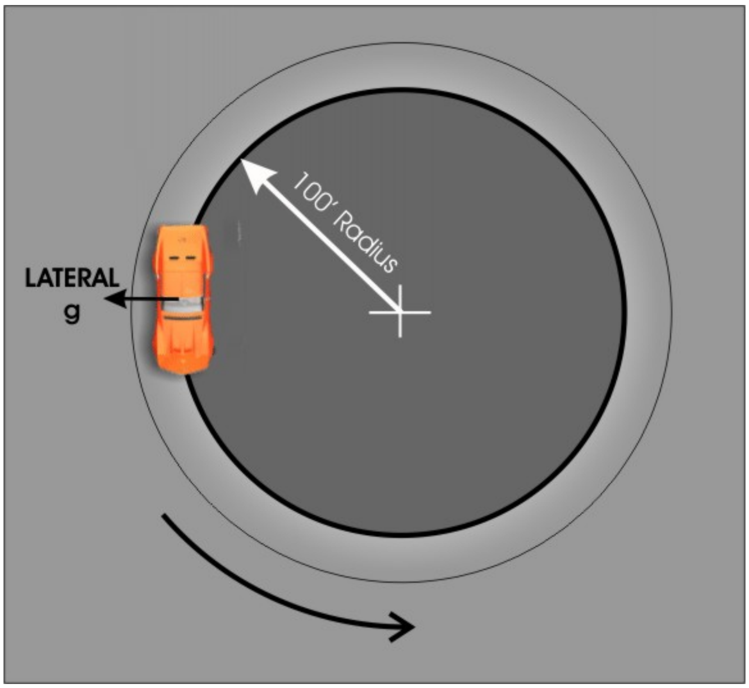
Handling Handbook

Basic Concepts in Understanding Your Car



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Alignment: How it Affects Handling.

If you are like me sometimes you overlook the obvious while in hot pursuit of the glitzy, cool (expensive) stuff. Front end alignment is one of those obvious things that seem so mundane that why bother? In some ways it's a trip to the alignment shop is like a trip to the dentist to get your teeth cleaned. Besides that it seems like some alignment shops are more interested in selling you things you really don't need so why go? We will look at the benefits and some tweaks which can be done with the front end alignment that will pay off in a better handling car.

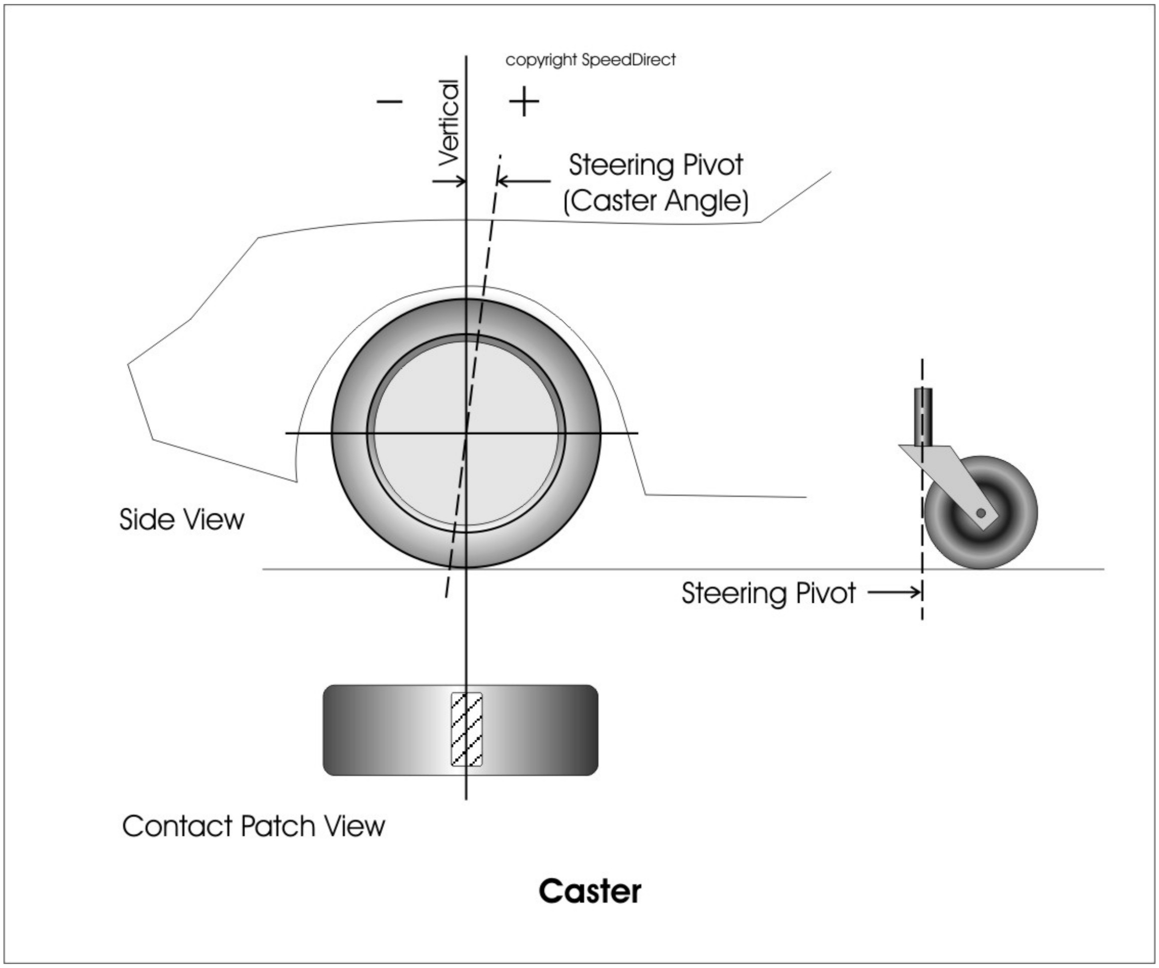
Factory specs for alignment are established as a trade off in tire wear and better handling. This is because of some basic geometric principals like camber, covered later, which can improve how your car "feels" can cause more than normal tire wear. It is all about the kind of driving you want to do. If you are a boulevard cruiser and corners are not of interest then probably the factory settings are close but no where optimum. With that said, things have radically changed in tire profile since our classics were new which may mean you might want to revisit the factory settings.

Let's look at the alignment settings for a typical classic car's front suspension and see what they do.

CASTER

This is what makes shopping cart wheels run straight. This is illustrated in the figure. As you can see the steering pivot is in front of where the wheel contacts the ground in the direction of travel. This forces the wheel to always track straight when the cart is pushed forward or backward without wandering. (Depending on how beat up the shopping cart is.) The same principal applies to the front end of most rear wheel drive cars.

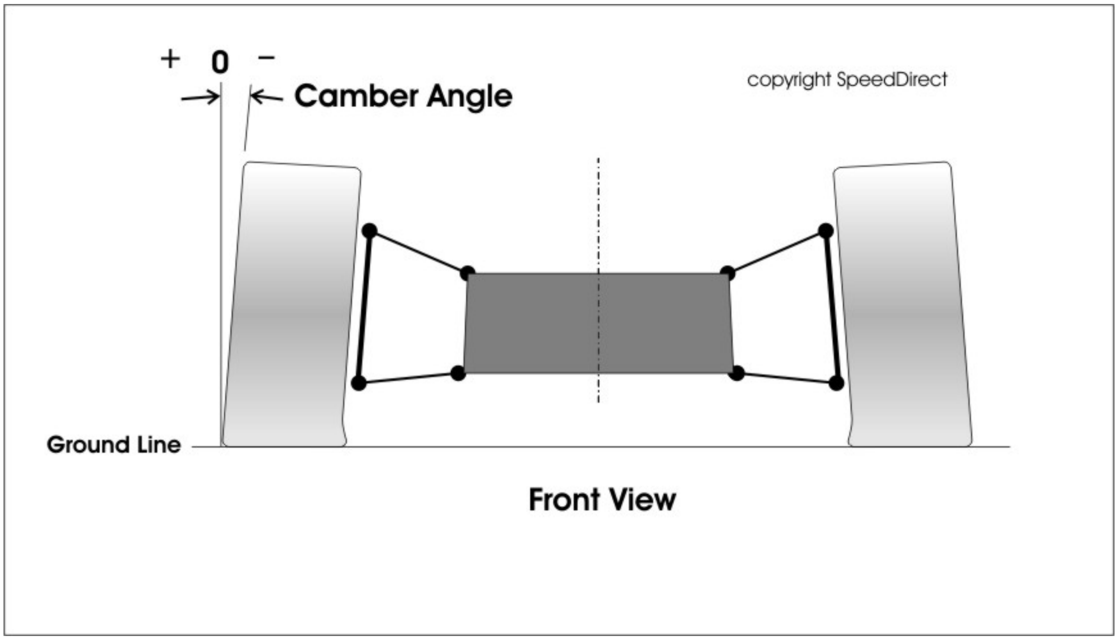
The factory usually sets the angle near zero depending on the vehicle. This was fine when they ran those skinny balloon tires in the good old days. Today the contact patch, the "foot print", of the tire where it touches the road is much larger. Leaving the caster at or near zero will cause the car to wander and the steering to not want to return to center after a turn. This is because the contact patch is so much bigger on modern tires and no opposing force to "caster" the wheels straight like a shopping cart wheel. With positive caster (tipping the steering pivot angle toward the back of the car) the wheel now has a force ahead of the contact patch to align the wheel in the direction of travel.



