5 N/mm increments for the front and 50 N/mm to 130 N/mm in 5 N/mm increments at the rear. Notice the front is generally higher? In general front anti-roll bars, as well as springs, are stiffer than those in the rear of the car are. This facilitates better front-end turn-in response and rear-end traction under corner turn-in and exit acceleration.

Suspension: how it all works together

General principles:

Springs (Primary usage) Establish ride height and "rough-in" the handling balance of the car.
Springs (front): Use as stiff a spring as possible for quick driver response and lowest possible ride height.
Springs (rear): Use as soft a spring as possible for better traction under braking/turn-in and acceleration.

Dampers (Primary usage) Fine-tune handling by controlling spring loading/unloading over bumps and under weight transfer.
Dampers (front): Use as soft a setting as possible for best front-end grip.
Dampers (rear): Use as stiff a setting as possible for good high-speed cornering stability.
Slow settings: Controls sprung weight (chassis pitch and roll) during weight transfer.
Fast settings: Controls unsprung weight (tires and wheels) over bumps and kerbs.

Anti-roll bar (Primary usage) Limit chassis roll under steady state corner loading.
Anti-roll bar (front): Use as stiff a roll bar as possible for good corner turn-in stability.
Anti-roll bar (rear): Use as soft a roll bar as possible for better traction under acceleration on exit.

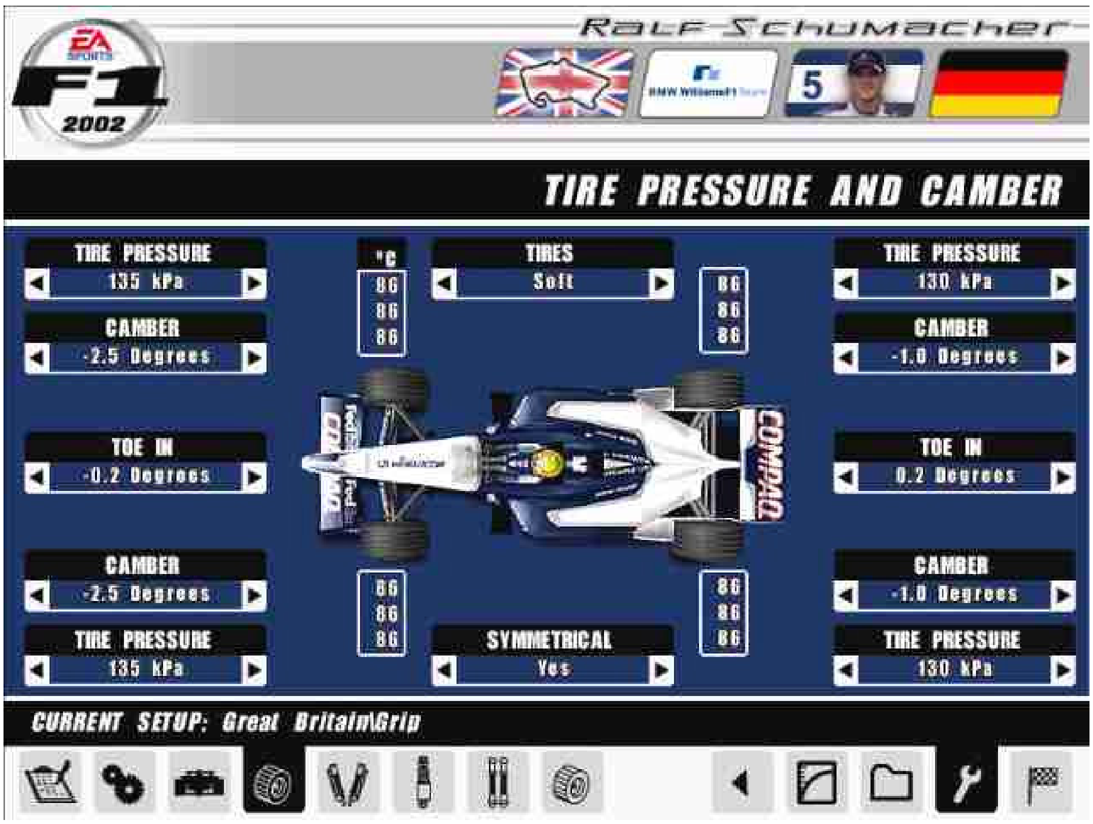
All of these components work together create mechanical grip. Remember the objective it to get the tires up to their optimum operating temperature so they can produce their maximum grip. Those temperatures are a direct result of the weight loaded into the tire. While mechanical grip does assist the dominant aerodynamics at high speeds, it really contributes greatly at lower speeds when aerodynamic downforce is less influential. Here's how the suspension contributes to mechanical grip:

1. The springs establish a basic ride height and mechanical grip balance from front to rear.
2. As the car brakes for a turn, lighter rear springs efficiently deal with the transferring weight from the rear, allowing the suspension to maintain some rear-end grip by not fully unloading the tires. The dampers control the springs transition and reactions from sudden bumps that may upset that the spring's ability to transfer this weight.
3. On initial turn-in, the dampers continue to control the transition of the springs as the weight transfer shifts from inside to outside on the chassis.
4. As the car transits from turn-in to steady state cornering, the anti-roll bars limit the chassis roll from inside to outside, thus reloading the inside tires with weight.
5. As the car approaches the exit of the turn, the anti-roll bars begin releasing their energy, placing the weight transfer back onto the springs under the control of the dampers.
6. On exit as power is reapplied to the rear tires, the weight transfers to the rear. The softer rear springs now allow the rear to absorb that energy quicker and apply it towards maximum traction under acceleration.

Note: A compromise must always be obtained when setting up the car. Example: Damper values set too high when using soft spring rates will negate the spring rate all together as they will control the loading to such a degree as the spring never fully loads, or to a more detrimental degree unloads more rapidly. All components should work together, each one doing its specific part, and it's this synergy that allows the most efficient handling of weight transfer over the various attributes of the given circuit. This guide will demonstrate all this at greater detail in the chapter "Establishing a setup".

Tires

A formula car has purpose-built racing tires. These tires come in five variations with an associated optimum running temperature: ‘soft” (112 °C) and ‘hard” (114 °C) dry weather tires, light-treaded ‘intermediate” (109 °C) wet weather tires, medium-treaded ‘wet” (107 °C) rain tires, and deep-treaded ‘monsoon” (105 °C) severe rain tires. The general rule is the softer the compound, the higher the tires grip level. But the softer tire is more susceptible to heat therefore increased wear. Wet weather tires are usually softer than dry weather tires to maximize a cars grip in wet conditions, so don’t get caught on a dry track with wet tires for long or you’ll quickly overheat and blister them.



RacerAlex Advanced Garage Menu

Because the tires are the cars sole contact patches with the track, we can learn a wealth of information by taking temperature readings from each tire throughout a session. This is the single most important physical indicator of what the suspension is doing. These readings are taken from three locations across the tire tread: inside edge, middle, and outside edge. In the above Tire Pressure and Camber menu shot you can see the tire temperature readings above and below their respective tires. The readings are, as if looking at the tire from above: outside temperature on top for the cars right side and outside temperature on the bottom for the car’s left side. Using these readings, you can accurately setup the tires camber angle adjustments and tire pressure, as well as getting indications as to the efficiency of your spring rate and damper choices. When all temperatures across a specific tire are equal, this indicates the tire contact patch is averaging flat against the track over a lap.

The tires will achieve maximum grip when run at their associated optimum running temperatures. The higher the temperatures, the more loading under weight transfer that tire is experiencing. The lower the temperature, not enough weight is being loaded into the tire (or too much weight is being unloaded from that tire).

Camber and tire pressure

Camber adjustments and tire pressure settings allow us to fine-tune the tire contact patch to the road surface. The camber adjustment fine-tunes how flat the tires contact patch is to the ground by tilting the top of the wheel/hub assembly towards or away from the chassis. With this in mind, the camber helps us even out the individual tire wear based on temperature readings from the tires inside and outside edges. Let's take a look at the two camber adjustment extremes:

+2.0 degrees front camber

-6.0 degrees front camber

The above left picture shows the maximum positive camber adjustment of +2.0 degrees (we measure camber in degrees of the radius in which the wheel tilts). Positive camber is where the top of the wheel/tire assembly leans away from the car. Let's be honest here: you will probably never use positive camber in a modern F1 racing car. In the above setting, the outside edges of the front tires will carry most of the loading, therefore run much hotter than the rest of the tire. And that heat means greater tire wear to the outside edges, not to mention loss of grip from less tire contact. Remember the objective is to maximize tire grip and the beauty is that maximum grip means even temperatures across the tire.

On the other hand, the right picture shows an extreme amount of negative camber. Negative camber is when the top of the wheel/tire assembly leans in towards the car. Under nominal conditions, this extreme amount of negative camber setup will heat the inside edges of the tires prematurely and yield uneven tire wear plus less than the maximum amount of mechanical grip. However, some degree of negative camber is the most efficient setting for maximizing tire grip. As the car turns-in with a slight amount of chassis roll, weight is transferred to the outside tires. The outside tire bares the majority of the load during cornering. Negative camber helps the outside tires move into a more perpendicular position under this weight transfer.

One thing though: ***The amount of laps and how hard the car was pushed should always be taken into consideration when taking tire temperature readings***. A setup with negative camber will be heating up tires inside edges under straight-line running. However this heat (tire wear) is insignificant to the amount of heat built-up during hard cornering. Still, it raises an interesting observation. Should you apply negative camber to a setup, then go out and run two laps at 80% of the cars ability (not really pushing it), your temperature readings might prove false information by showing hotter inside temps than when the car is being pushed hard. For best results, you should run at least three laps at 95% of the cars ability before expecting conclusive temperature readings.

Tire pressure is the way to increase or decrease the middle temperature reading (at the tires 'crown') on each tire relative to the edges. In most upper forms of racing, nitrogen is used as the pressurizing substance rather than air. Nitrogen being an inert gas has little fluctuation of pressure brought on by temperature changes. Also, it's less likely to allow moisture to condense within the tire (which in turn can cause a tire imbalance).

The sidewall of an F1 racing tire is fairly stiff, so if tire pressure is low, the tire tends to bulge in the sides (where it begins to bare the static weight of the car) and pull the middle of the treads crown inward towards the wheel rim. In this condition, the outside edges heat up more than the inside since they're contacting the road more than the center. Likewise, if the tire is over-inflated, the middle of the tires crown will protrude outward further than its two edges. In either case, if the tire is not flat against the track, the point that impacts greatest will generate higher temperatures under increased friction. The result is less grip, more wear.

Enough cannot be said about understanding the relationship between tire temperatures and camber and tire pressure adjustments. It's vital that one consistently observes the tire temperatures during setup changes, and more importantly, takes the time to analyze why they are at the temperatures monitored after the laps.

All this factors into the suspension settings as well. If we are to lower the spring rates, then it will effect the camber adjustments. Since the softer springs absorb more weight, the static ride height lowers. Under the suspension compression, the tires begin to lean in as the wishbones move up. This in turn causes the need for a camber adjustment to counter the effects and place the tires back perpendicular to the road surface. The process continuously cycles through. But don't worry, as you get the car closer and closer to your liking the changes will become smaller and smaller.

"The aim of a driver and his team in setting up the car is to ensure that the tyres operate in the best possible conditions. Only in this way will a tyre, which is one of the fundamental components of a Formula 1 car, perform to the limit of its potential"

Ayrton Senna from his book "*Principles of Race Driving*"

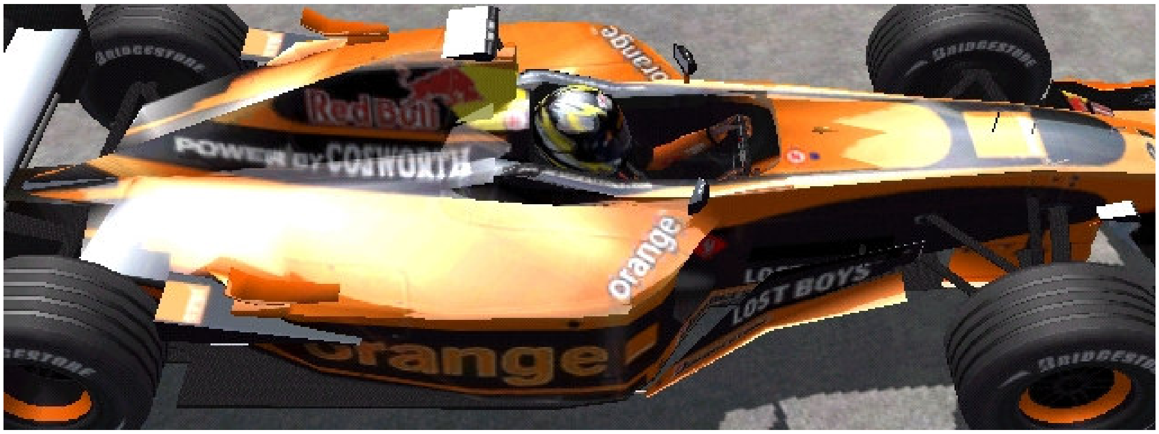
Toe-in

Toe is the static angle of the wheels, as seen from above, as to whether they point in (leading edge towards the car, which is negative or toe-in) or out (leading edge away from the car, which is positive or toe-out). The reason most cars have a bit of front negative toe, or toe-in, is to promote straight-line steering stability. If a car was to have 0-degree toe it would be very nervous on a straight road, wanting to dart and wander at any little bump, rut or groove. By adding toe-in (negative toe), each wheel attempts to turn the car "inward" at all times. This in turn creates that centering feel we have through the steering wheel and promotes better straight-line stability.

