A Guide to the Physics & Car Dynamics Model

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Introduction

For the more technically inclined amongst you, this document outlines the detailed physics and car dynamics modeling strategy employed in the SBDT's GT RACING 2002. In all, about 1200 hours of work has gone into these aspects of the GT RACING 2002 since I got the first EA Sports F1-2002 betas back in April 2002.

1. Suspension

All cars have unique (to that car) suspension geometry. The GT cars in the game feature traditional double A-arm suspension modeled, except, of course, the Porsches. The Porsches have a McPherson front strut, and the rear is the Weissac 5-link (both accurately modeled). ISI's Physics engine is unique in that it calculates real-time suspension geometry whilst the car is in motion. The roll centers, camber gains, anti-dive, bump-steer, caster are **all** done in real-time. So to have the car behave realistically, the suspension geometry must be realistic. I spent much time designing each car's suspension as a real car designer would – adding individual characteristics along the way. For instance, you may notice the Porsches have a bit of bump-steer, which is accurate, where as most of the double a-arm cars don't. ☺ Also because of the McPherson front strut, the Porsches require a bit more front static negative camber to compensate for their lack of camber control. And, in case you're wondering – no, GPL doesn't do this. ;)

1.1 Suspension Travel

The cars have approximately 40-50mm bump travel at the default ride height until you hit the bumpstop. You will hit it even without packers. The packers just space the bumpstop close to the shock body, limiting travel. Default ride height is 60mm front and 70mm rear. The bumpstop is modeled on a progressive Koni bumpstop from my own race shop. It starts around 150lbs/inch and after 20mm is around 1200lbs/inch.

1.2 Springs

All Spring values are wheel rate. This means it's the spring rate that the wheel "sees" after it works its way through the lever arms and installation angles of the shocks (the motion ratio). For instance, the Porsche might use, in real life, a 150nm front spring – but after it works its way through the motion ratio, the wheel only sees it as 110nm working rate. That's the number you are adjusting in the garage. So don't get worried if you try to plug in some real world spring values and the car doesn't handle how you'd expect it to.

1.3 Shocks

All Shock values are wheel rate too, like the springs. The dampening values are in newtons/meter/second - which means if you have a 1000 bump newtons setting in the garage, the shock will provide 1000 newtons of resistance when the shock is traveling at 1 meter/second (1000mm/sec). Most race cars of the GT type operate the shocks from 0-100mm/second at low speed (driver inputs) and up to 500mm/second at high-speed (bumps and curbs). Typical bumpy sections will be in the 200-400mm/sec range.

Now, the telemetry graphs need to be setup to display this properly or you won't get much use out of them. As shipped they seriously under-graphed and shouldn't be filtered (except for histograms). Also the sampling rate should be set to 40 in the .PLR file (from the default 10). Use the graphs I've included (should have been installed for you), which sets the shock velocities from 0-500mm/sec and takes out the filtering – you need to know the peaks with shocks. Anything under 100mm per second is considered "low-speed" and is mostly your driver inputs, and over that is considered "high-speed" - bumps and curbs. So if you have a problem at a certain part of the track, or a persistent problem with something like corner entry understeer, look at the shock velocity graph at that point of the track and pick out the shock speeds. If it's all under 100mm/sec then you want to change the low-speed dampening, if you see higher speeds going on (maybe bumps you don't feel) than adjust the high-speed – or sometimes both.

High-speed rebound dampening is typically at least double the fast bump because it is damping the main sprung mass in addition to the energy built up in the spring. On the other hand, the bump is only damping the unsprung mass (wheel, tire, spindle, brakes, and suspension arms) and the spring oscillations.

Slow speed dampening is not as cut and dry for the initial setting. I usually start slightly higher than the low-speed numbers and go from there. Here's a chart I did way back for

GP2, but it's still relevant and is based entirely on real world settings and effects. I've included the intro tests, but the most useful is the corner phase descriptions and the chart for adjusting them … (please ignore the specific GP2 references):

1.3.1 General

At all times cornering balance is affected by the weight distribution on the four tires. Springs, sway bars and wings give constant resistance or affect weight distribution through the ENTIRE length of a turn. Dampers however, and their amount of resistance, can affect the balance at different _parts_ of a turn. This occurs because at different parts (or what are called "phases") of a corner, different dampers and their travel are dominant at that point. This makes for a excellent way to adjust the corner entry and exit independent of each other, or to take a corner that is unbalanced from entry to exit, to one that is balanced (ie: understeer on the way in - oversteer on the way out).

1.3.2 Fast-Damping

Fast damping is what the tires see and feel i.e.: reactions over bumps or kerbs. Its job is to keep the rubber on the ground over the various surface undulations. Traveling over a bump at speed causes a relatively large and "fast" movement of the damper shaft, and hence it's name. If the front of your car is "overdamped" in the fast bump direction, then you will experience UNDERSTEER on the bumpy sections of turns. If the rear is overdamped you will experience OVERSTEER.