CAMBER

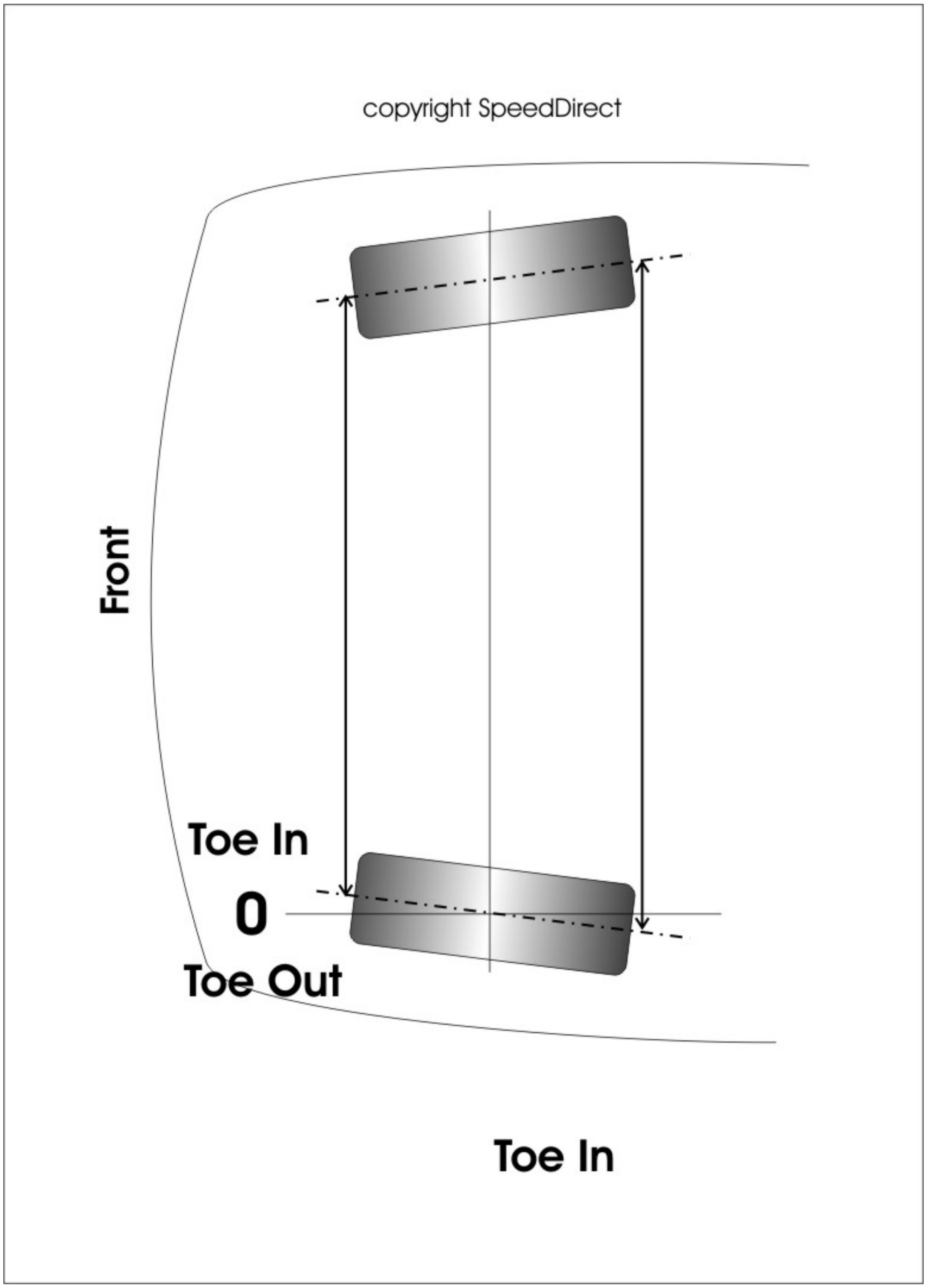
This is the “tip” of the wheels as viewed from the front. Negative is inward tipping of the top of the wheel; positive is outward tipping as shown in the diagram. Negative camber is preferred since it will counteract the geometric tendency for the suspension to lift the contact patch as the body rolls during cornering. This setting can have the most dramatic impact on the cars ability to hold front end traction in a corner. It also can cause the most uneven tire wear over time. That is because the inside edge of both tires are loaded higher than the outside causing them to wear more.

The factory setup opts for zero to positive camber to keep the car in an understeer setup. This makes the front end tend to “push” or “wash out”. The factory lawyers like this because novice drivers are less likely to have the back end come around if they aggressively make a turn. It results in decreased traction and a slower turning car.



TOE

This setting is the angle of the front wheels as viewed from above. Toe is determined by measuring the distance between the track of the wheels in front and in back. It can be toe out or toe in depending on how it is set. This setting is influenced by ride height. A car at high speed can have appreciable changes in the toe setting as the suspension is loaded by the aerodynamics of the car. Most cars are set with toe in.



NEXT STEP - Suggested Settings

Here is a chart of suggest settings depending on your driving preferences. These are just starting points. In order to set them to optimum you will need to do some experimentation and determine what is best for your car.

USE	CAMBER	CASTER	TOE
Touring	0.25 to 0.5 Deg neg.	2.5 to 5.0 Deg pos.	0 to 3/16” In
Autocross	0.5 - 1.0 Deg neg.	2.5 to 5.0 Deg pos.	1/8” Out to 0
Road Racing*	0.5 - 2.0 Deg neg.	2.0 to 7.0 Deg pos.	0 to 3/16” In

There are many variables to work with but the key is to make the adjustments and systematically measure performance improvement. The results will be a car that is dialed in for the type of driving you do, not what the factory decided you might do.

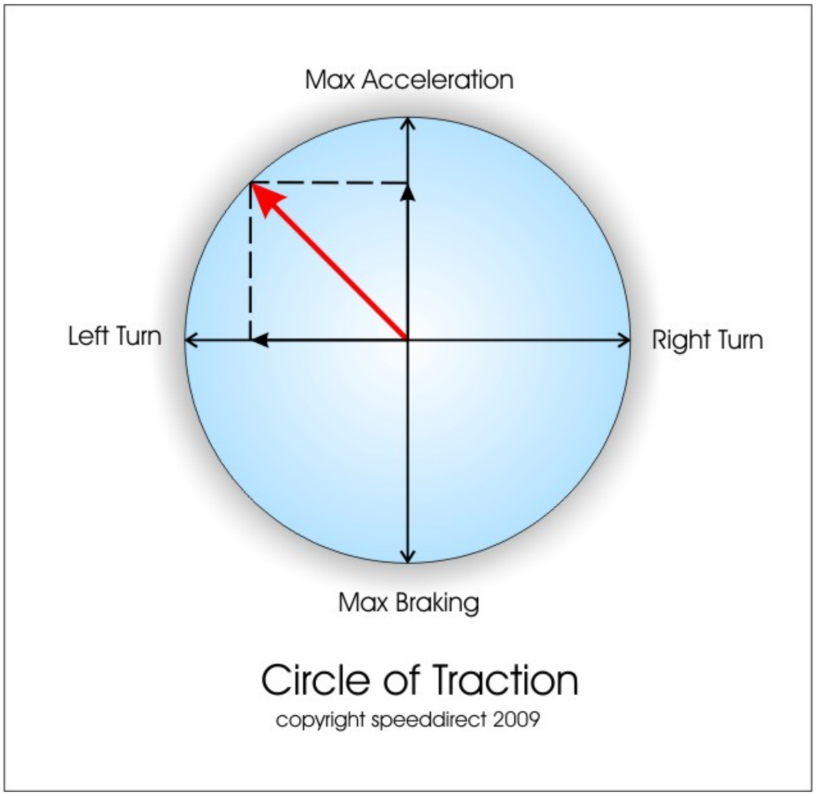
*Street tires. R compound and slicks require significant negative camber. Follow the tire manufacturers recommended alignment settings.

Cornering Concepts: Circle of Traction

The Circle of Traction is a concept which chassis engineers use to determine how the available traction of the tires is being used. This is because there is only so much traction any given set of tires is capable of producing and it is distributed between cornering, braking and acceleration. Using this concept it is possible to determine how much traction is left for cornering once the forces of braking or acceleration are accounted for.

What Does it Mean?

The figure below shows a Circle of Traction. Where the tire actually touches the road / track is called the contact patch. It is the total available area for traction and varies with the tire size and suspension geometry. From the drawing the arrow in red represents a car accelerating in a left turn. It is the sum of the turning force and the acceleration force. The position of the arrow varies as the car negotiates a section of roadway or race track but one thing is constant; the available traction which remains invariable ignoring special conditions like down force from aerodynamic devices.



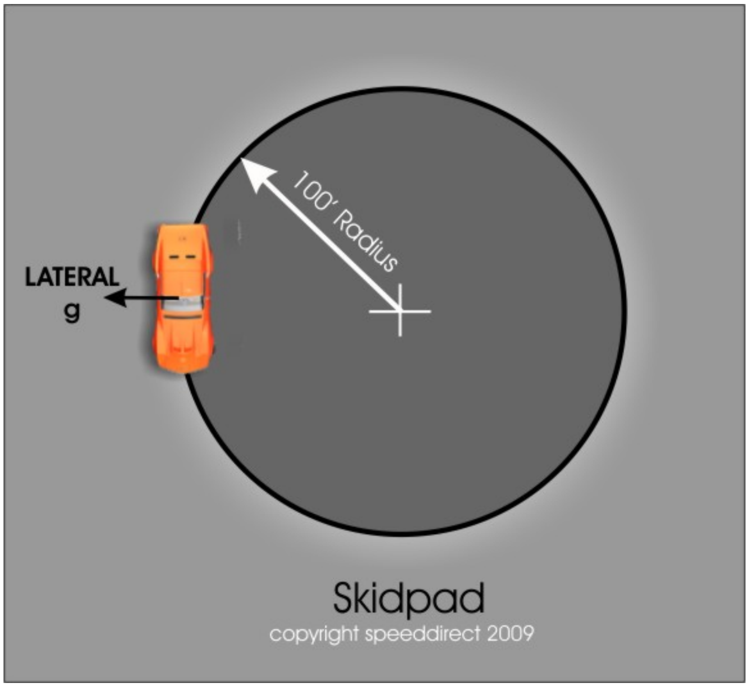
An example of this is a car is equally balanced and each tire has 750 lbs of load on them and the cornering efficiency is 100%. There is up to 750 lbs of traction per tire in which ever direction the driver turns or accelerates or brakes. Combine the maneuvers and there is less traction in other directions as shown by the dashed lines in the figure. The combined forces are subtractive. In the extreme case of either spinning the rear tires in acceleration or locking the brakes in hard braking there is no traction left for turning left or right. The car will either slide or the rear end will sway back and forth since there is no traction remaining to counter side forces.

g Forces During Cornering

A car is subject to acceleration. If it is parked and at rest the force acting on its mass is the force of gravity through the vehicles center of gravity and the center of the earth with the car being attracted to the earth and the tires “pushing” on the earth and the earth “pushing” back with the same force. This is commonly called 1 g of acceleration, normal (90 degrees) to the earth’s surface. It is said that the car “weighs” 2000 lbs for example due to the g force (gravity) acting on the car. When the same car is in motion and turning a lateral acceleration force is developed. The force of gravity is still acting on the car but now the second cornering force becomes important and it is referenced to the earth’s acceleration for convenience so we call it g or lateral g stated in a fraction of or multiple g as in “My car is capable of .9g.”, meaning the lateral or side force when cornering is approaching 1 g of normal earth acceleration (gravity). This allows comparisons to be made as modifications are done to improve cornering lateral force.