Rear toe is a highly debated topic. On the negative side, critics claim rear toe only adds to increased and uneven tire wear. And this comes with no discernable performance advantage. On the positive side, pundits claim a slight positive toe, or toe-out, at the rear can help stabilize the rear of the car under acceleration.

But be mindful; too much negative toe-in will heat the outside edges of the tires, creating friction and affecting speed to a small degree. Excessive toe-out meanwhile will heat the tires inside edge. You should counter these reactions with small camber adjustments.

Weight distribution



All Formula 1 designers attempt to deliver the car under the legal 600Kg minimum weight limit the FIA imposes. This is to allow the use of ballast to fine-tune the weight distribution of the car for a particular circuit. In fact, this is such a regular practice these days that most Formula 1 cars are delivered to the test track initially weighting less than a Formula 3 car.

With the advent of more stringent safety rules, the driver position has been pushed further back in recent years to reduce injuries. This in turn has shifted the majority of weight towards the rear of the car. While weight distribution seems to be a fix for this imbalance, it is simply not the case for a number of reasons. Foremost is the FIA rule stating that any ballast must be secured to the car and non-movable. This means F1 cars cannot take advantage of weight-jacker systems and instead must have built-in compartments to bolt the weight in around the car. This does limit the possibilities somewhat.

The ideal materials for ballast are depleted bars of Uranium, and Mallory. These materials are very, very dense in relation to size making them ideal to helping F1 teams conform to the FIA regulations while giving them as many options towards placement as possible. Still compartments are very difficult to design into the chassis, with most compartments placed under the drivers' legs in the nose of the car. The placement of the engine/transmission (as well as the fact that the majority of weight is already in the rear) makes ballast compartments in the rear not as popular of an option.

Because of this, weight distribution is a sublimely difficult thing to grasp. The weight typically is adding traction to the end of the car that you shift it towards. This means that weight shifted towards the rear will put less weight on the front end resulting in increasing understeer. Shift it forward, and less weight is distributed to the rear under acceleration. Then again, it depends on how well balanced the setup is initially as it relies on spring and damper choices. So with this in mind, weight distribution is a fine-adjustment of the cars handling characteristics. Typically, weight distribution is one of the final, finishing touches to a setup, and sometimes that last-ditch effort to make a stubborn car turn good.

In the simulation, each car has it's own distinct weight distribution. This is due to the vario us engine weights and chassis designs. Distribution of the ballast is in .5% increments forward or aft.

Weight distribution set furthest forward in the Arrows A23.

Braking system (overview)

If Formula 1 is the pinnacle of motor sports, then the braking system is the peak of that pinnacle. Time and time again upon receiving that elusive test session from a Formula 1 team, drivers from other formulae climb from the car afterwards absolute stunned by the car's braking abilities.

The braking system of an F1 car is a conventional hydraulic pressurized piston, pad, and disc system. The driver applies force to a pedal. This force is then converted into pressurized hydraulic fluid via a pump attached to the dual master-cylinders (feeding the front and rear brakes independently). These cylinders feed pressurized fluid to each of the cars four individual brake calipers (some designs have two calipers per wheel making eight calipers total). The fluid, under pressure, moves pistons (usually 4 per brake caliper), that press carbon fiber pads onto the rotating brake disc.

Brake pressure

Using add-on advance menus, it is possible to alter the brake system pressure (along with many additional braking system features). The default is 80%. That's 20% stopping power you cannot harness from the stock menus. This alone is a great reason to install one of the many advanced menus out there. I routinely set the brake pressure at 100%, only reducing it for extreme conditions, such as wet weather.

It should be noted though, increased brake system pressure also increases the brake wear rate. It is best to increase pressure and regulate your braking technique to decrease brake wear. This way, you can tap the full potential of the braking system at those moments when needed, such as a late braking pass.

RacerAlex Advanced Garage Menu

Formula cars do not use power assists within the braking system. The driver requires a very high degree of "feel" fed back through the system in order for him to modulate the brakes; modulation being the minute adjustment of pressure to prevent wheel lock-up. Wheel lock-up is undesirable, however since optimum braking is the nth degree prior to lock-up, we do experience locked wheels from time to time. Especially when driving in anger!

Modulating this pressure is the trait of a top-flight racing driver. One modulation technique especially effective is trail-braking. Trail-braking is the modulation of the brakes as so they lighten progressively during corner turn-in. Since the weight transfer is shifted forward, the rear end is prone to 'step out' during this phase of cornering. This lightening of the pressure helps to prevent this and effectively allows the driver to continue his braking further into the corner, sometimes even right up until the moment that throttle is re-applied at the apex. This in turn allows more speed to be carried into the corner.

Another technique is the application of light throttle during turn-in while the brakes are still being applied (this requires split axis pedal setups). This aggressive driving style in effect allows torque to the rear wheels to semi-control the weight transfer forward during this critical time. And in extreme instances, the application includes short bursts of throttle to induce oversteer to tuck the nose in towards the apex.

Both of these techniques are very difficult to master and the latter somewhat controversial. As the philosophy of this guide is based more on setup and less on technique, I recommend that you search you favorite forum to learn more on mastering these techniques, particularly trail-braking, as it is commonly used.

Brake Bias

Since the performance of a Formula 1 car is based on it's ability to exploit weight transfer, it is necessary to alter the braking balance of the car. When we alter the braking balance, we're merely shifting the force of the brakes so as half the car experiences more stopping power to the wheels than the other. The half we always shift towards is the front for the simply reason that weight transfers to the front under braking. We compensate because without this shift in bias, the transfer tends to makes the rear tires less tractable.

The means of the setting braking bias is via a pivot connection behind the brake pedal. This pivot connects the pedal to the twin master cylinder pistons. By altering the angle of this pivot, the driver effectively adjusts how much of the pedal movement is transferred into which piston, which in turn adjusts the brake pressure independently. The adjustment of the brake bias is so critical, it must be set by the driver while driving the car. A lever or knob in the cockpit sets the pivot angle adjustment. Typically, the brakes bias is adjusted several times during a race to compensate for varying fuel load, tire wear, and track conditions.

With 50/50 braking bias, the rear wheels will lock prematurely as the weight shifts away from them under braking causing the car to oversteer during corner entry. The rule of thumb is to set the greatest amount of front bias without locking the front wheels under nominal braking conditions. Shifting this forward however will increase the cars tendency to understeer on corner entry.

Brake wear

The two most common braking system problems are brake fade brought on by excessive heat and system total failure brought on by excessive wear

Brakes require a certain temperature to operate at maximum efficiency. Cold brakes do not have the stopping force of a heated disc. Optimum brake temperature is 550 °C and at this temperature the brake will produce the most amount of stopping force. However, since the stopping friction creates heat, heat then turns into a detriment, causing increased pad wear and 'brake fade", or reduced stopping force. Above 550 °C brake fade begins progressively and by 1650 °C, the stopping force is half of that experienced at the optimum temperature. Running the brakes at close to their optimum temperature is crucial. Altering the brake cooling duct sizes controls this. Add-on advance menus offer various brake temperature readings for all four discs to aid in the adjustment of this setting.

In addition, add-on advanced menus monitor brake pad wear levels, by establishing the thickness of the pads at the beginning of a run. After the run, the reduced pad thickness indicates the wear rate. From here you can calculate exactly how long the pads will last. Combined with the temperature readings, you can precisely set the duct size for the required temperature to control brake wear for the calculated race length.

Disc size

Two sizes of brake discs are available using add-on advanced menus. The lighter brake discs are used for qualifying as they reduce unsprung weight. They are approximately 1/3rd the thickness of the standard brake discs. Temperature is more difficult to control in these thin discs.

Transmission (overview)

Modern Formula 1 cars employ a longitudinal inboard semi/fully automatic transmission. Paddle shifters behind the steering wheel are connected to servo-valves, which allow electrical connections to run to the rear of the car to four actuators. The actuators then use hydraulics to move gearbox selector rods which engage/disengage the selected gears. A CPU control system operates the clutch, matches engine revs and prohibits the system from shifting under potentially damaging conditions. This system also allows pre-programmed shift patterns for controlled downshifts, as well as fully automatic up and down shifting options. These systems are capable of shifting gears between 20 to 40 milliseconds.

Minardi's high tech die cast titanium gearbox casing

A crucial aspect to the gearbox is the casing itself. This in part is because the gearbox is a structural part of the chassis, with rear suspension mounting points integrated. Titanium was the material of choice for construction, but these have since been evolved towards titanium alloys and even carbon fiber, as in the case of the current Arrows A23.

The gearbox bolts to the back of the engine. A few years back, gears could be altered very rapidly with older outboard gearboxes (this placed the gears aft of the differential where they could be accessed from the rear of the car), however today's gearboxes require about 30 minutes to change out all 7 gears. Ferrari recently have successfully incorporated the gearbox into the main engine block casting process for a unified engine block/gearbox design, further improving the rigidity of the car.

Gearing

The transmissions main function is to maximize the engine peak horsepower and torque bands over the range of speeds and road conditions the car will encounter. It does this by altering the specifications of the forward speed gear cogs (FIA regulations allows from 4 to 7 speed gearboxes). Today, most F1 cars elect to use either 6 or 7 forward gear selections. Each of these gears when coupled between the crankshaft and the differential alters the ratio at which the drive wheels spin. These cogs are somewhat fragile and used for only one race and sometimes replaced several times during a race weekend. In addition to the forward gears, the FIA mandates that an F1 car must have at least a single reverse gear. In truth, this gear is of little consequence to performance, and therefore very lightweight and fragile.

Each "gear" is made up of two gear cogs that together make up a ratio. One gear, the pinion gear, is on the main shaft coming off the clutch. The other gear is on the output shaft, which is the shaft that delivers the rotation to the differential. These gears (the ones on the main shaft and the ones on the output shaft) are mated at all times, but only one gear ratio set is coupled to the output shaft at any time. This is the gear you've selected from the cockpit.

You basically have 69 different available gear ratios to choose from, that's not including the 3 final drive gears for the differential. Each gear is designated by two values. First there's the XX/XX tag which is the numeric value representing that specific gears. The two numbers represent the number of teeth on both gears that make up the ratio. Then there is the (XX.XXX) value, which is the final ratio of the selected gear once coupled to the final drive gear ratio. This value tells you how many revolutions the crankshaft spins relative to the driveshafts at the rear wheels. You'll note that as you change the final drive gear, these values will change where as the first values remain constant.

When selecting gear ratios, two factors control the first decision: what are the circuits expected top speed and what is the slowest corner on the racecourse. The latter most of the time is a second gear corner so we'll initially focus on second gear and then the 6th or 7th gear. After establishing those ratios, we will even space the remaining 3rd through 5th gears (or 6th in 7-speed gearboxes) for maximum and even acceleration up to the top speed.

If the circuit has a hairpin (like Magny-Cours in France) then sometimes 1st gear will be chosen for dependable navigation of that corner. If the slowest corner is a 2nd gear corner, then first gear is selected solely for the start of the race. Even then, certain factors play a role in making the ratio selection. The initial selection should be made for maximum acceleration up to 2nd gear from a flat starting grid position. If the qualified grid position is on a decline, one might want to shorten the ratio by 1 increment. If the qualified grid position is on a slight incline, the opposite would be true. With the advent of launch control systems, it is less crucial to set this, but none the less it makes good sense to better the cars performance in any way possible.

Differential (final drive gear)

The differential is the mechanical coupler between the transmission output and the driveshafts of the rear wheels and in an F1 car is integrated into the gearbox itself. This is where the engines crankshaft rotation, after being applied through the clutch and specific selected gear, is transferred by the associated final drive gearing ratio to the drive wheels.

Connection between the differential input shaft and the gearbox output shaft is via the final drive gear. The selection of one of three different ratios impacts all forward and reverse speeds. The lower ratio improves acceleration at the cost of top speed. The higher ratio has the opposite effect. It's a good idea to start with the middle ratio: 13/52 (bevel 30.42) and adjust up of down should you need to shift all you gearing at once (say you add quite a bit more wing). Another trick would be to adjust it up for converting a setup to wet weather running. This in turn reduces torque to the rear wheels.

