Getting it Balanced

(by Simon Oaten)

Most 2 Litre Sports Sedans are rear wheel drive, and have the following characteristics:

Weight: 800-920kg (excluding driver)
Weight balance: 50-55% front axle
Suspension design: either strut or wishbone front, live axle rear
Horsepower: 200-240 is typical
Torque: 160-180ft-lb
Engine management – most cars are EFI and this can enable some sort of data-logging of engine and chassis parameters.

The aim in car set-up and driver technique is to use as much throttle as possible, for as long as possible, to do so requires the car to "be balanced". This means the front and rear tyres "let go" at the same time. The driver should then drive the car either at the limit of the tyre, or just before that.

There are really ONLY TWO THINGS that determine if a car is balanced or not:

- Load on the tyres
- Slip angle of the tyres

Sadly, as soon as we turn the steering wheel, load transfers across (and diagonally) the car and the slip angle of each tyre changes – hence the conundrum! So how do we go about changing the balance?

Step 1: **Understand what you have –**

This involves measuring the car:

- Front and Rear Track widths
- Weight on each wheel
- A reasonably accurate drawing of the suspension layout (front view and side view)
- Front and rear motion ratio's and installed spring rates

Step 2: **Feedback from the "nut behind the wheel"**

The driver should drive the car as hard as possible (ie to the limit of the tyre).
The driver should be honest with assistants and himself.
The driver should be able to feel the tyre
The driver should be able to break down the corners into:

- Entry
- Mid-point (to the apex)
- Exit (after throttle is applied)

It is of little use to say "it pushes like a pig" ……where does it happen (slow or high speed corners?, At entry? At exit?
The assistants can then look at wheel speed / rpm / steering angle / brake sensors and try to understand what is actually going on !

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For example – data-logs suggest the driver continues to brake, after the steering wheel is turned into a low speed corner, then, most likely the understeer is being caused by the driver not braking hard enough and carrying the brake into the corner while turning the steering wheel.

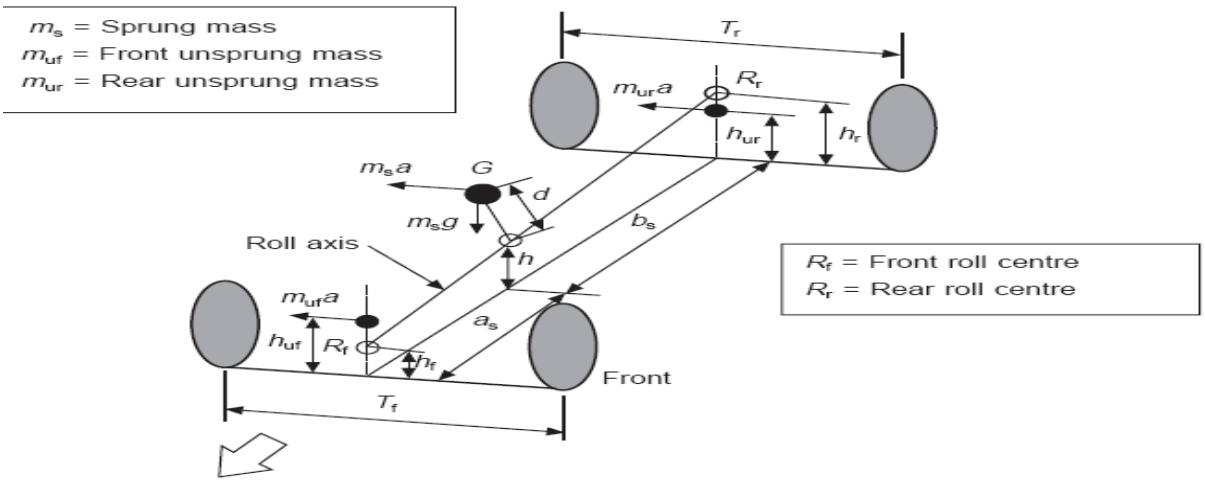
The tyre will not like being asked to do 2 things at once (see "friction circle" for an explanation).

Step3: **How to go about it!**

Once we have determined "what the car is doing" and "what do we actually want it to do" we have to work out what to adjust:

What are the change(s)?
How long will it take? (hint – make sure that it is possible to easily adjust ride heights, and that this has minimal affect on toe/camber, and also if possible make sway bars "easily adjustable" If roll centre is changeable – make sure it is easy to move)

What will the effects be? (low speed versus high speed)



From Carrol Smith books!

http://www.locost7.info/files/suspension/Suspension_spreadsheet.xls

This simple spreadsheet will help to understand "what is going-on" and what you can adjust to affect "lateral load transfer". The simple geometric approach is not exactly correct (see

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free body diagrams and "force based" roll centre analysis for a more complete approach). What the Geometric approach allows is a simplified look at what is happening to "the load on the tyre".

So the car understeers on entry we can then add a small amount of front sway bar (to see if the problem is not enough, or too much load), and if the Understeer persists - you can try the following:

1. Brake the car more aggressively and come out of the pedal before tipping it in, if Understeer continues then we need to look at trying to reduce load on the front tyres!
2. Reduce front spring rate, or increase rear
3. Wider front track (or narrow rear)
4. Lower front ride height (or raise rear)
5. Raise rear Roll Centre
6. Reduce front tyre slip angle!

Which is "the best solution" – well it depends if the corners are slow or fast !

Chassis balance does change with car speed. It also depends on driver preference (some drivers like a car that "rotates" quickly while others like a bit of stabilising push.
You also need to determine if there is any "aero" affects (normally this doesn't have any effect in low-speed corners).
For example you would be silly to try and reduce "high speed" oversteer at Phillip Island with simple geometric chassis adjustments, when aero forces are likely to be more significant.

Chassis balance is always a COMPROMISE and the car/driver with the best compromise will be faster!

References:

Carrol Smith "Tune to Win" – although this is old, the principals are still valid.

Milliken, William F & Milliken, Douglas L "Race Car Vehicle Dynamics" SAE International, Warrendale 1995, if you want to understand the math

www.optimumg.com – good site with some nice technical papers

Mark Ortiz – outstanding collection of technical papers that look at chassis / suspension effects, and helps explain the physics behind it all.