To Skid or Not to Skid?

The common method of determining lateral g force is to use a "skidpad". This is a circle marked on a section of pavement of a known radius. The car is driven around the circle as fast a possible and timed to determine how much force is being developed. It is a very common test for both street cars and race cars and manufacturers usually publish the numbers as a reference to how well their design performed. It is a significant factor in how well a car will corner. The higher the g number the better the car is at cornering.



The most basic way of arriving at this number if you don't have a g computer is to hand calculate the number. The formula is as follows:

Where:

R = Radius of the skidpad in feet.

T = The time in seconds required to turn 360 degrees.

g = Lateral acceleration expressed in earth normal acceleration (g).

Formula:

$$g = \frac{1.225 \times R}{T^2}$$

Let's look at an example:

You time your car as you make one 360 degree lap around the skidpad as fast as possible and it takes 13 sec. The skidpad has a 100 foot radius.

Sample:

$$g = \frac{1.225 \times 100}{13 \times 13}$$

$$g = \frac{122.5}{169}$$

$$g = .72$$

This g is equal to 72% of the normal earth gravity pushing laterally, sideways. As you make modifications to the car you repeat the process which gives you the ability to see by measurement what improvement has been achieved.

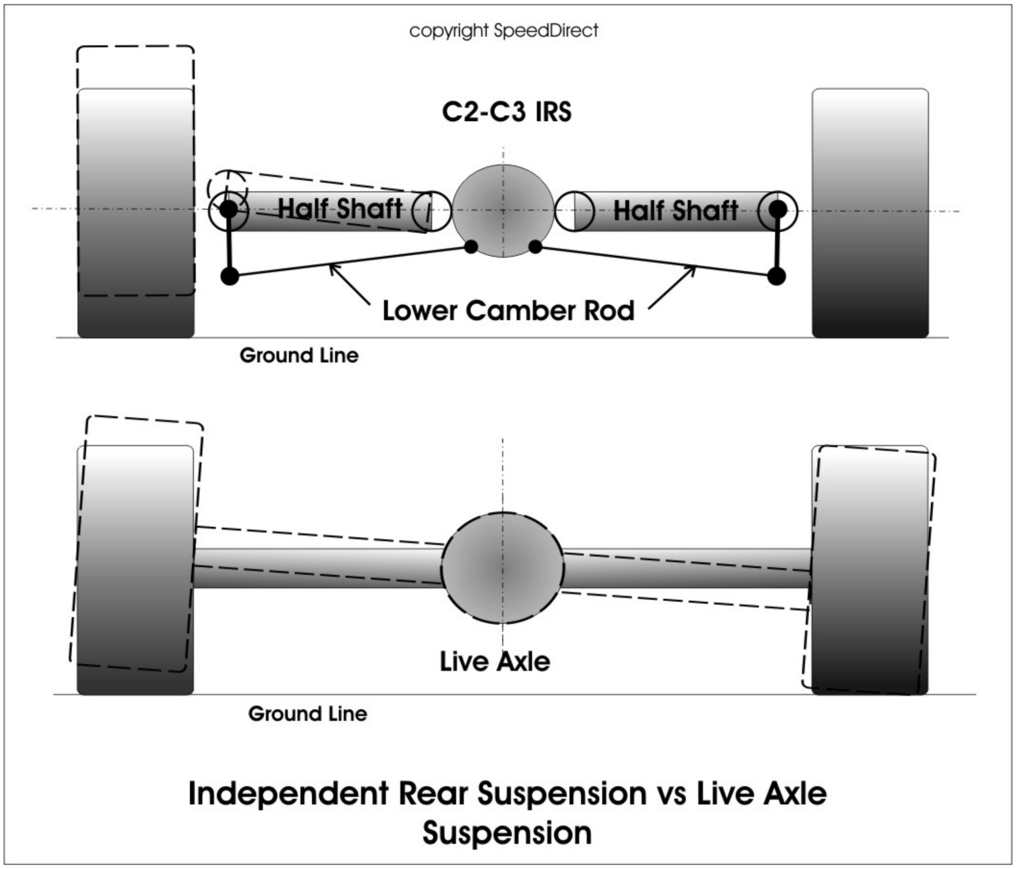
Improve Your g!

It is possible to improve the g your car is capable of developing. As mentioned earlier, contact patch of the tire is a key element. To keep the patch maximized SpeedDirect offers a number of solutions from individual parts like upper control arms which greatly improve the suspension geometry or complete handling packages or stage kits which include a tuned assemblage of sway bars, shocks and spring rates to vastly improve traction and lateral grip over a stock suspension.

Improving C2-C3 Independent Rear Suspension (IRS): 1963-1982

When the 1963 Corvette Stingray hit the market it not only was radical looking but it employed an independent rear suspension (IRS) which for its time was a huge leap in technology for any American production car. As with any technology there are advantages and disadvantages. We will look at the Corvette C2-C3 IRS and examine its weaknesses, strengths and what can be done to improve handling.

The biggest advantage the first Corvette IRS has is its ability to keep the rear tires in better contact with the road / track. This fact significantly improved the cars ability to corner as well as give a better ride than is possible with a live rear axle car like the C1 it replaced. The independence of wheel motion and straight tracking as it moves up and down in response to bumps allows it to adapt to irregular surfaces.



Along with this great ability to follow the surface better there are some deficiencies associated with the basic design of the system. All IRS systems are not alike and Corvette has some unique features which can cause head aches for some one wanting good cornering performance in all conditions.

Rear Camber

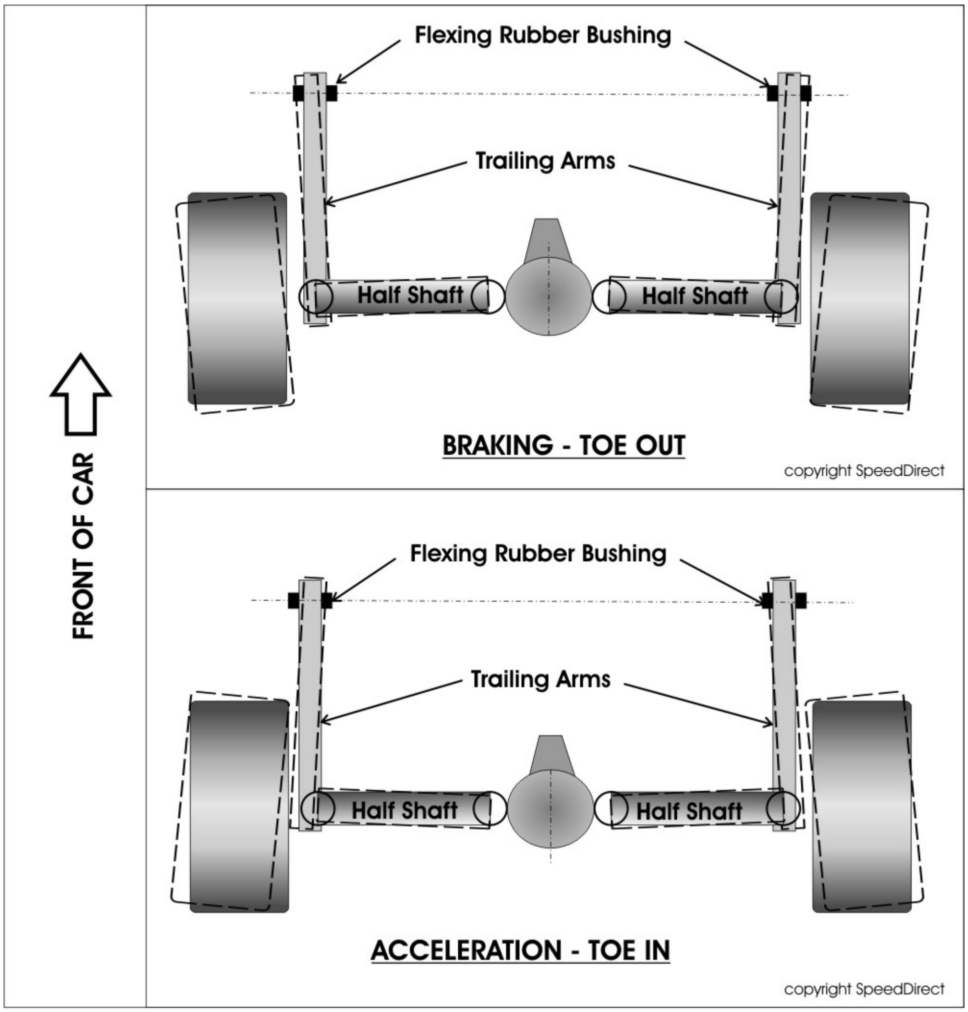
One disadvantage of this system is how rear camber is controlled. The diagram above shows two lower links called the lower camber rods. These rods are to establish the camber angle of each rear wheel. They have squishy rubber bushings at each end which flex as the car is cornered. The affect is to change length which results in the rear wheels changing the camber angle to more positive as it is hard cornered; this is not desirable. It tends to lift the contact patch of the tires and reduce traction when it is most needed. An affective solution is to replace the factory bushings with urethane bushings. One other method is to eliminate the bushings all together and use a hemispherical rod end linkage making the connection rigid thereby getting rid of camber changes. There is an additional benefit to this fix in that you can then adjust rear camber, something the factory camber rods do not allow you to do.

Another impact can arise if there is wear in the gear train inside the differential. This allows a similar problem to occur causing camber changes.