Differential Lock

F1 differentials are of a limited slip-type. This means the level of coupling between the differential input shaft and the rear wheel driveshafts is variable. The differential's level of coupling (or lock, as EA F1 2002 defines it) determines how the torque is applied to both the drive wheels in relation to one another. At 100% lock, both drive shafts are effectively LOCKED together, and torque is always applied from the differential to both wheels equally. At 0% lock, if one wheel should lose traction unequal to the opposite wheel (as if half the car goes onto the grass shoulder), then the differential shifts (or 'slips') torque away from the wheel with the least amount of traction.

Understand, as this is a mechanical process the differential CANNOT operate giving great shifts of torque from one wheel or the other. In other words, regardless of the differential-lock setting, both drive wheels will ALWAYS be getting a great amount of torque in an F1 car. Using a 0% differential-lock setting, the shift of torque from the offending wheel is still a minor percentage.

People tend to use the words "understeer" and "oversteer" when describing the effect of the differential lock. In reality, oversteer is truly the only thing you are actually adjusting. It's only because a lack of oversteer naturally moves the car closer to an understeer condition that understeer is used as a descriptor at all. Below are the test results of the differential lock extremes applied to a constant radius curve:

Differential Lock @ 0%

Throttle-off oversteer -**HIGH**
Throttle-on oversteer - **NIL**

Differential Lock @ 100%

Throttle-off oversteer - **NIL**
Throttle-on oversteer - **HIGH**

These can be confirmed using RSDG's "Test track" skidpad (if you do not have this track - GET IT). Throttle-ON meaning applying FULL throttle from a steady-state throttle condition (2nd gear, outside 80m ring, maintain 85-90mph - then step on it). Throttle-OFF oversteer being the opposite, a complete lift off the throttle from the aforementioned steady state throttle condition.

Think about that last part: throttle-off is exactly what we do when setting up a corner on the racing circuit: throttle-off, heavy on the brakes, turn-in. Set your differential-lock to 0% on a baseline setup and watch your corner entry spinouts increase. This is because the differential is helping to dissipate the torque at maximum efficiency in extreme braking/turn-in. As a result, your weight transfer moves forward more quickly than with a higher differential lock setting. Even under braking and cornering, the engine torque to the rear wheels is a factor in the cars transfer of weight.

If you make it through the corner though, you can apply much greater throttle, and apply it earlier in the corner exit. That's because the low percentage of differential lock is helping balance traction during the re-transfer of weight on exit, and as the rear fights the low-traction condition known as "maximum possible acceleration."

This may seem to contradict what many have read on the forums. But trust me and take it to the skidpad to run the above extreme tests... you'll see.

A high level of differential lock is a different beast altogether. The car is much more stable under braking and corner turn-in, but very difficult putting the power down on exit. Again, that's because the rear wheels now are "locked" together, both constantly applying maximum torque to the ground, regardless of weight transfer.

First off, when establishing a baseline, start with 50% on your setups. This is the balance point. Other than that, it depends on your preferred driving style just like every other setting. Think of it this way: it's not whether or not you like oversteer; it's WHEN and how much. Move the slider in that direction.

Here's an example: ISI/EA Sports sets a low differential-lock (25% to 35%) in its stock settings. This favors corner exiting stability and traction under acceleration, but makes the car edgy under late braking and turn-in.

On the other hand, Frenchman Jean Alesi is a master of the throttle-on power-slide. He steers the car with both ends regularly. I'd bet Jean has that differential lock setting pretty high. Imagine it: Alesi setting up Parabolica at Monza, braking late with the more stable braking/turn-in characteristic. Then powering up just before the initial apex of that high speed corner, using little jabs of throttle-induced oversteer to keep the nose tighter towards the inside, until he can floor it through Parabolica's second half and rocket onto the front straight.

Yeah right... easy for him to do!

"To assist in the process of setting up the car for a circuit a driver has to use all his powers of concentration. First of all, he has to tackle each corner in three stages. Then, once he has to establish reference points and the correct racing line, he should try to stick to them as closely as possible. Varying the line from one lap to the next alters the cars behavior and creates extra problems. As soon as a driver has got to grips with a circuit, he should be able to complete a lap in the same fashion time after time. If each lap follows the same pattern, the driver is better able to analyze events objectively. Indeed, such consistency makes the driver a reference point himself. This requires much attention to detail, but by maintaining the same procedure for lap after lap you become a good test driver"

From **"***Competition Driving"* by **Alain Prost** and **Pierre-Francois Rousselot**

Setup testing (overview)

Testing is a very important part of fielding a Formula 1 team in international competition. On a typical Grand Prix weekend, track time is limited to two 60 minute and two 45 minute practice sessions, 12 qualifying laps, and a brief 30 minute pre-race warm-up. This means teams must know their car and know it well. A driver must know what setup changes bring about the desired effects in handling over the diverse selection of circuits raced during the championship. Testing allows us to develop setups that permit us to use our individual driving styles to exploit the cars capabilities to its fullest.

As quoted above, it's also important to drive consistently so our setup changes are reflected legitimately through our lap times. This can be translated into driving at 95% of ones potential, making subtle changes, letting the cars speed account for increasing lap times. Then after meticulous setting adjustments are made, take on a light fuel load, soft tires and go for a 100% flat out flyer.

When making the initial adjustments to set the car up for a specific circuit, it's important to focus on one thing at a time and make detailed mental notes regarding the cars handling characteristic at the various parts of the circuits. This method to setting up the car follows a set routine to rough in all adjustments. Here's the method I use for setting up the car:

1. **Top speed**: First laps out, I establish the cars top speed with rear wing angle adjustments and gear selections. During this time, I'll adjust the front wing angle equal to the rear adjustments. Gear selection will start with top gear and the lowest racing gear, followed by evenly spacing all gears in between.
2. **Brake balance**: Next I set the brake bias to allow hard stable braking into the slowest corner on the circuit.
3. **Suspension (ride height)**: Next I begin to balance the car while setting ride height. This is where telemetry will start to become useful. Spring selection at this phase is to rough in the handling while setting ride height over the many track variations.

4. **Handling (rough balance)**: Keeping the dampers at their static reference settings, I'll next focus on using the spring rates and anti-roll bars to balance the handling, keeping ride height values in check. Tire pressures and camber settings become quite important during this phase and all phases following. Front wing adjustments help to balance front-end grip under specific adjustments. Differential lock adjustments are made to aid in the throttle response to the circuit's features.
5. **Handling (fine tune)**: After the car's balance is roughed in, I'll begin damper adjustments to fine-tune the handling through specific parts of the track. First I'll focus on damper slow adjustments and the cars transitions into and out of corners. Then I'll focus on damper fast settings and controlling the car over bumps and kerbs. Weight distribution can also aid in fine-tuning the handling characteristics around the track.

There may be many times when you find yourself being required to backtrack and make changes to things that worked well earlier, but as a result of recent changes, are no longer effective. This is common. The good part is that as you make progress towards fine-tuning your setup, this happens less and less, as well as the adjustments becoming smaller.

Again, it's important to make one change at a time and evaluate that change with a consistent lap and lap times. I tend to make extreme changes at first to establish the degree the change will effect the car. If the direction of the change is desirable (but maybe the effect is too great), I then reduce the change by half, and so forth until that adjustments is fine-tuned. It is vital to make changes to one component at a time (or a set of components as in both front springs) until one becomes comfortable with the effects of that change. While this seems costly in terms of time, it is well rewarded. During a cars initial shake down, you would be lucky to complete roughing in the handling by the end of day two. But by the end of the test, everyone will have a much greater understanding of both the car's capabilities and what the driver wants out of it.

As one becomes more comfortable with the car and the effects of setup changes, then you can make multiple changes to smaller degrees. This level of comprehension is vital to produce results during the limited running time of a Grand Prix weekend.

Static reference setup

Because we'll be dealing with many variables across several components, it becomes a useful tool to establish a static reference setup. What I mean by this is, we'll define the full spectrum of adjustments to all of our components and establish a mid-level mark. This way, we know at all times how far we've deviated from center and how far until we reach an extreme. This is useful in preventing us from creating a setup "dead-end" where we find ourselves at the end of a particular adjustment, which then requires us to backtrack. By understanding how soft is "softer" or how stiff is "stiffer" by defining the parameters, we can make critical changes at the most logical end of the car.

The following chart shows the static reference midpoint setup for EA Sports F1 2002 as well as the full range of adjustments to each set of components (this chart is available as a separate .pdf doc).

Mechanical and Aero

Weight Distribution	n/a	range: varies from team to team
Front wing:	25 degrees	range: 0 degrees to 50 degrees in 1 degree increments
Rear wing:	25 degrees	range: 0 degrees to 50 degrees in 1 degree increments
Anti-roll bar (front):	150 k/mm	range: 100 k/mm to 200 k/mm in 5 k/mm increments
Anti-roll bar (rear):	90 k/mm	range: 50 k/mm to 130 k/mm in 5 k/mm increments
Steering Lock:	14 degrees	range: 5 degrees to 23 degrees in 1 degree increments
Differential Lock:	50%	range: 0% to 100% in 5% increments
Brake duct size:	4	range 1 to 7
Radiator size:	3	range 1 to 5

Tire Pressure and Camber

Tire pressure* (all):	n/a	range: 90 kPa to 195 kPa
Camber (all):	0.0 degrees	range: -6.0 degrees to +2.0 degrees in .1 degree increments
Toe-in (front):	0.0 degrees	range: -2.0 degrees to +2.0 degrees in .1 degree increments
Toe-in (rear):	0.0 degrees	range: -2.0 degrees to +2.0 degrees in .1 degree increments

Springs, Packers and Ride Height

Ride height (front):	3.5 cm	range: 1.5 cm to 5.5 cm in .1 cm increments
Ride height (rear):	5.0 cm	range: 2.0 cm to 8.0 cm in .1 cm increments
Packers (front):	0.0 cm	range: 0.0 cm to 4.0 cm in .1 cm increments
Packers (rear):	0.0 cm	range: 0.0 cm to 8.0 cm in .1 cm increments
Spring rate (front):	175 k/mm	range: 100k/mm to 250 k/mm in 5 k/mm increments
Spring rate (rear):	175 k/mm	range: 100k/mm to 250 k/mm in 5 k/mm increments

Damper bump adjustments

Fast Bump (front):	1500 N/m/s	range: 1000 N/m/s to 2000 N/m/s in 100 N/m/s increments
Slow bump (front):	2300 N/m/s	range: 1500 N/m/s to 3000 N/m/s in 100 N/m/s increments
Fast Bump (rear):	1500 N/m/s	range: 1000 N/m/s to 2000 N/m/s in 100 N/m/s increments
Slow bump (rear):	2300 N/m/s	range: 1500 N/m/s to 3000 N/m/s in 100 N/m/s increments

Damper rebound adjustments

Fast rebound (front):	2000 N/m/s	range: 1000 N/m/s to 3000 N/m/s in 100 N/m/s increments
Slow rebound (front):	3500 N/m/s	range: 2000 N/m/s to 5000 N/m/s in 100 N/m/s increments
Fast rebound (rear):	2000 N/m/s	range: 1000 N/m/s to 3000 N/m/s in 100 N/m/s increments
Slow rebound (rear):	3500 N/m/s	range: 2000 N/m/s to 5000 N/m/s in 100 N/m/s increments

Brakes

Brake bias:	50.0%F/50.0%R	range: 80.0%F/20.0%R to 20.0%F/80.0%R in .5% increments
Brake pressure:	75%	range: 100% to 50% in 5% increments
Brake Disc (all):	2.8 cm	range: 2.1 cm or 2.8 cm
Brake duct size:	4	range: 1 to 7

Fuel tank specifications:

Fuel capacity:	125 Liters

Optimum tire temperatures:

Hard:	114 °C
Soft:	112 °C
Intermediate:	109 °C
Wet:	107 °C
Monsoon:	105 °C

Engine temperature range (coolant):

Nominal:	105 °C to 110.6 °C
Optimum:	107.3 °C (maximum power vs. engine wear)
Overheating:	> 110.6 °C

Brake system temperature range:

Nominal:	300 °C to 800 °C
Optimum:	550 °C (maximum stopping force)
Braking force halved at:	1650 °C (brake fade)

Telemetry fundamentals

te·lem·e·try - n.
The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources, as from space vehicles, to receiving stations for recording and analysis.

Modern F1 cars host an amazing array of potentiometers and sensors that are capable of monitoring almost every vital function of the car. These readings are stored in an onboard CPU and many functions can be monitored in real time by the team of engineers in the garage. Telemetry gives the driver and his engineer common ground to begin to dial-in the cars setup. It is also common place for teammates to share telemetry for the purposes of overlaying laps and helping define the cars handling characteristics from two separate reference points.

