

# Basic Weight Transfers

By

Keith Young  
4201-201 Forest Creek Ct  
Kentwood, MI 49512  
(616) 886-6001 (Cell)  
[keith.a.young@comcast.net](mailto:keith.a.young@comcast.net)  
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## INTRODUCTION:

I am a young man seeking a place in motor sport. I am writing this, and other papers, in an effort to both better my skills and showcase them. This paper is on the basics of weight transfers in single seaters-formula cars. Many of these same principles will relate to most other types of motor sport, and vehicle dynamics in general. I focus on open wheelers as this is my passion and my hopeful occupation in the future. Though this paper is mainly for research reasons for my aid, I do hope this may further your knowledge in this topic as well. So now I will spare you further boredom and get down to the subject at hand. For my sake please realize this is a complex subject, there are many forces encountered, including the main mechanics, as well as drag and aero and so on. I will often ignore certain dynamics as to simplify explaining this vast topic, and to make it both easier on me the writer and you the reader. Finally in this introduction I would like to take the time to say that anything you may read in this paper is neither telling you to practice it, or that motor sport is in any way safe. What you do is your own choice and I am not responsible for your actions.

## ACCELERATION:

Before you can understand the load transfers in your vehicle, you must comprehend the causes of such shifts. These transfers in weight at different areas of the car come from accelerations. First, we must understand exactly what acceleration is, and that is any change in velocity. Velocity is both the speed (unit distance per time unit,  $\Delta d/\Delta t$ ) and direction, which consists of front to back, left to right, up and down etc. Any change in velocity whether in the speed you are traveling or the direction in which you are going, requires acceleration. Acceleration, which can be summed up as velocity change per time change ( $\Delta v/\Delta t$ ), is in units of distance per time<sup>2</sup>. The mother of all equations states that (F) force equals (m) mass times (a) acceleration ( $F=ma$ ). One should notice immediately, the lighter the car, the more available acceleration; and that more force gets the same. The force comes mainly from the tires. When the driver turns the steering wheel, or applies throttle or brake, he is telling the tires to apply forces on

the ground. Since the ground does not move, the vehicle moves, every action is met with equal or opposite reactions.

The simplest acceleration to understand, and therefore to explain, is the linear acceleration. When applying throttle or brakes it will accelerate the car positively or negatively. For now we will assume no friction, and no steering input. The force available in forward acceleration from the engine is simply put ( $T_f$ ) torque times final ratio, divided by the tires rolling radius. Torque is in Pound Feet. The final ratio consists of gear ratio and differential ratio. Say for example your car weighs 1000 Lbs, your final drive ratio is 5.5, rolling radius is 1Ft, and your engine is outputting 300 Ft Lbs. The equation you get is  $300 * 5.5 / 1$ , which gets you 1750 lbs. What you should notice in this given scenario, the output force is greater than the weight of the vehicle. Theoretically you could pull 1.75 g's in acceleration, that is, if your tires have that much grip. That's not all either, your vehicle may weigh 1000 lbs, but your rear tires only have 500 lbs on them, figuring a 50/50 weight distribution. That means your tires need to output 3.5 worth of force to get such acceleration, which I find unlikely. If 1750 lbs of force is put to your 500 lbs on your rear tires, you will get wheel spin. Do realize that the moment you get on the throttle some weight will be taken from the front wheels and transferred to the rear, allowing your tires to use more of the force. I will cover this in more detail later.

The turning of the front wheels changes the direction of the car, which is changing the velocity and is therefore acceleration. Let's say the driver turns to the right, at a constant speed. The weight of the car will naturally be transferred to the left tires, this is not due to centrifical force, I would like to tell you this right off the bat. What you feel is referred to by many as centrifical force, but the untrue word is force; a force is not the feeling of g's due to acceleration, but a push or pull or the like. What is actually happening is a thing called Centrifugal force (note the spelling) that causes this sensation. Your mass wants to travel in a straight line at a constant speed, tangent to your current arc, but centrifugal force pushes you to the center of the arc you travel changing your path, and therefore you feel the acceleration. As I said the weight will transfer to the left, less weight will be on the right tires than before, and more on the left. This is also somewhat similar to linear acceleration; the amount of acceleration is obviously inverse to mass, and proportionate to the amount of force being used to make the corner. The simple way of saying this is Force is Mass times Velocity squared over the radius of the curve. Makes sense right? The tighter the radius the harder it is to turn, the faster you are the more sideways force is required on the tire, and obviously for mass, the less the better. The ways of improving your acceleration, or just simply put-cornering ability, you can do any one of many things. For one, you can increase the radius of the corner; this may sound impossible, but taking one line over another changes radius. I am sure you know the proper race line and I will spare you. Another way is to do the obvious and decrease the mass of the vehicle. Then there is the fact that maybe you can carry more speed through the corner, and therefore you are not using your full traction available. If you go over your maximum ability, the car will wash out in one way or another, basically summed up as understeer and overseer. One good example of this in more basic terms is in Carroll Smith's book Tune to Win, where he says think of it as a string tied around a rock, and spinning it in circles obviously.

## **WEIGHT TRANSFERS:**

Now that linear and cornering acceleration have been covered it's on to the load transfers. Both for/aft and cornering accelerations cause load transfers, and both are very similar when in steady state. It is basically common knowledge that the vertical loads on the individual tires change with accelerations, that is why you see cars roll when turning, lean back when pushing the throttle, and taking a bow when laying on the brakes. Down force aside and ignoring loss of fuel and all other things (remember to keep this simple if possible), the weight of the car will stay the same. Weight transfer is weight from one corner being transferred to another if looked at simply, and is addition and subtraction when looking at your final numbers. To find the weight transfer from front to rear tires when applying throttle is multiply weight in lbs times center of gravity height all over wheelbase in inches, and multiply that by acceleration in g's. (Acceleration X ((Weight X Height of Cg)/Wheelbase)). Of course this is better understood with an example and hopefully later a sketch of some kind. With our same car, let us say we are accelerating at .75 g's. Weight is still 1000 lbs and we will say the Cg height is 10" and the wheelbase is 85". That gets us  $.75 \times ((1000 \times 10)/85)$  which is about 88.25 lbs of transfer. Simply subtract that from our 500 on the front and add it to the 500 on the rear and u have 411.75/588.25. I am sure my intelligent audience can now figure out the simple way of figuring out right to left transfer, and the ways of reducing weight transfer, however I will briefly explain reducing transfer. This is achieved by lowering Cg height or increasing the wheelbase, mathematically you could reduce acceleration as well but who wants to do that?

## **CONCLUSION:**

So there is my very simple paper on weight transfers in racing. The basic idea of this paper is to show that lower Cg height and greater wheelbase and track width help reduce weight transfers in general. I am sure I will cover this in more detail later but the whole point was to try to keep it readable for all. As I said I will write more papers later but I have found this more time consuming than I had planned and my hopes of showering you with information on what makes cars fast have been slowed up. Of course any feedback you may have can be sent by email or however you see fit, whether you see a mistake or would like to request a new topic, I will reply though I might not have the answer you want to hear. I would like to take this time to thank you for reading the whole last paragraph, and for hopefully reading the bits above this as well. I hope this helped you either understand simple weight transfer or maybe made you want to hire me, wink wink. I'll talk to ya later.