This is because the C2-3's use the half shafts as a kind of upper a-arm. It is fine when things are new and tight but if you introduce wear it will impact camber in a bad way.

Controlling Rear Toe

Toe in or out of the IRS happens during acceleration and breaking. Once again rubber bushings are the culprit. The C2-3 years of Corvettes use a single rubber bushing trailing arm on each side of the car.



C2-C3 IRS Torque Steer (Top View)

The net result is unpredictable handling caused by the constantly changing torque steering inputs during braking and accelerating. This is a result of the toe in or toe out changes as the car brakes or accelerates hard. (see figure) One solution to minimize torque steering is to install urethane bushings instead of soft factory rubber bushings. This will minimize, but not eliminate torque steer.

Conclusion

By changing a few bushings and a little effort the C2 - C3 Corvette IRS can be improved significantly over stock. You will notice the difference in a more stable turn entry and exit, and more predictable handling all around.

Are all Rack & Pinion Kits Alike?

We take this question seriously as we believe you do. Looking for the right kit can be confusing. A kit which is complete, well designed, from a company that backs up their product with a solid warranty and real technical support. This is especially true if manufactures make bold unsubstantiated claims. We will look at what should be considered before you spend your hard earned money for a kit.

Is This Kit Really Bolt On?

What does that mean anyway? We pioneered bolt on rack and pinion kits over twelve years ago, so an average person could get under the car and bolt it on without fooling around. On our first design, which was for the Gen 1 Camaro, our design goals in engineering our rack and pinion kit were simple:

1) The kit must be able to be installed by someone with beginner to average mechanical skills.

2) No hacking up, sawing, welding on a classic car frame or components.

3) All the parts included in the kit to do a complete install on a car which had power steering.

The reasons for this were simple, we wanted people to buy our kit and install it themselves. We also believed that like us, most people did not want to start sawing away frame and suspension members on a frame that was vintage and valuable. Finally, we had enough bad experiences with “all inclusive” kits that had you scrambling to the part store to buy what the manufacturer should have provided, or worse you buy a shell of a product which needs a host of little assembly kits (which they are happy to provide) that add cost which the manufacture hid while trying to sell people on the lowest price. We call it dishonesty; some call it a “marketing strategy”.

To Bump Steer or Not to Bump Steer.

Here is a question you will see bantered around all of the time on forums by people who frankly don’t know bump steer from bum steer. At SpeedDirect we are suspension engineers, and as a famous person once said, “words mean things”. Bump steering is a nasty little habit that many cars have right from the factory, and it doesn’t get better as you lower your car or do other mods to the suspension. It can be a real thrill when you hit a bump in a car with poor bump steer response while right at the limit of traction in a hot corner! We understand it, we engineer our kits so you can adjust it and it is a major differentiator between a Steeroids and our competitors. (Even those that stole our design but offer non-adjustable tie rod ends!) If the kit is not adjustable for bump steer it is not a complete kit. There is no such thing as a kit designed that “accommodates bump steer” with out a way of adjusting it. If a company claims their kit does they are either not being truthful or maybe worse they are ignorant.

If you are shopping for the right kit, the one that is easy to install, designed to fit, adjustable for bump steer and is supported by knowledgeable technical staff to help if needed, then consider a Steeroids. Thousands of classic owners have. We challenge any shopper to see what owners have said on the many forums where our product is discussed.

Steering Response

Turns Lock to Lock vs. Overall Steering Ratio

This can be potentially confusing since some prefer to express steering response as an overall steering ratio, which would typically be around 16:1 on a car with traditionally “quick” steering. This ratio is calculated by measuring how many degrees of wheel movement results from one turn of the steering wheel. In the example above on full steering wheel turn (360 degrees) and with an overall steering ratio of 16:1 will yield 22.5 degrees of wheel rotation about the spindle since 360 degrees (in one rotation) divided by 22.5 degrees of measured travel=16, or a 16:1 ratio .

What do we mean when we say turns “lock to lock”? Lock being the hard stop where the steering wheel will not turn when rotated in each direction. We prefer using the lock to lock number because it is a lot easier for you to hop in your car, count the turns of the wheel when rotated all the way from one lock to the opposite lock, than to put your cars front tire on a degree table and measure angular rotation of the tire and wheel about the spindle with one turn of the steering wheel.

An example of how simple this is can be illustrated by using our development car, a 1964 Mustang. The factory stock car without power steering was five+ turns of the steering wheel lock to lock! A handful when trying to maneuver quickly. With our Steeroids power rack and pinion kit installed and no changes to the stock steering arms the driver now makes 2.5 turns lock to lock. This increases the response of the vehicle significantly, yet not to the point of being “twitchy” and subject to over control.

NOTE: *It is important know that power steering boost has nothing to do with the overall steering ratio. It affects other areas of steering feel as we shall see.*

Steering Feel

This is a subjective area of discussion in talking about handling, but a very important topic. Modern vehicles have significantly better “feel” than those manufactured in the ‘60’s through the ‘80’s. It is not about wear either, it’s about design. If you just look at the number of parts in the linkage between the steering wheel in your hand and the front wheels there is a major difference in opportunity for slop, friction and flex between a modern rack and pinion design and an old steering box design.

On a steering box design the path to the wheels starts with the box itself which has internal gear lash (play). Next the pitman arm with a joint linking it to a center link (track rod) which as two joints for each inner tire rod. In addition to this the center link has a pivot point called an idler arm for stabilizing the end, and finally the tie rod end. Altogether seven separate connections until you are actually turning the wheel, not including the gear lash in the steering box and the clearance for the re-circulating ball bearings inside the box.

Contrast this to a rack and pinion which has gear lash as well, but no re-circulating ball bearings, and has only two joints for the tie rod ends, and two inner tie rod joints. You can see how even in a new setup there are three more points to add play, and friction, and flexing to the feel. This linkage path is integral to another element that is inherent to both designs; on center feel.

On Center Feel

This is the most noticeable difference between steering box steering and rack & pinion steering. It can be best described by the response you receive while cruising with the wheel “on center”. The vehicle moves when you steer without lag or play. Even a new steering box with new steering parts will have lag. That is because of the extra joints for motion in the system as described in the Steering Feel Section. In addition to this it is very difficult to “back drive” a worm and segment gear found in a steering box. Back drive is when the front tires try to drive the steering wheel back to the center position. The incline of the worm gear (a spiral shaped gear) introduces a lot of friction that must be overcome by the natural tendency of the steering geometry to self center. The result is a vague and drifty with no center feel.

Rack and pinions have a different design with a horizontal “rack” of gear teeth that are meshed with a pinion gear. This is a much easier physical arrangement to back drive since there is no steep incline to drive against. *It is also directly driving the steering with the tie rods with no additional linkage to flex.* These facts plus only four steering joints to add friction make the steering try to center itself. This gives the driver a solid, crisp on center feel that is ready to accept steering wheel inputs.

Corvette Owners With Factory Power Steering: *In addition to these facts your Vette has a power steering servo valve at the end of the pitman arm. This is not like most steering box equipped cars which have the power boost built into the box. On the Corvette the pitman arm has a joint that moves as you turn the wheel. The force of turning the wheel causes a force sensor to activate the hydraulic ram in the direction you steer, and applies power boost to the to the steering. Every control system has “dead band”, an* *area where no control boost is applied. Some dead band is necessary, but this dead band outside the box when added to the natural poor back drive of a steering box makes the on center position vague with a lot of steering wheel “sawing” to keep the car pointed straight. This only gets worse with age as the joints wear.*

Steering Feedback

All of the previous discussion about feel and on center feel is the basis to understand steering feedback. From the basic design limitations of a steering box it is easy to explain why a car with this system has very imprecise feedback to the driver. All the force necessary for you to feel what the car is doing is absorbed in rotary joints and linkage needed to make the system work. If you add wear on those joints you have a steering system that is ambiguous to drive, it is not “telling” you what you really need to know. This is especially true if you are cornering hard up to the limit of available traction. The last thing you want when the tires are howling is to have no clue what the front end is doing.

Feedback is also affected by the amount of boost your power steering has, if so equipped. This is why a few drivers prefer manual steering over power, but that does not need to be the case. A properly designed power steering system is just as good if not better that a manual system. For one thing fatigue is a factor. That is why most race cars have power assisted steering. Make sure you consider the amount of boost you will get if you are converting. There are ways to limit this with certain pumps. It is well worth the effort to have a car that handles well at speed and that you can easily maneuver to park with the added friction of wide tires, so don’t dismiss the power steering option.

It’s Time to Update!

You now know that a steering box has serious technical limitations that can not be corrected by just a steering system rebuild. Even when your car was new the steering box did not provide either the proper steering ratio, feel, on center feel, or feedback that have become the hallmark of a modern steering system. We now take for granted how a modern car should feel. Driving a classic convinces us that something has drastically changed in steering technology since the car was designed, and its time to update.

Rebuilding is time consuming and expensive and the result is the same old technology “refreshed”. Here are some of the benefits of a rack and pinion conversion to consider:

- Truly a modification that is really gratifying; you can easily feel the results.
- Vastly improved handling that technically is not possible with outdated steering boxes.
- Tames the beast - makes the car more drivable and fun to be in.

- Modernization of your classics steering to take advantage of a superior and newer technology.
- Improves your competitive advantage if you road race or auto-cross.
- A rack and pinion conversion is easy to install, and will not eliminate the ability to return the car to factory stock steering if necessary. No drilling, welding, cutting whatsoever.
- Enhances the vehicles resale value.

Power Steering Basics

All of us have driven cars with power steering and never really understood what makes in all work. You usually know when it doesn't work, it's all too obvious, but what about when it sort of works. If you have added power steering to a car that formerly did not have it you may have uncovered a number of challenges to get it to "feel" right. Since SpeedDirect is big on after market steering conversions we are going to look at the basics of a power rack and pinion system and hopefully get a feel for its proper operation.