When starting a session, it's always a good idea to run some warm-up laps with no adjustments (20 to 30 laps) and save the fastest lap as your base reference lap. As you make adjustments to the car and increase you lap time, select the new fastest lap as you new base reference lap. Even though you may overlay many laps into the telemetry display, you'll find it easier to analyze you performance using just a base reference and your best lap from the latest stint. Again, when you better you base reference lap, the new best lap should become your new base reference lap. If you're just learning, you can use the telemetry default reference to help guide initial setup changes until you achieve a competitive lap time.

During a race weekend the 45 to 60-minute free practice sessions make on-track time highly valued, so teams will run a practice session and gather telemetry from the various changes they make. In the post-session debrief, the telemetry is analyzed and discussed between the driver, his engineer and head mechanic. Then setup changes based on this debrief are loaded onto the car as a base for the next session.

Here's what we can monitor, and what it means:

Velocity – Distance: This trace shows us our speed relative to the distance traveled. Overlaying two separate lap traces can enable one to see the effects of setup changes as they relate to the laptime. Overlaying a faster teammates trace can enable one to see where he's losing time, and therefore point to the area of the car in which adjustments are required.

Engine RPM – Distance: This shows the engines revolutions per minute relative to the distance traveled. This allows us to monitor where a driver is applying the engine power and if we are keeping the engine in it's peak power and torque bands at crucial points. This is also great for seeing where "short-shifting" out of the power/torque curve early might aid in cornering stability.

Longitude Acceleration – Lateral acceleration: The "Friction Circle". Once heavily debated, this graph is standard operating procedure today. The friction circle shows just how much the driver is pushing the car to its maximum limits. The ideal drivers exploitation of the car will display a very defined and repeatable pattern of G-loading reference points as he consistently pushes the car to it's extreme limits.

Incremental Time Difference: This shows the gain and/or loss of time that the trace laps contains relative to the reference lap. Spikes indicate large gains/losses and should be analyzed. This is one of the first traces to examine when overlaying laptimes.

Here is an incremental time difference trace from the 2nd free practice installation laps at the German Grand Prix. This is a comparison of a qualifying setup reference lap from the 1st free practice session and a fully fueled race setup overlaid. These are the two base setups we started with for the weekend.

Gear – Distance: This charts the gear selections made over the course of the lap.

Rear Wheel Speed Difference – Distance: This trace shows the effect of the differential lock setting, by charting the relative difference in rear wheel rotation.

Track View: Track map showing a drivers racing line plotted by compiling the various other parameters in the gathered telemetry. Useful for comparing the subtleties of various racing lines when attacking corners.

Throttle – Distance: This charts the percentage of throttle pedal position during a lap. This trace is good for referencing how the throttle is applied coming off various turns in a percentage value. This is great for seeing how effective setup changes are when the goal is trying to apply power sooner on corner exits.

Brake – Distance: This charts the brake pedal position during a lap. This trace is good for referencing how the brake is applied in a percentage value. Effective trail braking shows up as a rounded backside of a brake spike. Trace overlays can show where braking is gaining/losing time.

Steering – Distance: This charts the percentage movement of the steering wheel over the course of a lap. Useful for comparing turn-in points between lap traces and referencing how much the drivers input has effected oversteer conditions.

Clutch – Distance: Shows clutch travel during a lap. Keep in mind that an F1 semi/fully automatic transmission does activate the clutch automatically. This is not adjustable.

Damper Velocity – Distance: This trace charts the four damper's speed of movement vs. piston travel distance over the course of a lap. Bump is displayed as an upward spike (sharpness of spiking equating speed and vertical size is distance). Rebound is displayed as a downward spike. The higher the spikes, the lower the damper settings it represents (indicating less resistance/more movement). This graph is more representative of the damper fast velocity adjustment, or how the dampers react to bumps and kerbs. When adjusting damper fast settings, cross-reference this graph with Suspension Travel.

Damper Velocity (Smoothed): This chart smoothes the trace of the four dampers speed of movement vs. piston travel distance, thus being more indicative of slow damper settings, or how the dampers affect weight transfer during cornering. Bump is displayed as an upward spike. Rebound is displayed as a downward spike. Good for fine-tuning of damper slow adjustments and should be cross-referenced with Ride Height (Smoothed) and Suspension Travel graphs.

Longitude Acceleration – Distance: This shows the G-forces that the chassis is experiencing under acceleration and braking. Acceleration produces a downward spike. Braking produces an upward spike.

Lateral Acceleration – Distance: This shows the G-forces that the chassis is experiencing under cornering. Right turn G-loading produces a downward spike. Left turn G-loading produces an upward spike.

Vertical Acceleration – Distance: This shows the G-forces that the chassis is experiencing in the vertical plane induced by bumps and track elevation changes. Up is up and down is down.

Front and Rear Ride Height: This charts the space between the track (bottom of graph) and the bottom of the plank (line trace) measured in mm. It represents all ride height variation due to all factors including bumps and road undulations. This is useful for general spring rates and setting damper fast setting fine-tune adjustments.

Front and Rear Ride Height Smoothed: This charts the space between the track (bottom of graph) and the bottom of the plank (line trace) measures in mm. By smoothing the trace line, we gain a more accurate indicator of ride height variations during weight transfer only. This is good for fine-tuning of spring rates as well as general damper slow adjustments and packer sizes.

Chassis Slip Angle: This shows the lateral slip of the car on the road. Ideally, these traces should be small and as gradual as possible under nominal driving.

Suspension travel: This measures individual wheel vertical movement at the damper rocker arm in mm. The reference plan (0) marks the damper piston fully extended (full rebound) as if the car is suspended from a lift crane. Vertical spiking up denotes suspension compression. This monitors how effective the springs, dampers, and anti-roll bars are a controlling the individual wheels under weight transfer and over kerbs and road undulations. By examining either both fronts together, or both rears together in steady state cornering conditions (along with Chassis Slip Angle cross-referencing), this can help define anti-roll bar adjustments. When using soft springs and damper settings, this graph can aid in packer thickness. Packers can affect the response of the spikes.

Tire Temperatures (Inside/Middle/Outside): This charts tire temperature in degree Celsius over the course of a lap. It groups the inside/outside temperatures together as "Camber Temperature" and shows the center temperature as "Crown Temperature". The center reference point on the graph denotes the tires optimum operating temperature. This data is very reliable for reaching the optimum tire temperatures over the course of a lap. When making adjustments though, it is more helpful in analyzing tire pressure settings rather than wheel camber.

Wheel Spin: This trace shows the percentage of individual tire wheel spin relative to distance traveled over the course of a lap. Down is spin initiated under braking while up is wheel spin initiated under acceleration.

Tire wear: This charts tire wear over the course of a lap. It's good to compare this trace with , suspension travel, Chassis Slip Angle, Wheel Spin and Tire Temperatures to help identify possible causes of premature tire wear.

Other useful stored information includes weather at the time of the recorded lap.

Air Temperature – Distance: Tracks the ambient air temperature of the course of the lap.

Track Temperature – Distance: Tracks the track surface temperature of the course of the lap.

Rain – Distance: tracks the amount of rainfall over the course of the lap.

Track Dampness – Distance: Tracks the moisture content on the track surface over the course of the lap.

The telemetry program sorts these various readings under a collection of headings. In other words, we can monitor the track map, velocity to distance, and incremental time to distance under the heading "Incremental Time". By clicking on the "help" icon in the telemetry program, an MS Word .doc file will be opened. It goes into detail about some of the features of the telemetry program and has some useful tips for navigating through its windows and manipulating the data efficiently. Below is the very useful controls summary included in that file:

Window Controls
Left Mouse Button (hold and drag): Select a specific portion of the telemetry data.
Right Mouse Button: Zoom out in 1-step increments.
Middle Mouse Button (Button 3): Maximize/minimize a specific trace window.

Keyboard Shortcuts
RETURN: Zoom in to currently selected portion of telemetry.
SPACE: Restore default view windows and zoom levels.
BACKSPACE: Unselect telemetry data.

Corner phases and types

"The racing tracks on which F1 cars do battle are by definition a series of bends interrupted by straights of varying length. Given that the idea is to lap in the least amount of time, the way you take corners becomes fundamental, not least because the first thing to understand is that an error on a bend is always paid for in lost hundredths of a second."

Ayrton Senna from his book "*Principles of Race Driving*"

Every corner has three distinct phases: corner entry, corner apex, and corner exit. It's vital to recognize each phase per corner when describing the cars handling characteristics through that corner.

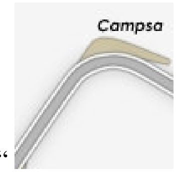
Corner Entry is the point at which the car begins turn-in. Braking usually, but not always, precedes this phase. Sometimes, braking is actually continued into this phase and in specific cases, carried through to the following phase. During this phase, weight begins being transferred from the inside tires to the outside tires. If braking happens during this phase, the weight transfer is actually more concentrated across a diagonal from the inside rear tire to the outside front tire.

During the ***Corner Apex*** phase, the car has reached the mid-point that separates corner entry and corner exit. This phase can be very brief, in the case of a quick kink or chicane (see **Corner types**) or rather extended as is the case in long constant radius corners such as Curve 2 at Brazils' Interlagos circuit or Turn 13 at the Indianapolis Motor Speedway. During this phase, weight transfer stays relatively steady from front to rear, and is concentrated to the outside tires. Corner apex is the slowest part of a corner.

Corner Exit begins at the point that steering input is begins to be decreased as the driver unwinds the wheel. Acceleration usually, but no always is involved in this phase. During this phase, weight transfer begins its restoration back towards the cars center of gravity be unloading off from the outside tires. The more acceleration is involved, the more this transfer shifts towards the rear and again a diagonal may be drawn from outside front to inside rear. This occurs until the cars forward travel straightens and the weight equals out to both rears.

One should always examine the track layout to decide which corners and combinations are the key features to focus on. It is simple not possible to set the car up to handle all the variations at the highest level of efficiency. This is where compromise begins. Another thing to consider is the successive combination of corners and straights. Sometimes it's important to compromise the exit of one corner to maximize the speed through the next. This is especially important when exiting onto, or entering from a long, fast straight. But as always, the tale is in the timing and a fast laptime is the ultimate deciding factor.

To better understand the various racing lines, and how to maximize efficiency over the course of a lap, I highly recommend the books "Principles of Race Driving" by Ayrton Senna and "Competition Driving" by Alain Prost. These two books are written by arguably the two finest racing drivers of the twentieth century. But for now, let's examine some different corner types and comment on how on there own, they influence car setup.



Constant radius Example: Circuit de Catalunya, Spain “Compsa“

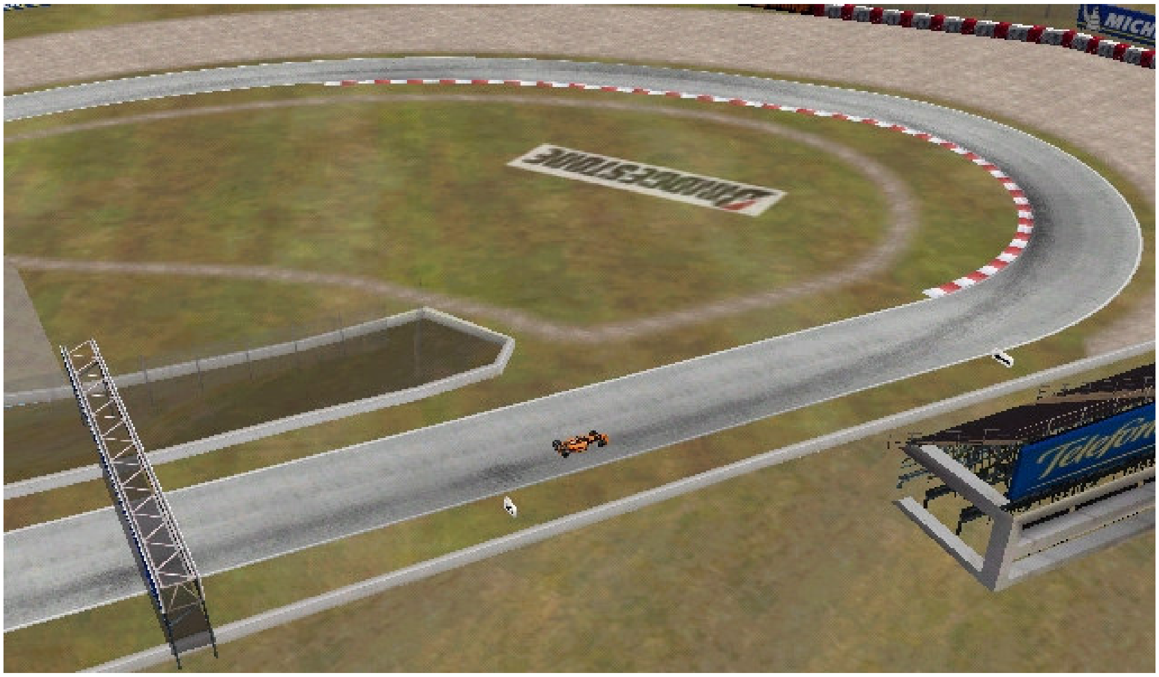
A constant radius corner is one that has a quick gentle turn-in, a long consistent apex, and a gentle exit. Providing the track is fairly level, setup for the corner can be tackled in a fairly routine manor. As in all corners, how vital it is towards the overall laptime and how many like corners are on the circuit should be analyzed before determining how much the corner should effect the car setup.