For fast speed adjustments, pick a bumpy turn at the particular track you're working on. Start with bump at 0 and rebound at 2 and work your way up until the front UNDERSTEERS over the bumps, then back off 1 or 2 clicks. Then do the same for the rear until it OVERSTEERS over bumps, again back off 1 or 2 clicks. Always keep the fast rebound higher than the bump - 1.5 to 3 times so. The stiffer the spring the stiffer the rebound setting. It is the fast rebound's job to resist spring pressure and unsprung weight (wheel, tire, hubs, brakes etc) when the suspension oscillates. Usually a setting of 2 times the fast bump works well in GP2. Make sure the car likes "usable" kerbs, too. This may require softer settings than done in your bumpy turn test - everything is a compromise.

1.3.3. Slow-Damping

Slow damping is what the driver feels ie: turn-in throttle-out, and mid-corner transitions (chicanes). It controls the dynamic weight transfer and overall motion of the main chassis relative to the track surface as the car is turned, slowed, and accelerated. These motions cause "slow" and small movements of the damper shaft, again the name. The slow rebound usually ends up being higher than the bump, but can be at times 1:1. Most fiddling will be done with the slow speed settings. First settle on a spring and roll bar setting using a constant radius neutral throttle corner. Next do the "fast" bump adjustments as described previously, then fine tune with slow speed adjustments. First we'll need to understand the different cornering "phases" before we can make a decision as to what slow speed adjustments to make.

1.3.4. Different Corner Phases

Entry type 1: Increasing braking + increasing steering

This phase is the first part of a fast decreasing radius turn. This phase will not occur at all if you get all your braking done *before* you turn-in. Since weight is being transferred both forward and outboard, the outside front damper moves in bump and the inside rear damper moves in rebound. These are the dominant two dampers in this phase of turn-in. The other two have minimal effects during this phase.

Entry type 2: Decreasing braking + increasing steering

This is the turn-in phase of a slow corner. This phase may or may not occur depending on the type of turn or driving technique. Weight is being transferred outboard and to the rear, so the outboard rear damper moves in bump and the inside front damper moves in rebound. The other two dampers are considered stationary.

Entry type 3: Increasing steering at constant throttle

This phase can be a chicane turn-in or a turn entry taken at *full* throttle. Weight is being transferred outboard only, so *both* outside dampers are moving in bump and *both* inside dampers are moving in rebound.

Mid-corner Transition: Decreasing steering back to zero at constant throttle

This is really the opposite of a type 3 entry. It's what happens in the middle of a chicane, as you flick the steering back away from the current cornering direction. As soon as the lateral acceleration passes back through zero, the turn reverts to a type 3 entry again.

Exit: Decreasing steering + increasing throttle (or decreasing braking)

This is the apex-to-exit phase. Weight is being transferred inboard and to the rear. The outside front damper moves in rebound and the inside rear moves in bump. The others are considered stationary.

Below is a chart to help understand low speed damper adjustments:

Diagram 1: Slow-Speed Damper Adjustments

Cornering Phase	More Understeer	More Oversteer
Entry Type1	F bump + R rebound -	F bump - R rebound +
Entry Type2	F rebound + R bump -	F rebound - R bump +
Entry Type3	F bump + F rebound + or R bump - R rebound -	F bump - F rebound - or R bump + R rebound +
Mid-corner Transition	F bump - F rebound - or R bump + R rebound +	F bump + F bump + or R bump - R rebound -
Exit	F rebound - R bump +	F rebound + R bump -

Key:

+ = increase adj.
- = decrease adj.
F = front
R = rear

2. Tyres

We've included 4 different tire types in GTR2002. Here's an overview of the minor differences:

Dunlop: Broad slip curve, probably the most forgiving of the lot. Medium wear, but will generate heat (which leads to wear) if abused.

Michelin: Narrowest slip curve of them all. More precise, but rewarding if driven that way. Medium heat – the worst wear, but if you drive them like they demand, the wear will be quite good. Don't over-drive them if you are looking to last 100 litres fuel run

Pirelli: Similar to the Michelin, but not quite as precise. The most durable of the bunch, with the best wear rate, but will reach its slip peak at a lower load then the others, so they might bite a bit more than the rest. These tires are hard to beat in long races, though.

Yokohama: GT only. A bit behind the rest in technology so grip is a tad below the rest, but very similar to the Dunlops in forgiveness, but has the excellent wear of the Pirelli. Only used on the 993GT2.

2.1. Tyre Warming

The optimum temperature range for all the tires is 95-115C. Please note that the tires take **two full laps** to get up to operating temperature. So don't judge any setup changes until you've done 4 or 5 laps.

2.2. Rain Tyres

Rain tyres are fully implemented in GT Racing 2002 ☺. However, the characteristic differences outlined above are not as great as with the dry tyres.