The powered version of a rack and pinion has several basic components that a manual system does not have as shown in the drawing below. The key elements are as follows:

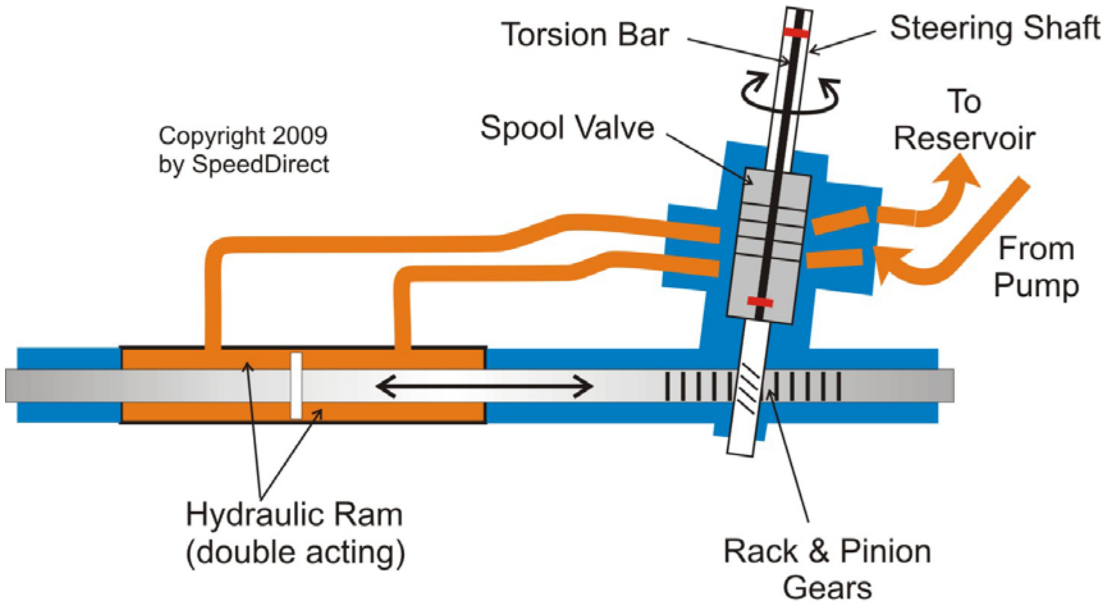
A Hydraulic Ram which is "double acting" meaning it is powered in both directions.

Spool Valve to control when and how hard the ram pushes.

Torsion Bar to create the desired power boost response.

A hydraulic pump.

A Reservoir for hydraulic fluid.



Power Rack & Pinion Unit

How it All Works Together

The components interact like this: When you turn the steering wheel you are actually twisting the steering shaft. The steering shaft that connects to the rack & pinion unit is in two pieces inside the rack unit which are connected by a torsion bar nested inside the hollow steering shaft. The bar twists before the rack and pinion gears on the bottom start to turn, as it does this it opens passages in the spool valve allowing pressurized power steering fluid from the pump to enter only one side of the hydraulic ram chamber; the rack moves, assisted by the ram in the direction you are turning. As it does this is displaces the fluid in the other chamber opposite the direction you are turning and allows that fluid to escape with very little pressure through a second set of passages in the spool valve that are synchronized with the passages that opened on the pump side. These passages connect to the return line and lead back to the power steering reservoir.

You will notice that since both sides of the ram and lines are filled with fluid. This allows the ram to move quickly either direction you decide to steer. Since this takes a volume of fluid to move the rack; pumps are designed to move volume with pressure being secondary. Pressure does come into affect as we will see a little later, but is clearly volume what is at work.

The torsion bar is there to give some “feel” to the system, it acts to delay response of the ram otherwise you would have over assisted steering that would feel “twitchy” every time you barely moved the steering wheel.

Speaking of Twitchy

The over boosted feeling can happen when you adapt a system using a pump from say a steering box system. It has a different base line pressure; the base line pressure is a minimum pressure where steering response of the torsion bar / spool valve combination starts to assist. Passenger car steering systems range from approximately 30 - 200 psi base line pressure depending on if it is a steering box or rack & pinion pump / valve combination. If you have an over sensitive, twitchy feel here is what you can do to determine one possible solution.

With the car running, brake set, tires clear of curbs or obstructions and the engine at its normal idle with the steering wheel centered, turn the wheel to the stop one way.

You should notice some feel or resistance just as you begin to turn.

As you continue to turn you should feel progressively increasing resistance until you hit the stop.

If this is not the case you may have too high of a baseline pressure. SpeedDirect offers a kit for GM pumps that will allow adjustment of the bypass pressure.

A Little is Good A Lot is Better

Don’t be tempted to lower the pressure as low as you can. The system needs a certain pressure to move the volume of fluid; it is required by how fast you turn the wheel. If the pressure is too low you will start to feel it “catch” or briefly stick until the fluid builds in the ram. Don’t expect a pressure reduction of the by pass regulator in the pump to change the response of the overall rack feel, that is the torsion bars job. But if the base line pressure is too high the kit will affectively lower that pressure and allow the torsion bar to do its job properly.

SHOCKS: Single vs. Double Adjustable Shocks

Shock absorbers, like every other component of a modern suspension system can drastically affect the way the car handles. It is easy to overlook some of the options that can enhance the way our car corners and greatly improve drivability if we make the right choices. Let’s take a look at what a shock does, and what can be done to make a difference.

A shock is a hydraulic damper; as a matter of fact our friends in England and elsewhere call them dampers. I’m sure some ad guy came up with the name “shock absorber” to make the point clear to non-technical customers and so in the U.S. we use that term. A damper is used in a mechanical system to absorb the energy when a sudden displacement is input into a spring element. It damps, resists, the sudden movement. If you have ever played with a slinky you have seen un-damped motion as the slinky bounces up and down; our cars suspension is no different. I remember vividly a high school friend who had a ‘50s Packard which had rear coil springs. He took the shocks off the back (why he did that, I don’t know but he did). The result was that when the car came to a quick stop at a traffic light the rear of the car would bob up and down wildly for thirty seconds or more until the energy was absorbed. Just like the slinky it was a classic example of an un-damped spring in motion.

A shock has a method of handling energy during and after compression and release of a spring. Inside the shock is a piston moving within an oil filled tube as the car suspension moves. As the piston travels with the cars suspension either up or down in the tube the oil is displaced by the piston and flows through a small hole (orifice) in the piston. In the process of traveling down the tube it resists movement as a function of how big the orifice is. A big orifice equals lower damping, while a small orifice equals more damping. The shocks which come on our cars have a fixed orifice which the factory chassis engineer sized for an “average” driver in average driving conditions. I’m not sure I have ever met an average driver who owned a performance car.

Once we decide that average is not for us we must make some changes. Usually we go for an increased spring rate to limit body roll, since average drivers don’t hot corner and we do. Higher spring rate means our factory “tuned” suspension hits a sour note. Not enough damping for the new higher spring rate. This result is that our car no longer feelings right, it rolls out of a corner much quicker since the springs rebound faster and put more force than stock springs do to push the body back upright. The result is a kind of oingo boingo oscillation that can upset the car and require us have to make a lot of corrections to keep it going in the intended direction.

A solution is to add more damping by switching to a shock which is stiffer, more resistive, giving more damping. This is great for when the spring is being compressed, but what about the rebound? Depending on which side of the car we are discussing one side the spring is compressing, the other it is extending.

Single adjustable shocks are a type of shock in which the amount of damping can be set - adjusted - for rebound & compression damping all at once. This is a great way to address the problem of compression and rebound with the flexibility of it being adjustable. The shock body has a knob on it with a series of adjusting points from low to high damping. We can customize our setting to fit the additional amount of spring rate we chose giving us a much better response, and a stable feel.

Double adjustable shocks are the next step where both compression and rebound damping can be separately set for each shock. These types of shocks have two knobs, one for compression, and one rebound which can be independently set. This is a great way to tweak exactly how much damping we need in both directions. When fitted on all four wheels we can now truly set up the car for forward and rearward bias and damping in both directions. This is what race cars are all about; being able to set up the car for conditions and driver preference. Once we select double adjustable shocks we have moved into an area of performance not possible with just stiffer shocks, or for that matter just single adjustable shocks.

The huge benefit to either single or double adjustable shocks is that you can drive them all week set up for the street, go to a driving event, either autocross, track day, drag race, land speed record, what ever, and crank up the damping for the conditions. It can be different front to back, side to side or all four wheels different. We take our "average" ride and turn into our customized ride specific for what ever we are doing that day, and isn't that what performance cars & driving them is all about?

Lowering by Cutting a Coil Spring

Lowering a car will result in lowering the center of gravity lessening roll and generally improving handling. There is a very inexpensive way of doing this and it involves cutting the coil springs on your cars suspension.

Many gasp in horror at the thought of cutting a coil spring. The reasoning goes something like this, "You use heat, that will ruin the temper and the spring will collapse." Another angle, "The spring will not properly fit the pocket, and you won't get full travel. These are misconceptions about what is being done from people who have never done it. Let's examine the facts and look at the reasons and the proper way to do this modification.

My older brother was a not so elegant hot rodder who lowered his cars for appearance sake by "torching" the springs. He would run a cutting torch along one of the vertical set of coils of a coil spring while it was on the car, with weight on the wheels until the poor spring mostly collapsed. The result was a "slambed" ride with about an inch of suspension travel; not recommended. What he was doing was heating the spring steel until it became plastic, about 1800 deg F (orange yellow) while it was loaded. The weigh of the vehicle made it sag. The spring colapse and "springiness" on the heated side transferring the load to the half not heated.