A constant radius corner is actually quite simple. Providing you’ve roughed in your spring settings for fairly neutral handling, then this is all about aerodynamic downforce and anti-roll bars. The transition for turn-in to steady state cornering is fast. The car is on the bars quick and stays there for quite awhile. Typically, a well balanced car will automatically have reliable handling traits through most constant radius corners and one can determine quite quickly if a change in downforce will help. For this reason, constant radius corners are good corners to focus on early in the initial setup of the car adjustments including springs and anti-roll bars.

If one is experiencing trouble being competitive, and the corner is high speed, then front wing adjustments would be first on the list, with anti-roll bars and weight distribution a close second. If the corner is medium speed, that order might flip-flop.

But I wouldn’t spend much time on damper settings here, unless you’re having turn-in imbalances everywhere else on the circuit…specifically medium speed corners. Also, any adjustments to the dampers should be performed with thought towards what compromises in other corners may occur, particularly if the circuit has one or more decreasing radius corners elsewhere.

Increasing radius Example: Circuit de Catalunya, Spain 'La Caixa"



An increasing radius corner is one that features a longer corner exit than corner entry, and is usually accompanied by a small corner apex. In an increasing radius corner, the idea is to brake late and turn in sharp, advancing the corner apex early, then quickly and progressively initiating throttle for maximum exit speed. Because the corner exit line usually has no reference points, it becomes difficult to judge.

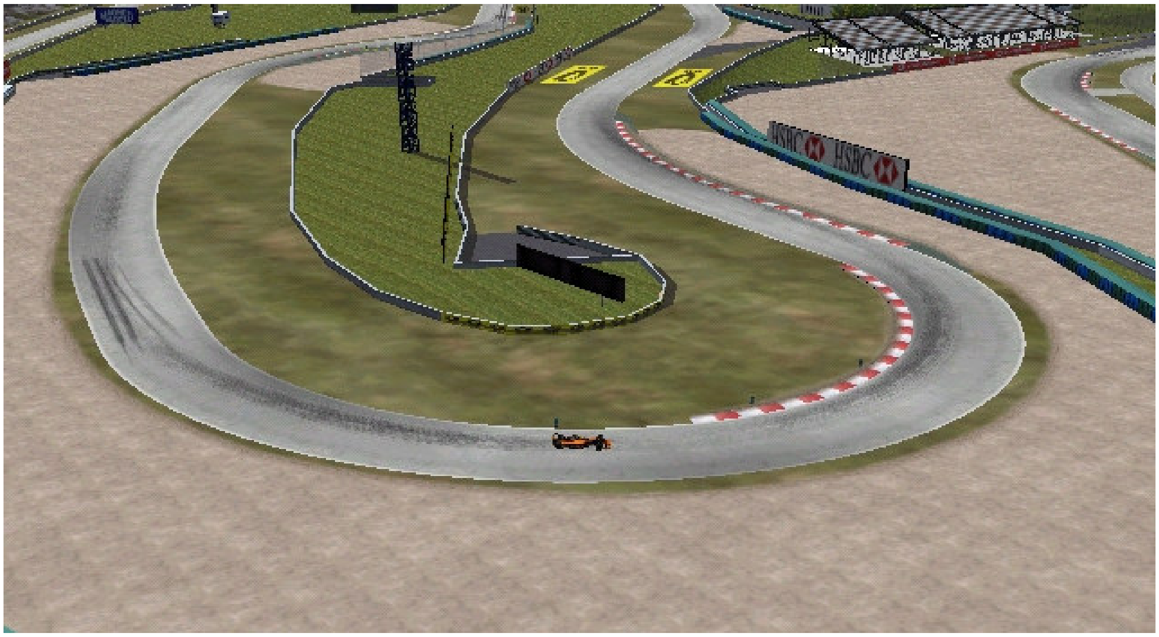
Due to the extended corner exit, if one cannot accelerate properly this becomes a section where a relatively large amount of time may be lost. Therefore traction under acceleration is important to minimize time in this type of corner. This is crucially important if the corner exits onto a primary fast straight.

A rookie driver might want to run the differential lock setting at a lower value to help control wheel spin. But a more experienced driver might prefer to control the rear himself using the throttle to induce oversteer. This however requires a very fine tuned neutral balance.

To start with, you'll want a softer rear setup for more traction under acceleration. Choose front and rear spring rates to accommodate the overall circuit handling requirements, then fine tune with damper adjustments. As usual, slow damper settings are useful for adjustments to the spring response during weight transfer. Here you'll want to run softer slow damper settings. While softening the rear, be aware of the packers vs. ride height. For the car to hit the packers (especially the outside rear) is detrimental towards the goal as it will instantly overload the tire with weight.

Typically, the anti-roll bars and aerodynamics are not good things to adjust specifically for this type of corner, unless you're experiencing imbalances elsewhere.

Decreasing radius Example: Magny-Cours, France "180 Degrees"



A decreasing radius corner is indeed one of the most difficult corners to setup for. As you can see from the above picture, your braking zone follows an arc leading to the late apex. It's imperative that the car be able to brake deep and turn in simultaneously. A well-honed trail-braking technique will defiantly aid in making the pass here.

The basic setup principles for this type of corner are such that you want the car to have good turn-in, but more importantly, a stable rear. Because the transition from turn-in to steady state cornering is so long anti-roll bars are less critical. That's not to say don't adjust them, its just the bars don't have a significant impact except from about 25 yards before and through the first half of that inside rumble strip, right at the apex. Plus, if you have high-speed constant radius turns elsewhere, and the cars pretty well balanced there, I'd leave the bars alone for now.

Softening the rear springs, helping the rears not to unload as much weight, is a great starting point if you're having trouble being competitive here (and providing this is a critical point on the circuit). But most importantly, dampers are the keys to unlock the cars maximum potential under braking and turn-in. One must control to weight transfer. More specifically, the rear dampers' slow rebound. Soften them to help maintain weight at the rear for as long as possible. The second the rear goes light enough to get loose, you better stop turning and brake straight and hard. An alternative might be to go to the front and increase the front damper slow bump values. But unless you're either having problems at the front elsewhere, or have run the rear setting close to maximum (with room to spare at the front) then I'd focus on the rear.

You could also run your brake bias forward more. But if you're not having problems with oversteer under braking elsewhere, then I say leave it and tackle those dampers.

Differential lock values of 50% or higher can help here as well. You're already turning when you have to get off the throttle, so you defiantly want that torque under control. But be careful of oversteer while reapplying the power. As stated earlier, the differential lock setting is very dependent on your personal driving style.

Fast esse Example: Silverstone, Great Britain 'Maggots & Becketts"

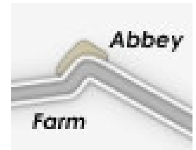
A fast esse is typically a combination of two or more corners. At these speeds, aerodynamic balance is a key factor. But probably equally important is the correct line which allows the fastest cumulative sector time. Missing the best line during a phase by just a few feet can cost massive time loss as it disrupts the flow for the next phase, or worse yet, the entire following corner. For this reason, front-end steering response is crucial. One also must have faith in ones setup as the speeds traveled here repay mistakes with big spins.

Like mentioned above, aerodynamics has a big influence through these types of corners. After setting gear ratios and a rear wing angle based on the circuits' top speed, the front wing angle can be roughed in through fast esses to balance the car.

Basic spring settings can be put to the test through these high-speed direction changes. Stiff font springs give the car the much-needed quick steering response. Too high a spring rate will adversely affect the desired level of grip though and must be countered by additional front wing or a softer anti-roll bar. Special attention should be paid to the tire temperatures as overheating can occur from these changes. Softer rear springs enable the rear tires to bite and keep the power transmitting to the track. Use the damper slow settings to control weight loading and unloading into the tires during changes of directions. Also, this is a big anti-roll bar fine-tuning section as the car is changing directions and loading the bars in both directions. Once the anti-roll bar settings are roughed in here, they should require only minor adjustments for other sections around the circuit. The exception would be when adjusting the anti-roll bars to compensate for another adjustment such as mentioned above.

Differential lock settings can prove useful here, especially if one is using engine braking by coming off the throttle to slow the car to setup the following corner.

Medium esse Example: Silverstone, Great Britain "Abbey "

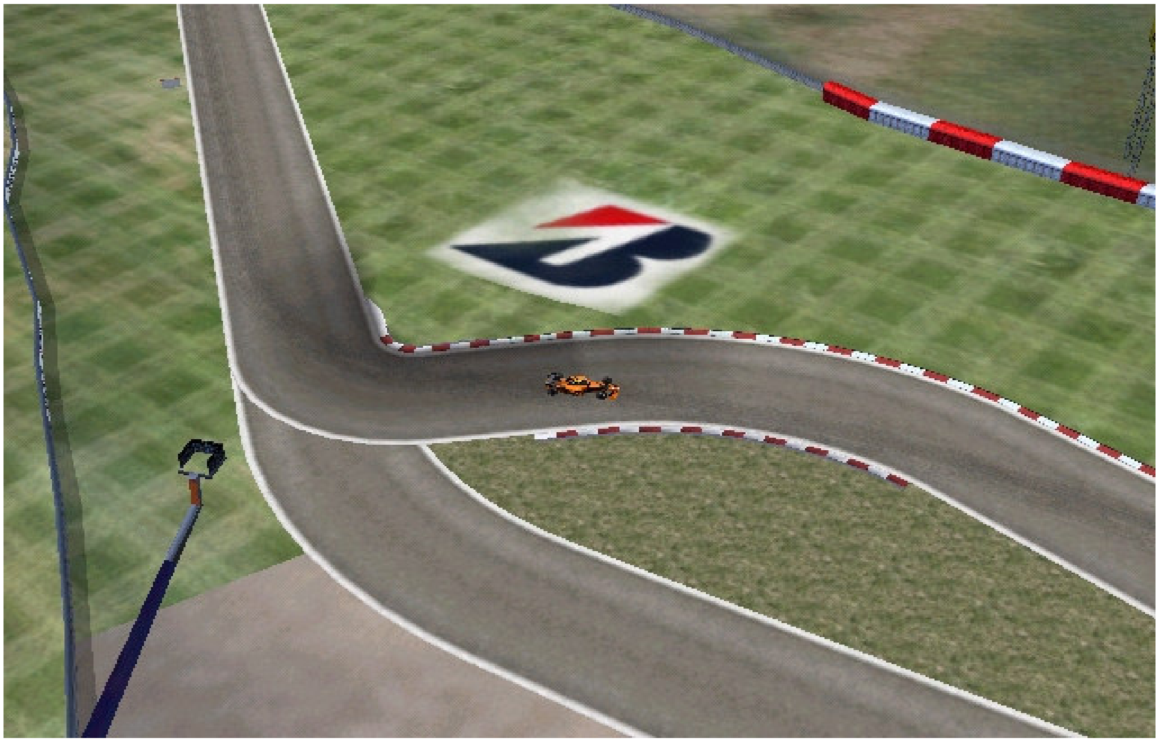


Like a fast esse, the medium-speed esse is typically a combination of two or more corners. Here, however the springs and dampers are more important than aerodynamics, mainly due to the fact that the car is either increasing or decreasing speed as it traverses these corners.

If the car has fairly well balanced characteristics through faster corners, then focus should certainly be placed on the springs and dampers slow settings. Medium speed corners are really where you can start to fine-tune the springs and dampers. The latter probably more so. You'll want to focus on sharp turn-in characteristics with front springs, dampers and anti-roll bar adjustments. Go as stiff as possible with the front spring settings without upsetting the overall balance of the car. Try to balance out any induced understeer by increasing front wing angle or choose a smaller front anti-roll bar until a more neutral balance is obtained. Be careful though as these types of adjustments can quickly result in above optimum tire temperatures by overloading the front tires with weight. From here, soften the damper slow response to dial in the amount of front grip desired.

Also a more aggressive driver might use the kerbs here, so damper fast settings become a factor as well. Damper fast settings aid in the cars ability to react to bumps, so if loosing grip while riding kerbs you might try lowering the fast bump settings. Be careful though of riding kerbs while the car is experiencing big swings of weight transfer, such as the transition from Abbey's left-right.

Chicane Example: Nurburgring, Germany, “Veedol S” 



Chicanes are essentially slow esses, so all of the medium esse characteristics apply here. Also, because the phases happen in rapid succession (do to the overall smaller size of the chicane features), car imbalances tend to be magnified at the point of weight shift during the change in direction. Also, the overall slower speeds mean aerodynamics has less of a factor in car balance and mechanical grip has a great deal of influence. Do to the tight nature of most chicanes, riding over kerbs is an acceptable risk.