3. Aerodynamics

Each car is accurately modeled in their aerodynamic packages. Each car has four different "splitter" configurations. These set the tone of the aero package as it relates to the track type. Here's a small list with basic splitter wing configurations:

3.1. Splitter setting

1 – Le Mans or the Old Hockenheim
2 – Monza
3 – Most medium speed tracks. You will use this the most.
4 – Short tracks like Hungary and Monaco.

3.2. Rear Wing setting

Basically 5 degrees of rear wing for every splitter setting is the baseline you use. So for a 3 front splitter you'd use a 15 rear wing. The rear wing has a much finer adjustment that the splitter so that's what you'll be doing your "at the track" aero balancing with. So splitter x 5 will get you a basic rear wing setting. Choose the splitter first for the speed of the track.

3.3. Sensitivity to ride height

This has also been tuned to what the real world cars should have. They are not super-sensitive to ride height changes like the F1 cars are and this been changed accordingly. If you run RSDG's excellent Le Mans track, the cars will still pull the front wheel over the Mulsanne "hump", but will no longer flip over as our V3 cars – or Mark Webber – did. F1-2002 has allowed us the avenue to fix this now.

3.4. Aero Torque

Again, tuned to an individual characteristic of what and where the forces are on the real car models. It shows in the differences the car exhibits in high speed directional changes. Not only do the cars have chassis mass moment of inertia, but they have a similar aero "torque" moment of inertia depending on where the aero-centers of the front splitter, rear wing, main body, and diffuser is located. Yeah, yeah, I know – aero can't have a MOI, but you get the idea. ☺

4. Brakes

Much time went into making the brakes act like the real thing: mostly the warm-up rate; where the peak friction torque is made; and how much, and how far, past the peak the brakes start to fade. And they will fade. ☺

Peak brake torque occurs at 500C; noticeable fade will happen at 800C. Also, if you go out with dead cold brakes out of the pits, don't go stampeding into the first corner, you ain't gonna' stop. As with the tyres, give it **at least 1 lap** to get near the peak stopping temperature.

Basically the brake ducts have 5 settings and this will give you the whole cooling range. 1-3 for Lemans and Monza, 4 for most of the medium tracks, and remember, Monaco needs 5.

5. Engine Heat

Engine heat is also modeled. It's controlled by the radiator opening duct. Low settings for the fast tracks and higher for the slow tracks. You will lunch (in British English, "blow") the motor if you run it hot for an extended length of time. Not only smoke, but fire – big flames! Optimum temp is 95-105 degrees.

6. Gearbox and Clutch

Gear ratios are taken from Quaife and X-track: the two biggest suppliers of transmissions to GT racing. Clutch torques and friction have been extensively tweaked to make them feel realistic when using a clutch.

6.1. Semi-automatic gearboxes

Although they are implemented in the game as shipped (for playability reasons), they are illegal to use in the FIAGT series. For the ultimate, realistic experience, change this line in the HDV of the car you are driving:

[DRIVELINE]
semiautomatic=1 change to “0”

Now you will have to do your own throttle blipping on up and down shifts à la GPL. ☺
Myself and most of SBDT team, prefer this method.

7. Fueluse

Unfortunately, F1-2002 guesses fuel use off-throttle position and RPM’s when the AIW (AI line) is constructed. Since the NGT’s run a higher RPM range than most of the GT’s, the Laps the game calculates that you will make in a GT car is off by 30% or so. It will under estimate the laps, so don’t worry, you won’t run out of fuel. The NGT’s are accurate. ISI is working to make this more flexible in future releases.

8. AIW (Artifical Intelligence Waypoint file)

These are completely re-done for GTR2002. It’s no secret now that ISI has entrusted me with their AIW creation tools to allow completely new AIW to be made. The AIW line is actually “driven” and recorded by the type of car that is used. This is why the F1 car AIW’s can be so bad for the GT car. They can get away with slightly sloppy AIW lines because of their raw stick. The GT cars, on the other hand can have a lot of trouble negotiating the same paths. For this reason, I created new and highly tuned AIW’s specifically for GTR2002’s cars. Great pain was taken to drive the lines as accurately and smoothly as possible. Also many of the “bad passing attempt” areas have been marked illegal for the AI to drive on, making for a better racing experience. It’s far from perfect and there are still issues with the underlying AI decision making process, but I dare say it’s pretty damn good in general: at 100% strength they are really tough. One known issue is that the AI is better at putting the power down out of the corners, and this was compensated for as best as was possible, but you will notice this somewhat.

8.1 AI setup files

These are no longer located in the \save folder, but in each individual car's folder. This was a change implemented in F1-2002 (and requested by me – thanks T-Bone!) so we could individually setup each car as the cars are all so different. So if for some reason you want to do some messing around with them, don't look in the \GTR2002save folder they'll be in each teams folder.

And finally …

ENJOY! ENJOY! ☺

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