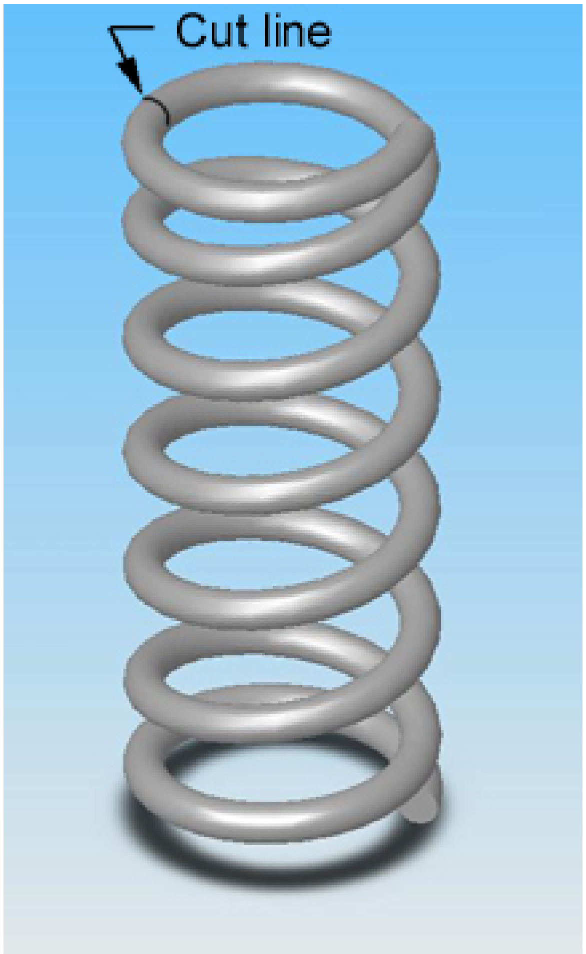
Addressing the first issue of cutting the spring; namely temper, will not be affected for the portion of the coils left after cutting. That is because the uncut coils do not get hot enough to loose their set or temper if done correctly, and that is very easy to control. Springs are trimmed while unloaded and off of the car, using an oxy-acetylene cutting torch.

The second myth is that they will not fit the pocket and / or get full travel. Most stock springs can be trimmed a half coil to lower the car just enough for to improve handling. The spring must be LOCALLY heated a half coil below the cut so it can be bent to match the spring pocket.

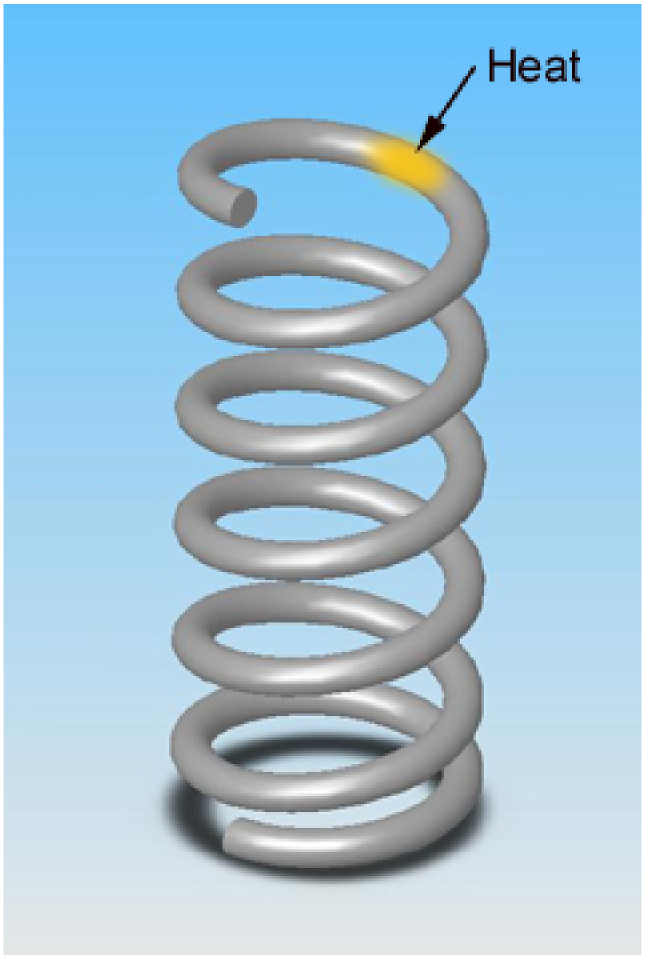
Let's look at each step and address the proper method to achieve a professional result.

CAUTION: Carefully remove the coil spring from the vehicle. Springs are under load, even when the car is jacked up. Carelessly releasing that load can result in serious injury. Many shop manuals give you the step by step method to easily and safely remove the spring; follow the guidance! Study what is recommended for your car, and follow their directions. You may need a spring compressor to safely do this which is available from most tool rental shops.

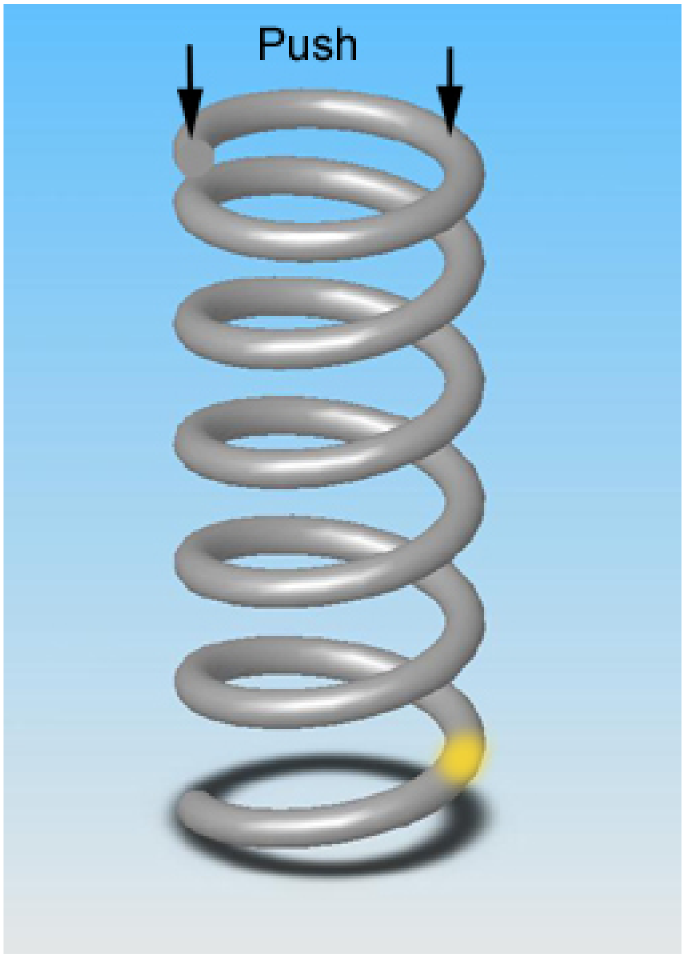
Mark the spring one half coil directly across from the original end.



Cut the spring with an oxy acetylene torch on the mark.



Now locally heat the spring as shown, one half coil beyond where you just cut.



Quickly flip the spring and push the newly cut end against the shop floor to set the end so it will fit the pocket. Keep it vertical so the end forms flat for the pocket. **DO NOT quench the spring in water**, rather let it air cool slowly.

Give the spring a coat of paint and re-install per the shop manual taking care that you will once again be “loading” the spring with tension. CAUTION: *Following the shop manuals instruction and using the proper tools is essential to safely installing the cut spring.* You should re-align the front end since the lower ride height will affect alignment.

Once completed you will have a lower stance, lower center of gravity and improved cornering ability all at little or no cost.

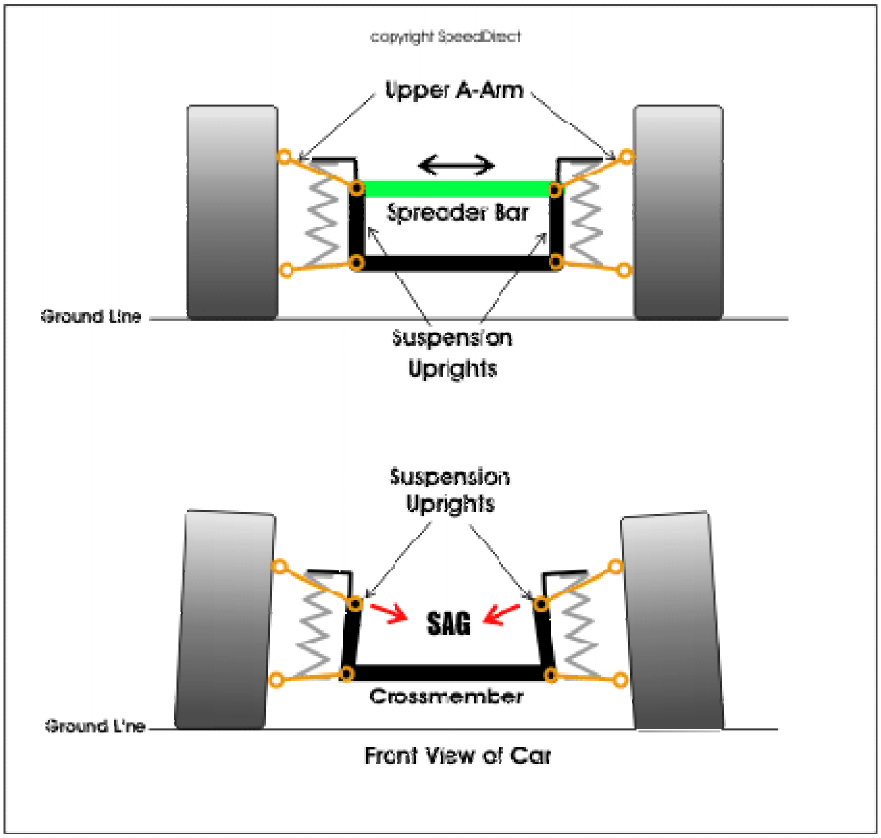
Spreader Bars: What do they do?

You read a lot of discussion on the forums about spreader bars and it would sure be nice to know what they do for our cars and why we need them. This post should take some of fog away from whats and whys of installing a spreader bar.

First let's see why we should even need such a device. Our cars are designed and built to a cost target. Usually there is nothing on the frame and suspension that was not absolutely required to deliver them to the customer. This is a generalization but for the most part it is true. Many of the old body on frame cars like Corvettes and Muscle cars were very light with big engines squeezed in to narrow frame rails or sub-frames. In this case the car usually suffers from a very flexible suspension mounting arrangement. It wasn't that the factory didn't care, its more a case of it suited the need and did not need to be anymore robust; or so they thought.

As these cars age the constant forces of driving, cornering and the shock of many thousands of road miles take their toll and they sag where they shouldn't. Another aspect is that many of these cars are now driven in ways that were not considered in the original design requirements. Performance Driving Events (PDE) like Autocross or track day events were not on the engineer's check list of forces to design around. Consequently they need a little help to bring things all back in alignment so they will predictably handle as we expect.