Many times, a chicane will denote the slowest corner on a particular circuit. This means it is many times preceded by a heavy braking zone, making it a great point to fine-tuning the braking bias. As this makes the chicane a prime overtaking location, focus should be given to car setup through the preceding corner as to allow the most efficient exit. This will, in turn give the car maximum speed on the ensuing straight leading to the chicane, making overtaking that much easier.

This also means this is the corner to help select your lowest racing gear. Quite often it is the case that second gear it the lowest selected gear once the race has gotten under way. If this is the case, second gear becomes the lowest racing gear. If this is the case, then second gear can be adjusted to allow the best possible acceleration while maintaining stability when exiting the chicane. Otherwise, first gear should be a compromise of chicane exit stability and standing start efficiency.

Hairpin Example: Magny-Cours, France "Adelaide"

Hairpin corners stress the cars braking capabilities to their maximum. Typically, the car is being coaxed into slowing from top speed down to anywhere from 40mph to 60mph. Sharp front-end grip is essential to allow a driver for be competitive here, particularly when passing. The above picture shows the Arrows A23 taking a conservative line through the Adelaide hairpin. The turn-in comes early and the short apex is at the middle of the inside kerb. While qualifying the line will vary. The braking will be kept to as late as possible (allowing the car to travel at top speed a few hundredths on a second longer), followed by a late turn-in. This will shift the apex back later in the turn (the skid marks represent a good fast line). By moving the apex later, the radius of the exit is lessened, allowing power to be applied sooner and more importantly, at a more aggressive rate. Again, I point to the books from Ayrton Senna and Alain Prost to learn more on these principles.

Like chicanes, hairpins are great places to set the braking bias during early session laps because the most aggressive braking zones on the circuit typically precede them.

I typically don't concern myself with tuning a car around a hairpin beyond the basic roughing-in of the chassis balance (wings, springs, anti-roll bars, and ride height). I find if I focus on other medium and high-speed corners, the hairpin tends to fall into place. One thing I do focus on is my gear ratio for this turn. It tends to dictate my lowest racing gear and therefore the gear should be chosen to allow the most stable acceleration out of the hairpin possible.

The hairpin is also a prime passing zone for most circuits. This makes the prior corner extremely critical as far as the setup is concerned. Remember that the pass that happens here was really executed through the previous corner, allowing the car to gain an advantage over a rival heading into this turn.

Double Apex Example: Sepang Circuit, Malaysia 'Turns 7 & 8"

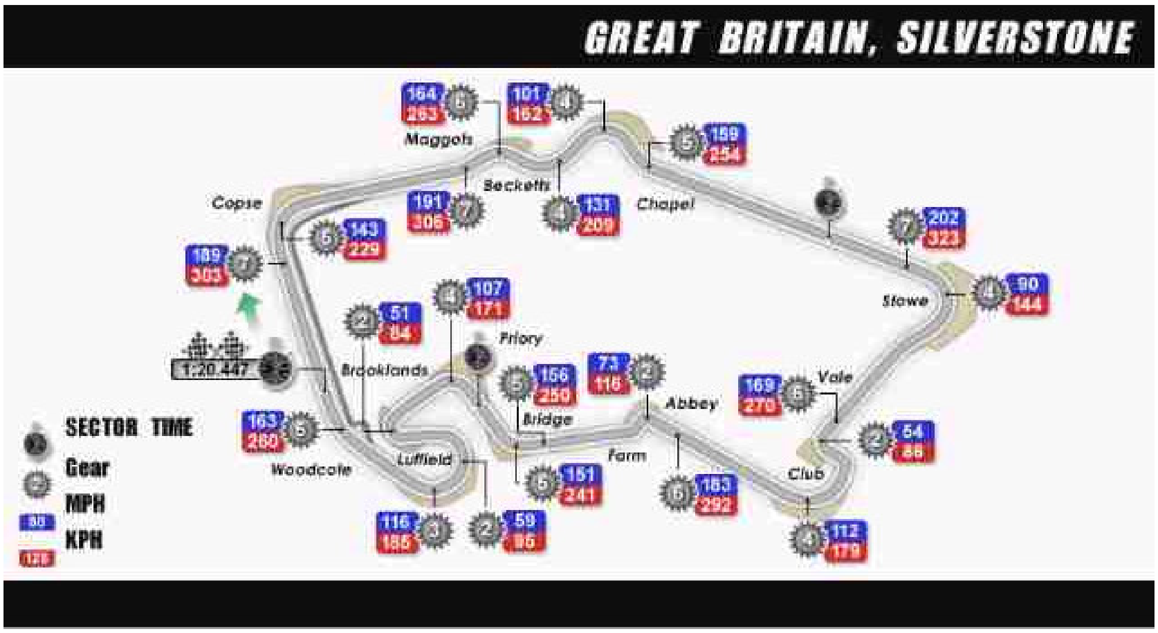
From time to time, two successive corners will line up in such a way that it enables a driver to attack them both as a single corner. This means the first corners' exit (phase 3) and the second corners' entry (phase 1) become essentially both corners phase 2, or the overall corner apex. In this instance, the 2nd phase is rather large and may contain some throttle adjustments. The car must be set to allow mid-corner throttle adjustments to not effect the car in a negative way.

Because of these things, these types of corners have the same characteristics of the constant radius corner. Basic balance is achieved with springs and anti-roll bars, assuming aerodynamic balance has been achieved.

A more stable throttle behavior can be fine-tuned by differential lock adjustments. If the double apex requires a slight throttle lift at the apex, and this in turn cases too much oversteer, then a higher differential lock setting is required.

Gathering circuit information

The first thing we need to do is gather some information regarding the circuit we're about to run on. In this case, it's Silverstone in Great Britain. In a minute, I'm going to look for the combinations of straights and corners, maximum and minimum expected speeds, and any ‘key corners" which will influence the setup. But for now lets identify all the corner types.



Copse is a high-speed, subtle decreasing radius corner. Next, **Maggots** and **Becketts** form a high-speed esse, the latter of which has a decreasing radius corner connecting to **Chapel**, which empties onto **Hanger Straight**. **Stowe** is another decreasing radius right-hand corner that bends back to the left on exit. **Vale** is made up of a slow constant radius, 90-degree left hander, followed by **Club**, a long increasing radius right hander. **Abbey** is a medium speed esse that opens up on exit. **Bridge** and **Priory** are both constant radius corners. **Brooklands** is a subtle increasing radius followed by the double apex **Luffield** and the flat-out, constant radius kink, **Woodcote**.

Now let's identify those key features of the track. Looking at the above track map, we can see that there are two big straights. That's the main start/finish straight and **Hanger straight** connecting **Chapel** to **Stowe**. As a result of identifying these big straights, we can see top speed is expected to be 200-plus MPH.

Key corners would be **Copse**, the **Maggots/Becketts/Chapel** complex, and **Stowe**, the majority of which are medium to high-speed corners (three of which are decreasing radius). These denoted features account for 2/3rds of the circuit, and while not Monza-like fast, would tell me to start by setting the car up for medium to high speed cornering with a focus on aerodynamics and springs. Then fine-tune the mechanical grip for the slower parts like **Club** and the **Brooklands/Luffeild** complex. This is, if for no other reason, giving us a place to start and an idea of the direction we think we're going to go in. The main concept here is one should always analyze the circuit and visualize the plan of attack. That way, you're not taking random stabs at things hoping to stumble across an acceptable setup. Racing, though is a very dynamic sport, and one should always be ready to try something new should the initial direction not pay dividends. The ultimate deciding factor is, as always the stopwatch. A faster laptime is a faster laptime regardless of how you arrive at it.

Just for the record, your highest lateral G loading should be around 3.5G in **Copse** and **Bridge**.

Gathering car setup information

It’s very important to document your setup changes as you go. There are various methods and here is some detail about the one I use. I use a log, which I’ve included with this guide as a separate document titled ‘F1 2002 Setup Log,” that allows me to document and track the changes and their resulting lap times. This adds great insight as I look at telemetry, since I have a written reference from that stint and the changes put on the car.

The method I use is three sets of adjustments per saved setup. I use a logical saved name: EA A23 T1-01 where ‘EA” are my initials, “A23” is the chassis used, “T” is for test, and 1-01 is the identifier (1 being the session, -01 being the revision during the session). For each saved setup, the revision will increase by one. On the Setup Log, the line ‘Setup Name (base)” is the setup that we began with. If we start with a pre-existing EA Sports F1 2002 setup, that might be ‘Great Britain” or ‘Grip.” Additionally, if this becomes a race setup, I’ll add identifiers for tires and strategy while maintaining the same revision number from the test setup. So a saved setup named EA A23 RH2-16 S1 would indicate the Arrows (A23) race setup (R) with hard compound tires (H) derived from testing session 2 - setup revision 16, for a 1-stop strategy. EA A23 RS2-16 S2 would be identical with the exception of soft tires and a 2-stop fuel strategy. This is my method. You may use any other, but it definitely becomes an advantage to choose a logical system that allows quick identification. Also, as you turn faster laps during testing, the setup that produced the fastest lap should always be loaded as your ‘Favorite Setup” so as you begin any additional sessions, that setup will already be loaded onto your car. In the end, you can simply copy your final setup and rename it ‘Race,” ‘Qualify,” or anything else you chose to simplify the process of finding the final setup(s).

As we get into our setup session, please keep in mind that I’m logging all the changes that I make. To include all the minute changes made to the car into this section of the guide is simply not possible. Therefore, what is included is an overview of the direction taken. The ‘F1 2002 Setup Log” is included for you convenience when making your own setup changes.

Establishing a setup – Aerodynamics & Ride Height

The first thing you should do is load your base, or starting setup and run about 20 laps to familiarize yourself with the circuit and cars characteristics. At Silverstone, I begin with the standard ‘Great Britain” setup on the Arrows A23. During this run I set a fast lap of 1m21s509. Mind you, during this run my focus is not on quick times, but establishing a basic rhythm and noting various details.

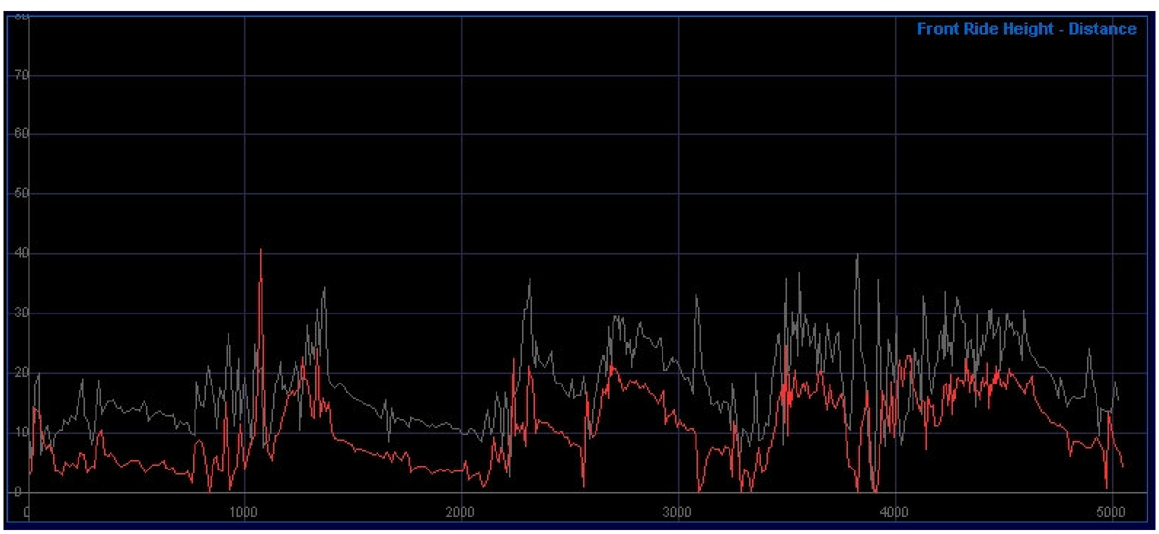
After establishing the stock setup characteristics, you can proceed to make the initial changes. The stock setup lacks top-speed (192mph) and is not geared well to my tastes, so the first changes I make are to the wings and gearing. I'll alter the strategy to '0 stops" and add 22 liters of fuel (good for 6 laps) and then proceed to make multiple short runs while making the wing and gear changes. At this stage, it's obvious whether the change is right or not, and you can come right back in to the garage as soon as it's apparent. Initial wing and gear changes are quite black and white; it either works or it doesn't. This setup phase can usually be accomplished in about 10 minutes, or 4 to 5 single-lap stints. Also at this same time, you should set your braking bias and start camber and tire pressure adjustments.

To achieve the 200mph-plus top speed, I end up with significantly less wing (25 front and rear). This becomes the aerodynamic base to from which to fine-tune the mechanical grip. But in the same respect, it is only a base or starting point.

Establishing a setup – Suspension Rough-in

The next phase is to rough in the suspension. Initially, you should adjust the dampers to their static reference mid-point. This allows you to make spring changes knowing that later, you can easily go in either direction with the dampers during their fine-tuning phase. Silverstone is a very bumpy track in some spots and the bumps affect the car at both the front and the rear. For this reason, I'm going with softer springs to allow the suspension to have enough travel to deal with the bumps effectively. Still filling the car with only 22 liters of fuel, I make several runs of 4 to 6 laps, making adjustments to the springs, anti-roll bar and front wing to balance the car.

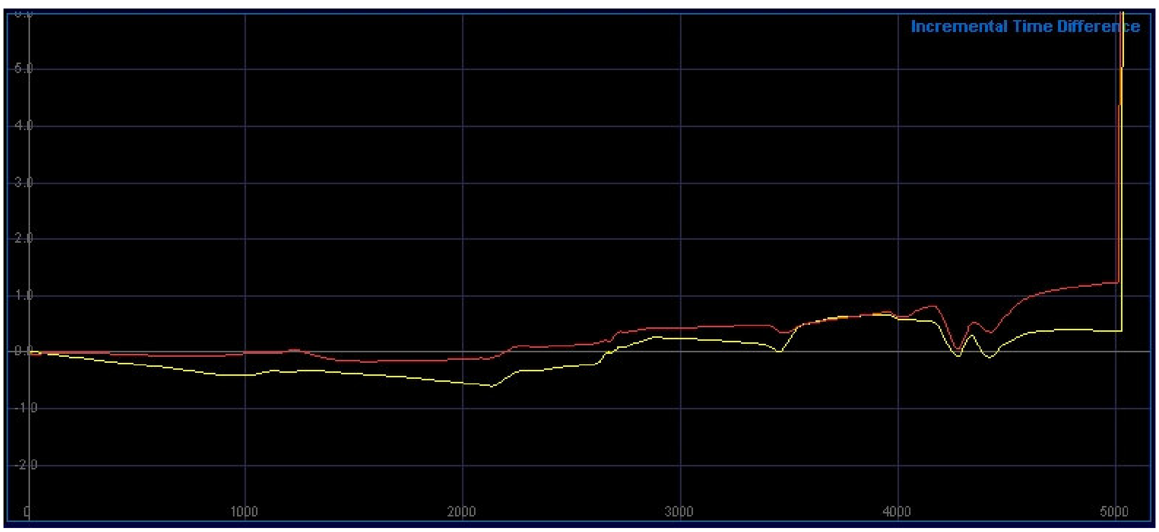
Since one of the stock setups' characteristics is a lack of rear traction under acceleration on exit, I really soften the rear springs and bars in relation to the front. After making each run, I download telemetry from the fastest lap and check ride height (un-smoothed). The ride height needs to be higher than normal to accommodate the spring movement. To lower the ride height and use packers to prevent severe bottoming will only negate the effects of the softer springs over bumps in the corners. [*Just for the record: if the track was smooth like Magny-Cours, we could run stiffer springs and a lower ride height. Typically with this type of setup, the car's tendency to bottom happens more often at the end of a long straight where aerodynamic downforce is pushing the car into the track. In this case, packers are the instruments of choice, as they don't severely affect the handling while preventing plank wear.*]



E. Alexander's 1m21s509 front ride height trace over C. Wynn's 1m19.853 reference lap. In the above trace you can see how the front is bottoming at seven distinct points during the lap. This will require raising the front ride height slightly.

You should select spring rates for response and grip over the various track surfaces, as well as tire temps. Use the anti-roll bars, as well as the front wing, to balance the car. This phase typically takes a while and you can easily make a dozen or so saved setup changes before feeling good enough to proceed. The general philosophy is to soften the rear to cope with oversteer on turn-in and give better acceleration out of the corners. Meanwhile, what I've done is softened the front springs for better grip over the bumps and increased the front anti-roll bar to balance out the cars rear adjustments. All during this time, I'm more focused on feel and response as opposed to laptimes. Incidentally, as a result of these simple adjustments, my lap time drops to 1m20s612. Almost a second faster. The car is very good under acceleration on corner exit, but the turn-in response still needs to be fine-tuned. The car is overall easier to drive.

You should also constantly be analyzing your line around the lap. The diagram to the left shows my line through Bridge. The telemetry track map is very useful to show which line is faster and why. Use the left mouse button to click and drag a section to analyze. This will zoom in on the track map and highlight the accompanying traces. Incremental Time Difference is a great trace to use for this (see below).



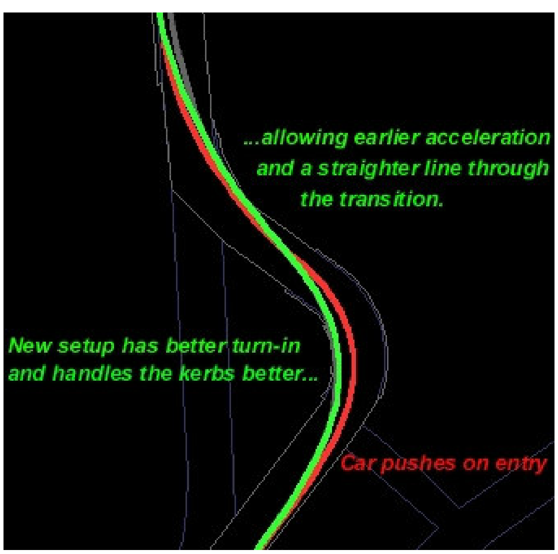
Incremental time difference: Gray = C.W. 1m19.987; red = E.A. 1m21m506; yellow = E.A. 1m20s612

In the above trace I can see that I'm losing time at Stowe, Club, and Abbey. There is a second and a half to be had there. During the fine-tuning phase with the dampers, I'll focus on these corners to set the changes.

Establishing a setup – Suspension Fine-tuning

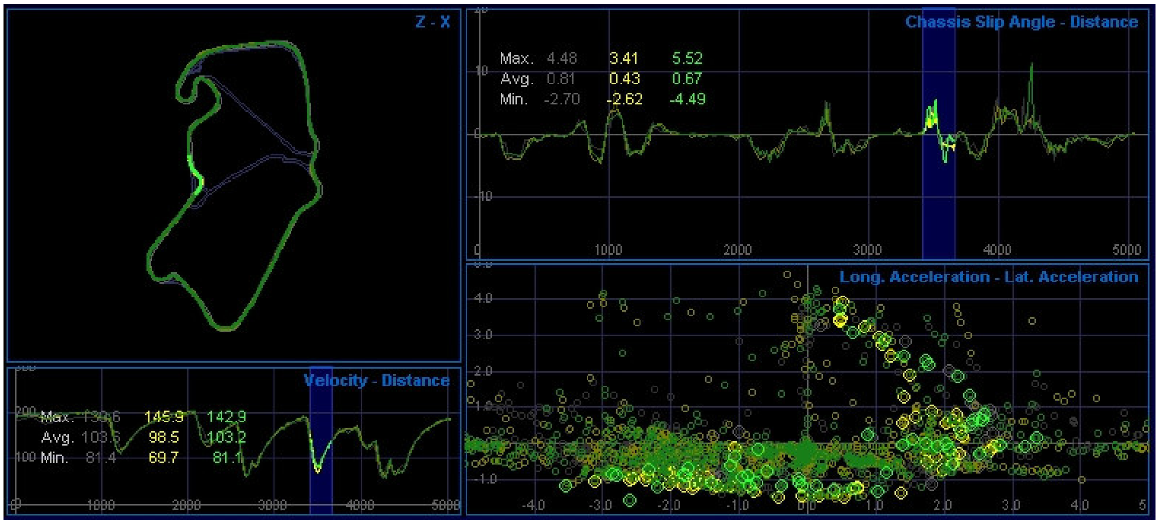
Still doing low-fuel, 4 to 6 lap stints, you can proceed to start damper adjustments. From the corner characteristics already noted, I increase the front dampers slow response to increase the responsiveness of the front end. At the same time, I decrease the rear damper slow adjustments (both bump and rebound) to improve rear grip even more. This is a win-win situation. Remember how stiff springs deflect energy? With the latest changes, the front dampers are keeping the weight rearward and the soft rear springs keep the energy stored there for a longer period under transfer. In other words: more grip at the rear. At the same time, those stiffer front dampers help the steering wheel movements to translate more quickly into the front wheels. I accompany the stiffer front damper adjustments with some additional front wing angle to regain any grip I may lose from the front tires.

After several stints while making the above adjustments, I find that the car still doesn't have the front grip that I'd like it to. Response is much improved, but the car still understeers when pushed. I turn to my static setup reference chart to see where I have some room to make adjustments and find my front anti-roll bar to be only 20 k/mm below midpoint. This leads to a radical 50 k/mm reduction to see what type of change I can achieve. Amazingly, this works wonders, and as a result of this plus a bit more front wing angle, I'm able to get to the apex with more control while carrying more speed.



This allows me to really start to focus on my line again. The diagram to the left shows how I can achieve the correct line through Abbey easier and with more precision than before. However this points out the cars poor behavior when accelerating over the kerbs. To help with this I reduce the rear damper fast bump and rebound. This gives the suspension a bit more give when the tire impacts the kerbs and thus keeps the tires weighted longer. This in turn keeps them from hopping off the ground whereas the engine torque would start to spin the rear tires.

The car is now feels more nimble and can be handled aggressively around the track. Time to put on some new Bridgestones and get that time down. I go for a few "flyers" back to back and put in a time of 1m19s197. More importantly, most laps are in the 1m19s range. Bumps don't upset the car and the power can be put down earlier than ever before.



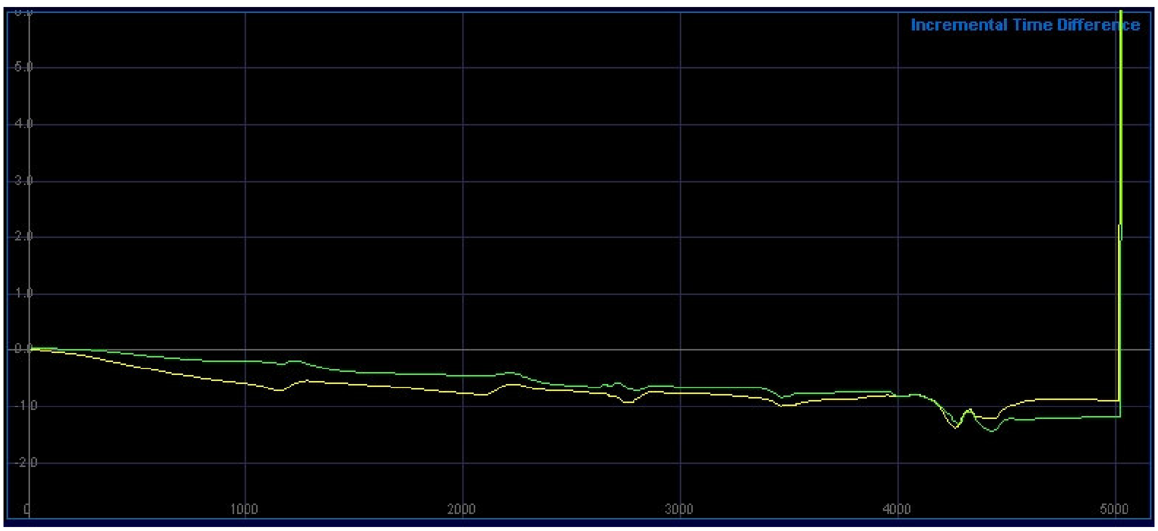
The above Chassis Slip Angle trace shows the added grip the car has achieved. Note the grip is not rail-like, but rather, the car handles better by breaking away slower and more gradually, allowing the cars limit to exploited easier. This is reflected in the top right trace: note how in the highlighted Abbey section, the 1m19s197 lap (green) has much more slip than the slower 1m20s612 lap (yellow). The friction circle in the lower right corner shows how this increased slip allows a higher lateral acceleration to be maintained. The Velocity trace shows I'm averaging almost 5mph more through Abbey now.

Note the method so far: aerodynamic wing/gear ratio/brake bias adjustments. Next, spring, anti-roll bar and ride height adjustments. Finally, fine-tune the mechanical grip with damper adjustments. The whole time, you should be monitoring and adjusting the tire pressures and camber settings to maximize the tires grip and dial in the optimum tire temperatures. [*Here's a side note: higher tire temps are caused when the springs/damper combinations don't absorb enough energy and the resulting weight transfer is deflected directly into the tire. This will become more critical in adapting this to a race setup*.]

After quite a few more unsuccessful changes, I find myself unable to break into the 1m18s times. This makes me rethink my downforce from the wings. I decide to add downforce, losing top speed, but hoping to make up even more time in the third sector. In order to do this, I have to start back at the top as far as fine-tuning the wings, gears and ride height goes. I add 6 degrees of wing, front and rear, adjusting the gears accordingly. And I raise the cars ride height 2/10th of a centimeter.