What happens to the front end suspension can be illustrated on the Corvette C2-C3 front cross member, which is notorious for the flimsy vertical attachment on the cross member where the upper a-arm bolts on. This weak point allows the upright to settle and flex inward, adversely changing the suspension geometry. (See figure) In addition the front cross member lower control arm attachment point is a focal point for fatigue and cracking of the mount.



A spreader bar will push; spread, the sagging upright mounts back to their proper upright position. The front suspension will then be back to where it was designed to be positioned, and will resist flexing associated with cornering. By “boxing” the front end with an additional member (the spreader bar) overall stiffness is greatly increased. The car will hold its intended alignment and camber closer to what it needs to be to corner and handle consistently.

If you are a performance driver and you like to know that your suspension is properly located and braced you should consider a spreader bar kit. They are usually easy to install and result in a car that is rock solid with correct suspension alignment on the road or track.

Springs: The Basics

When setting up your car for better handling springs and shocks are a natural choice to quickly improve the ability to corner harder, with less lean and sway. Here are a few basic definitions and some examples to help you understand the components and make choices.

Springs: Springs are for the most part linear mechanical devices (although there are non-linear springs like variable rate springs that we will not cover here).

Linear springs: For every increment of compression or extension from the resting length, a predictable force is produced. They are manufactured in a variety of form factors like coil, leaf, mono-leaf, torsion etc.

Spring Types: Two principal types of spring are used in most cars, they are leaf and coil. The leaf spring acts like a simply supported beam in loading while a coil spring is mostly torsional loading.

Spring rate: The amount of force exerted by a spring as it is compressed, extended or rotated depending on the type.

EXAMPLE: A coil spring with a spring rate of 200 inch/pounds will exert 200 lbs of force for the first inch it is compressed, 400 lbs of force if compressed two inches, 600 lbs of force if compressed three inches and so on until the spring coils are touching (fully compressed).

> **IMPORTANT CONCEPT:** This spring force is irrespective of how fast the spring is compressed. The spring force is *independent* of time.

Coil vs Leaf: The purpose of an independent suspension is independence of motion for road / track conditions. When a spring element ties the two sides together you loose some of that independence. There is some coupling side to side in transverse mounted springs so when you introduce body roll, as in cornering, both ends are loaded but the wheel on the outside of the corner tends to load more than it should because of the couple to the body / frame rolling moment. The same is true on the inside wheel only that wheel experiences unloading due to the same coupling. Now consider an independent coil spring which has no such body / frame coupling. It will still be loaded on the outside and unloaded on the inside, but *there is no added body roll coupling through the mount since the spring does not have a frame mount point.* This is true of both front and rear leaf springs.

The same event occurs when you hit a bump. There is coupling where there should not be coupling and it impacts handling. It’s as though you have a solid axel with one wheel affecting the other negatively.

> **NOTE:** *Mono-leaf springs are just another type of leaf spring with an important difference; damping. A multi-leaf spring*

> *is made of a stack of leaf elements which move against each other when loaded. The friction of their movement helps to damp the spring. A mono-leaf has no such damping so the spring tends to be more "bouncy" requiring more shock damping that the multi-leaf spring of the same rate and size. They still have the inherent body / frame coupling disadvantage of leaf springs.*

A coil spring allows truly independent action of the suspension. In addition to this the spring rate can be adjusted separately to balance the car. This is one of the big reasons that the coil over spring and shock combination is so good. It gives the ability to easily and quickly adjust the height and load of a given wheel independent of other wheels.

Coil springs allow for true independence of action for both cornering and bumps.

Shock Absorber: A mechanical device to damp, or slow motion. It does this by absorbing energy which it converts into heat in the case of a hydraulic shock absorber found in a car.

> **IMPORTANT CONCEPT:** A shock absorber in combination with a spring affects how *quickly* a spring will compress and rebound. Shock absorbers have a damping rate that is *dependent* on time.

CHANGING THE DAMPING RATE (LIKE STIFFER SHOCKS) WILL *NOT* AFFECT THE SPRING RATE.

It is very important to understand that the shock rates of a given spring are set to work with the spring rates and the weight of the car. The dampening (shock) rates are then tuned, or adjusted, to a somewhat subjective compromise between sport and casual driving for the given spring rate. This means that a major change in spring rates REQUIRES a change in the shock valving. This is the principal advantage of adjustable shocks.

EXAMPLE: *Different springs will give you a stiffer or softer suspension, but shock adjustment can affect that ride. If you go cruising into a long corner, the stiffer your springs are, the less body roll (leaning) you will get. The softer the springs are, the more body roll you will get. The valving of the shocks will determine how fast you get to that maximum roll point.*

Next Steps: Now that you know some fundamental concepts it's time to select the products to improve the handling of your car. The

Shark Bite™ front and rear coil over kits for Corvettes are an ideal way to achieve both a higher spring rate, better shock damping, and true independent suspension. The kits offer the following advantages:

- Shark Bite™ Coil Over Suspensions offers truly independent suspension - no communication from left to right from the leaf spring.
- Shark Bite™ kits offer adjustable ride height in minutes while on the vehicle.
- Variety of spring rates available.
- With Shark Bite™ kits you can change your springs on the rear in less than 20 minutes - easy access and quick release pins allow for instant spring changes for on the road or on the track.
- Lighter weight - Shark Bite™ rear kit weigh less than the factory leaf spring.
- Shark Bite™ kits are a Bolt-On installation -absolutely no welding, cutting or drilling. Installs with basic hand tools in approximately 3 hours.
- Shark Bite™ kits offer adjustable shock valving so you can tune the ride to exactly the way you like it.
- Works with factory exhaust and with factory spare tire.
- Highly visible - great presentation!

Transverse Leaf vs. Coil Springs

There are many factors which affect a suspension system, and one of the most important is the type, attachment & location of whichever spring is selected. Most modern passenger cars and performance car suspensions use coil springs, with Corvette being the exception which we will discuss later. Let’s look at some of the considerations for retrofitting our suspensions.

Spring Rate

Every spring is rated by its ability to resist force. This is measured in pounds of force per inch or usually annotated as LB/IN preceded by a number like: 450 LB/IN. We are discussing linear springs which produce a constant change in force as the spring is deflected (for a leaf spring) or compressed for a coil spring. In the example of 450 LB/IN the spring force increases as it is deflected or compressed so: 1 inch of compression will produce 450 LB, 2 inches = 900 LB, 3 inches = 1350 LB and so on until the spring reaches its solid height, the point where a coil spring is squished so all the coils touch.

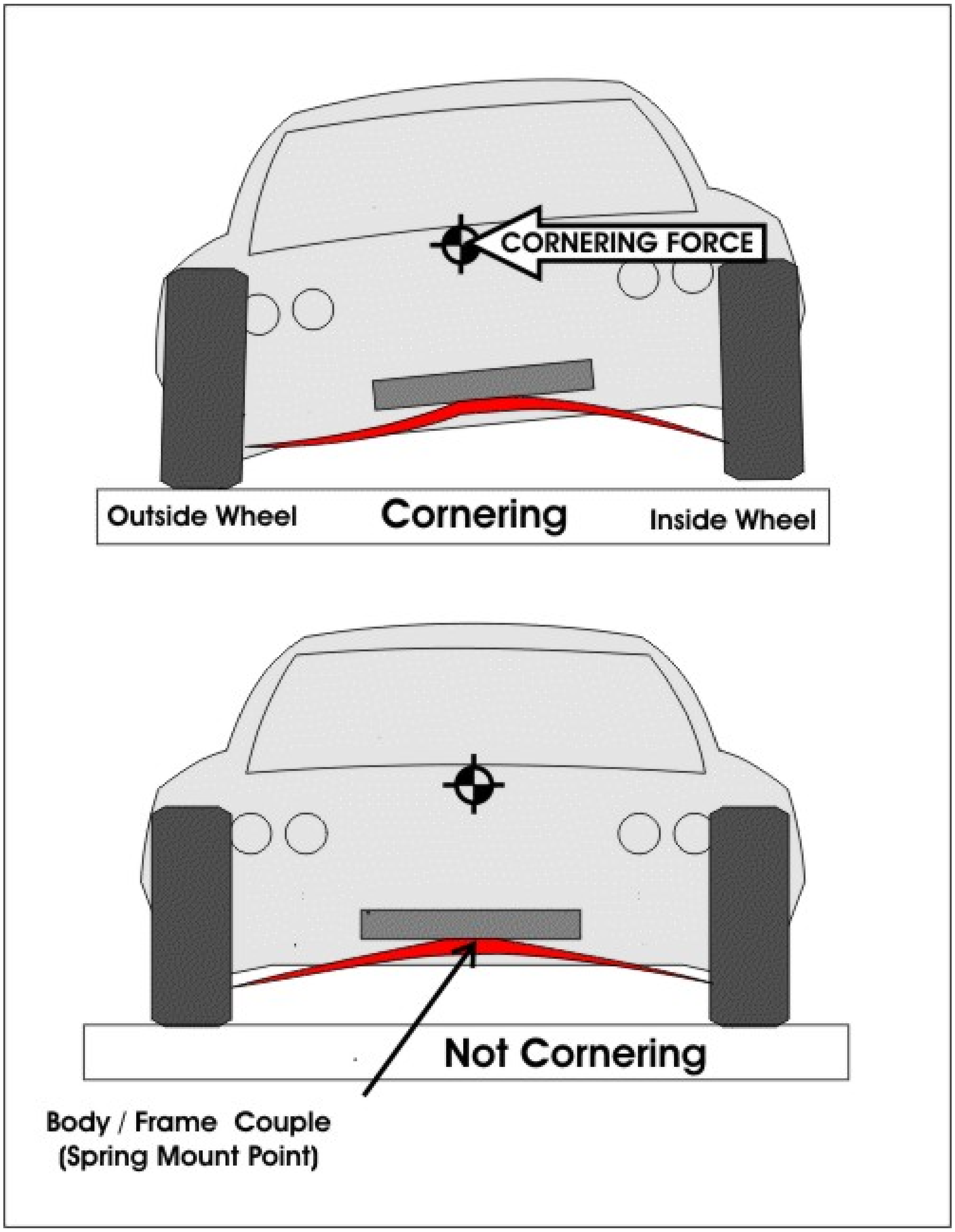
Spring Rate is important because it is the quickest way to reduce body roll, or the tendency for our car to lean as it corners. Increasing the spring rate has its advantages and disadvantages. Stiffer (higher rate) springs resist body roll but they also make the ride a lot more firm up to the point that it is uncomfortable to ride in or drive the car.