Another thing to revisit is my camber and tire pressure settings. While I've been constantly fine-tuning these parameters to near perfection, these new downforce adjustments mean I'll probably have to make a few minor re-adjustments. But the basic properties of the springs, dampers and anti-roll bars will transition fine to my new downforce settings.

After a few stints to perfect the gearing, I'm ready to go for times. I run three 5-lap stints back to back and set a new session fast lap of 1m18s873. I also think I could better that time down to a 1m18s5 with a bit more running. And again, the consistency is there as I ran several high 1m18s and low 1m19s. Not only is the car easier to drive, without a doubt it's a second and a half faster than when I started, even though my top speed on Hanger Straight is now 196mph. The Arrows Cosworth V-10 is about 30-40hp down on the Ferrari, BMW, and Mercedes engines. That puts me at an estimated second to a one-and-a-half second deficit to those top tier cars. It's quite possible that this setup would yield a 1m17s lap in the Ferrari with some minor alterations. That's in the running for pole position at 100% opposition levels.



Incremental time difference: Gray = C.W. 1m19.987; yellow = E.A. 1m19m197; green = E.A. 1m18s873

In the above trace, we can see the car is consistently fast across the entire lap, constantly making up time against the gray reference line. I lost a bit at Brooklands, but quickly regained that immediately. We can also see how the added downforce made the car slower in the first 2 sectors, but it came out faster overall by the decreased time in the 3rd sector.

Establishing a setup – Qualifying Setup

My setup is already a good qualifying setup, but there are a few things I can do to take it a bit further. Plank wear is less of a factor so you can try lowering the car a small amount more. Be careful not to lose performance by lowering it too much: dragging the rear end can be very costly to the stopwatch on a long straight.

You might also make small adjustments to camber and toe to improve the cars directional response, as tire wear will not be an issue for the twelve qualifying laps allowed. Some people adjust the brake and radiators to their smallest settings, but this can have bad side effects. Be sure not to run those brakes too hot, as you'll get slightly reduced braking performance.

Practice your qualifying runs so as to have an idea of what you can do. During qualifying, I like to go out and run five to six laps, that way I can be sure to get three to four hot laps in, just to get a good lap on the boards. After that, I can wait and see what everyone else's initial times are. Later, I can run two separate 3-lap stints, or another 6-lap stint depending on how good I feel about the setup. Still, it helps to practice this in advance as the twelve laps allowed in qualifying allow little room for last minute adjustments.

Establishing a setup – Race Setup

Racing is a different beast altogether. The driver must be able to take care of the tires and brakes over the race distance. Typically this means adding downforce, adding ride height, and altering the springs and dampers to keep the tires at their optimum temperatures. The race setup is directly tied to the race strategy. Many things should be considered in the decision making process:

1. Speed: How fast can you run on the various tire compounds? Try running full-tank stints and log average lap times as well as fastest and slowest lap times.
2. Tire wear: Can you run the desired number of laps with the soft compound?
3. Pit lane: How quick is the pit lane from pit in to pit out? Silverstone or Monza: short, straight, and quick. Magny-Cours or Sepang: long, winding, and risky.
4. Starting position: Starting up front: be more conservative, attempt to control the pace. Starting in back: Risk more by using extreme setups. Run a light fuel load hoping to make up positions early or run a heavy fuel load and make fewer stops.

Typically the racing setup has more downforce to cope with the higher levels of fuel. You should run several stints with 70 liters or so of fuel onboard, making necessary changes to ride height and small aerodynamic balance adjustments. The only reason to deviate from the setups spring and damper settings would be to try to lower a specific tires temperature in order to get the necessary tire wear for the chosen strategy.

Another thing to watch out for is brake wear. At the end of your full tank run, be sure to check brake wear. This can be used to calculate pad wear over the race distance. And while on that run, take note of any adjustment to brake bias as the car lightens. It can be made into a science as to when and how much to adjust the bias during a race stint.

Try different fuel levels and tire compounds to see what works best for your car and driving style. In the end, you should have a good idea of what your strategy is, down to the lap times you'll be looking to run. Also practice those pit stops including pit in and pit out laps. The last thing you need in a race is to run a great first stint followed by a pit speed limit infraction (or worse: accelerating out of the pits into a spin on the pit exit lane). And don't forget to reset you brake bias during the pit stop.

Establishing a setup – Wet Setup

Rain changes everything, and being prepared can really pay off. I like to have a full wet setup ready "just in case." To convert a race setup to a wet setup involves several things:

1. Increase your wing angles.
2. Soften you spring rates (make any necessary ride height compensations).
3. Lengthen your gear ratios.

In the wet, grip is everything. For a full wet setup you should dramatically increase downforce, sometimes as much as 50%. You'll also want to soften you spring rate to get maximum grip from the tires. Try to keep both of these in proportion to your race setup. In other words, add equal wing front and rear, and soften the front and rear springs by equal amounts. As a result of these modifications, you'll need to re-examine the ride height. Be liberal with the ride height, as bottoming in the rain can be catastrophic.

Finally, you want to adjust the gear ratios so as to lower the torque applied to the rear wheels. Lengthening the final drive ratio can sometimes easily accomplish this. Other times, more precise alterations to each gear ratio are required for the various corners of the circuit. Alternatively, the driver can also employ a simple technique known as "short shifting." This involves the driver shifting before the engines' peak horsepower is reached, always keeping the car just out of the maximum power band.

A good idea is to develop a wet setup at a medium downforce track with a variety of corners such as Silverstone, and label it as your "Base-WET" setup. It then becomes relatively easy to adapt the "Base-WET" setup to various circuits' attributes as opposed to modifying your current race set-up at the last moment. This concept works only with full wet or monsoon setups, as an intermediate setup is best derived from your race setup.

Another thing to consider is how to setup the car for a damp, but drying track at the start of the race. In it's easiest guise it might be only fitting intermediate tires to the car. Other times, it's the always-risky choice of adding a bit more downforce on the grid. But be careful, as the pitfall is a dry track late in the race with a car having not enough top speed to be competitive.

"I believe that my personal speed – compared with the drivers I've driven with, because it's only those guys I can compare myself with - may come from what you do out of your possibilities. I believe that pure speed isn't always the point; it's what you manage to get out of your potential. And that's where I've always been very successful. You know, really working deep with the team, maximizing my possibilities."

Michael Schumacher during an interview with "*F1 Racing*" magazine January 2000

Conclusions

Hopefully this guide has enlightened you to what exactly these various components are and more importantly how they interact inside an F1 car. As Micheal Schumacher points out in the quote above, it's what you manage to get out of your potential. And this certainly includes the cars potential and maximizing that as well.

Driving style should always be regarded as another factor in setup. One should put forth a lot of analysis into what attributes his or her driving style requires. Through careful understanding of this, one can quickly discern which direction a setup must go in order to accommodate the drivers' particular style. Every setup is like a meticulously tailored suit; while it works great for one driver, it can be totally counter-productive to another. With this in mind, one should understand that when trying another's setup, instant speed is not always the case. In fact, many times it's the exact opposite. In this case, the setup itself is not poor, it's just missing the technique required to maximize its capabilities. Still, by understanding the contents of this guide, a driver should be able to quickly identify the setup characteristics and make adjustments attempting to shift the effectiveness towards a more positive result.

A few last things to take with you: when things become frustrating, I find it best to load a proven and stable setup on to the car, go out and focus on consistently quick lap times. Sometimes, quite often in fact, the setup is not the problem. It's a line taken through a corner or a braking point that's being pushed to far (or not far enough). I quit focusing on the setup and switch my attention to my line, reference points, and technique. Many a time, this will eventually show up a couple of tenths of a second and a better way to tackle part of the circuit, after which I can resume setup modifications.

And finally, I refer to this guides' beginning lines again: There is no substitute for logging the laps that make your reactions to the car become second nature. There is no quick way to learn a new circuit so you can concentrate totally on what the car is doing at any given point in time. The only way to be faster is to practice, read, learn, and practice some more.

References and resources

Conversion formulas: Imperial to Metric

Length Conversion Factors

To convert from	**to**	**multiply by**
mile (US Statute)	kilometer (km)	1.609347
inch (in)	millimeter (mm)	25.4 *
inch (in)	centimeter (cm)	2.54 *
inch (in)	meter (m)	0.0254 *
foot (ft)	meter (m)	0.3048 *
yard (yd)	meter (m)	0.9144 *

Volume Conversion Factors

To convert from	**to**	**multiply by**
gallon (gal) Canada liquid	liter	4.546
gallon (gal) Canada liquid	cubic meter (cu m)	0.004546
gallon (gal) U.S. liquid**	liter	3.7854118
gallon (gal) U.S. liquid	cubic meter (cu m)	0.00378541

Force Conversion Factors

To convert from	**to**	**multiply by**
pound (lb) avoirdupois	kilogram (kg)	0.4535924
pound (lb)	newton (N)	4.448222

Pressure or Stress Conversion Factors

To convert from	**to**	**multiply by**
pound per square inch (psi)	pascal (Pa)	6,894.757
pound per square inch (psi)	megapascal (MPa)	0.00689476

Mass (weight) Conversion Factor

To convert from	**to**	**multiply by**
pound (lb)	kilogram (kg)	0.4535924

Temperature Conversion Factors

Temperature

degree Fahrenheit (F)	degree Celsius (C)	tc=(tF-32)/1.8
degree Fahrenheit (F)	kelvin (K)	tk = (tF+459.7)/1.8
kelvin (K)	degree Celsius (C)	tc=tk-273.15

Power Conversion Factors

Velocity

mile per hour (mph)	kilometer per hour(km/hr)	1.60934
mile per hour (mph)	meter per second (m/s)	0.44704

*indicates that the factor given is exact.
**One U.S. gallon equals 0.8327 Canadian gallon.
t--A pascal equals 1.000 newton per square meter.

More Useful Conversion Factors

Quantity	From English *Units*	To Metric *Units*	***Multiply by****
Mass	lb	kg	0.4536
	kip (1000 lb)	metric ton (1000kg)	0.4536
Mass/unit length	plf	kg/m	1.488
Mass/unit area	psf	kg/m 2	4.882
Mass density	pcf	kg/m 3	16.02
Force	lb	N	4.448
	kip	kN	4.448
Force/unit length	plf	N/m	14.59
	klf	kN/m	14.59
Pressure (stress) modules of elasticity	psf	Pa	47.88
	ksf	kPa	47.88
	psi	kPa	6.895
	ksi	MPa	6.895
Bending moment,	ft-lb	N . m	1.356
Torque (moment of force)	ft-kip	kN . m	1.356

* 4 significant digits
**denotes exact conversion

Websites:

Technical information (Formula 1)

GTF1 - Gruers Technical F1
http://www.gtf1.com

F1 Factor
http://www.f1factor.co.uk/articles/2002/tech

F1 technical
http://www.f1technical.net

F1Mech.com
http://www.f1mech.com

Technical F1
http://www.technicalf1.com

EA Sports F1 2002 add-ons and info

01 Ferrari-Fans SpeedsimS Zone
http://teamspeedsims.com/zero1ferrarifan

Driving Italia
http://www.drivingitalia.com

EA Sports F1 2002 World Lap Records
http://f1lap.ea-europe.com/lapup/default.aspx

Emac F1
http://www.emacf1.com./

F1 Online
http://f1online.m4driving.sm

F12K1.de
http://f12k2.relaygames.com/

Find the Limit
http://www.findthelimit.com

HighGear EA F1 2002 Forum
http://dynamic2.gamespy.com/~hg/forums/forumdisplay.php?s=&forumid=23

Racing Sim Developers Group
http://www.rsdg.net

SimBin Development Team
http://www.simbin.com/sbdt/index.html

Websites (continued):

Advanced Menus

FlyingCamel's advance menu
http://www.simbin.com/forum/index.php?act=ST&f=28&t=3875&hl=advanced+menu&s=2396b8ba3a4abc8bd4965a04d05e4b07

FlyingCamel's compact advance menu
http://www.simbin.com/forum/index.php?act=ST&f=30&t=4161&s=a95e2462daf867c8984b6087c6b2b048

RacerAlex advance setup menu
http://dynamic2.gamespy.com/~hg/forums/showthread.php?s=&threadid=47419&highlight=menu

Publications

"Competition Driving" by Alain Prost and Pierre-Francois Rousselot
Hazelton Publishing LTD, 3 Richmond Hill, Richmond, Surrey, TW106RE
England
http://www.hazeltonpublishing.com/

"HARDCORESIM Racer" magazine
HARDCORESIM Publishing, P.O. Box 5532 Kingsport, Tennessee, 37663
United States
http://www.hardcoresim.com

"Principles of Race Driving" by Ayrton Senna
Hazelton Publishing LTD, 3 Richmond Hill, Richmond, Surrey, TW106RE
England
http://www.hazeltonpublishing.com/