Leaf or Coil, Which is Best?

Here is a question that has several facets. Leaf springs, specifically transverse leaf springs like in C2-C3 (rear only) and C6 (front & rear) Corvettes can act as anti-sway bars if properly designed, thereby eliminating a component and its weight. This is a difficult problem because of all the geometry it takes to make this work perfectly in all conditions is close to impossible. It is interesting to note that even though the current version of the Corvette uses front and rear mono-leaf transverse springs they still have anti-sway bars, so the chassis engineers at Corvette found it better to stick with anti-sway bars to achieve the best all around handling.

Many owners have found that the coil over shock added to either a mono-leaf spring, or just replacing a coil spring with a coil over shock is the best way to achieve the suspension performance and flexibility needed. That is because the coil over arrangement lends itself to quick spring rate changes compared to removing and replacing a leaf spring. There is also the added benefit of being able to adjust the ride height. Weight biasing or “wedging” a chassis for optimum cornering is also made possible by coil over springs which are adjustable, something not possible with a straight mono-leaf spring.

The last comparison between spring type is how much body coupling do the two spring types have? The body roll coupling of a coil spring on a fully independent rear suspension is nearly zero. That can not be said about a transverse leaf spring since the spring is attached to the frame at the center and both wheels. If the frame rolls, the wheel outside the corner is compressed while the inside wheel is unloaded by whatever the body roll produces. This is in addition to normal weight transfer of cornering. The suspension is not truly independent since the transverse spring makes them dependent on each other, and the motion of the frame / body .



The Shark Bite rear coil over design offered by SpeedDirect for the C2-C3 Corvette is great way to sever the tie between both sides and restore true independence. It is also designed with quick release pins to enable both springs to be changed in about twenty minutes! We believe this arrangement, plus the adjustability mentioned gives a performance driver the most flexibility in setting up the car to handle beyond what is possible with a transverse leaf spring.

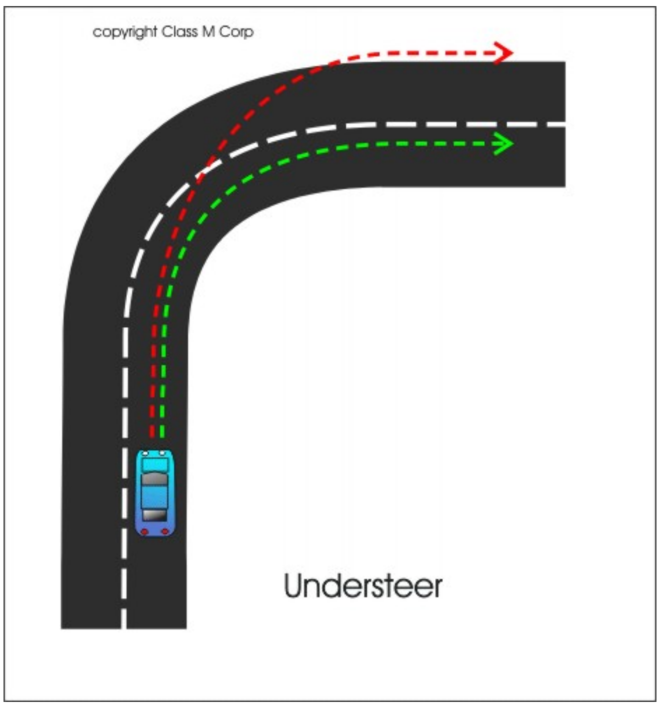
Evaluating Basic Handling

All of have opinions on how are cars handle. It can be difficult some times to express what are car is or isn't doing when describing a problem we are struggling with. This article will address the basic handling trouble spots so you can easily identify what your car is doing and some general guidelines on what you could do to possibly correct the trouble.

Cornering

UNDERSTEER

Entering a corner our car can exhibit several tendencies, the most common is understeer. It is that sickening feeling you get when you rack your car into a turn and the front wheels slide or "push" instead of following the turn path you had in mind. Most factory cars are set up by design to understeer. It is a compromise that engineers and lawyers came up with so you wont "hurt yourself", and it is very prevalent on classic cars. The diagram show what is happening. The radius of turn which the car can accommodate considering available traction & speed is greater that the radius of the road or track corner.



Symptom: You turn the wheel but the car wants to go straight as the tires scrub along the paving.

Possible Corrective Actions:

Camber angle - more negative

Anti-sway bar - Add or resize.

Ride height - lower.

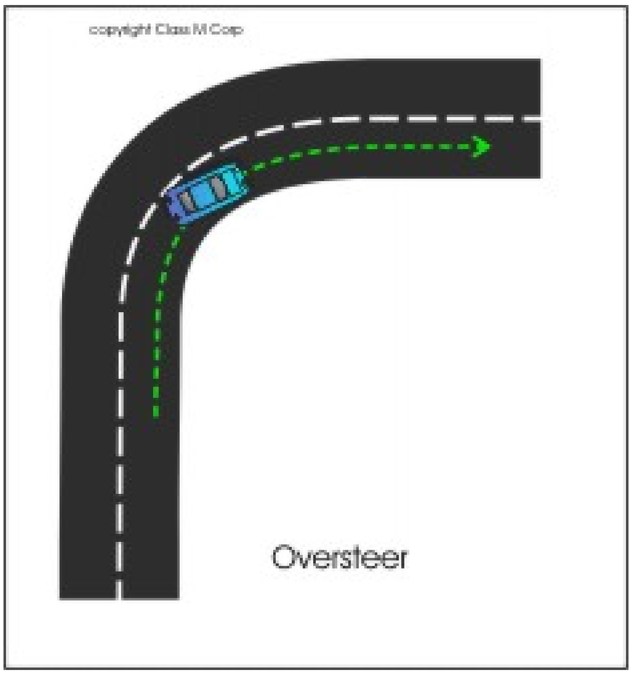
Center of Gravity - lower

Tire pressure - lower (down to the safe limit, never under inflated)

Tire size - wider, lower profile.

OVERSTEER

Just as you would imagine oversteer is the opposite of understeer. It can be tricky to manage using driving technique since the rear end of the car wants to swing out forcing the driver to take quick action. Those actions are usually to turn in the direction of the skid, reduce the throttle but not completely off, or the slight application of brakes to avert a complete spin. These actions are a learned response and take practice to balance the forces so the car stays in control.



Symptom - You turn and the front end has greater traction than the rear and the rear end swings out in the direction of the corner.

Possible Corrective Actions:

Camber angle - less negative

Anti-sway bar - resize.

Tire pressure - increase (incremental up to max allowed by manufacturer)

NEUTRAL STEER

Just like Goldie Locks we are looking for steering that is “just right”. A car set up for neutral steer will be the quickest through a corner. It will follow where you point it which presumably is where you want it. It is an elusive setup since there are many variables not the least of which is speed. At higher speeds your vehicles aerodynamics start to play a bigger roll in steering response. A car can go from understeer to neutral to oversteer just with changing the speed but as a general rule the neutral steer set up is the most desirable because it is the most predictable.

Symptom - Great feel and command of the direction the car is pointing at any given instant.

Possible Corrective Action - You’re kidding right?

Now the next time you are trying to explain what your car is doing, or not doing in a corner you will have a vocabulary that will allow you to explain it terms which someone skilled in the art of chassis setup can advise you.

Why Suspension Stage Kits?

It is a fair question, why buy a complete stage kit? In this article we are going to look at the reason installing a stage kit is important and what the advantages are.

All of us want noticeable results for spending our money on our cars. For some it is appearance, we want our ride noticed, or we want that look which expresses our personality. For others it is the esoteric “feel” of how the car handles. Many owners of beautiful classics, which really turn heads, are appalled at how poor the car drives. This is especially true after owning a modern vehicle. Why is this so?

Think a about the world thirty or more years ago when our classics were new, would you be satisfied looking at a television set of that vintage, even if it had a beautiful wood grained cabinet? Probably not, but if you were hooked on the looks of the wood cabinetry you might strip out the old electronics with its glass picture tube and replace it with a wide screen HD set, and maybe add a BlueRay player and Surround. The same is true of our classics and the suspension under that awesome iconic looking body. The style and look is what usually attracts us to a vintage car, and then we drive it; what a disappointment.

“So where is this guy going?”, some may be asking. The stage kit is the quick path to modernizing your gorgeous ride. In the TV analogy the upgrade involved multiple components to get the job done. The same is true of stage kits. They include a stepped approach where we can increase the aggressiveness of the suspension to meet our needs. This is done with proper spring rates, shock selection and sway bar choice as well as getting rid of that ancient clunky steering box. All the components are engineered, designed and selected to work in harmony with each other to give a marked improvement in handling and performance and to really bring out the crisp point-and-go feel we need when we drive. Just like you wouldn't add an old VCR to an HD set, you don't want to "shot gun" a solution to better drivability with a half done, partial result that will not deliver what you expect or need.

Another great reason besides the handling improvement is price. When you buy a stage kit the bundled price is significantly lower than buying everything separately. So not only do you get everything you need to upgrade to better handling, you get it at lower price. Look over the stage kits, decide on how you want to drive and select the one right for your preference. Everything needed is there, it's an all "bolt on" installation so you won't trash you chassis with cutting, drilling or welding. You will not believe the difference it will make, just like watching Star Wars on an old clubby '60s TV, then switching to High Definition; get the picture?

Suspension Bushings & Deflection

The suspension on our car needs to handle a lot of loads. As we corner the forces are transferred through the body to the tires via the suspension. This adds up to thousands of pounds of force which the frame, a-arm and spindle or axel must transfer. In the process it all must travel through the lowly suspension bushing, a part which you may have given little thought or attention. We will address suspension bushings and show you why it is essential to understand its purpose & environment and some options to help improve how your car handles and responds.

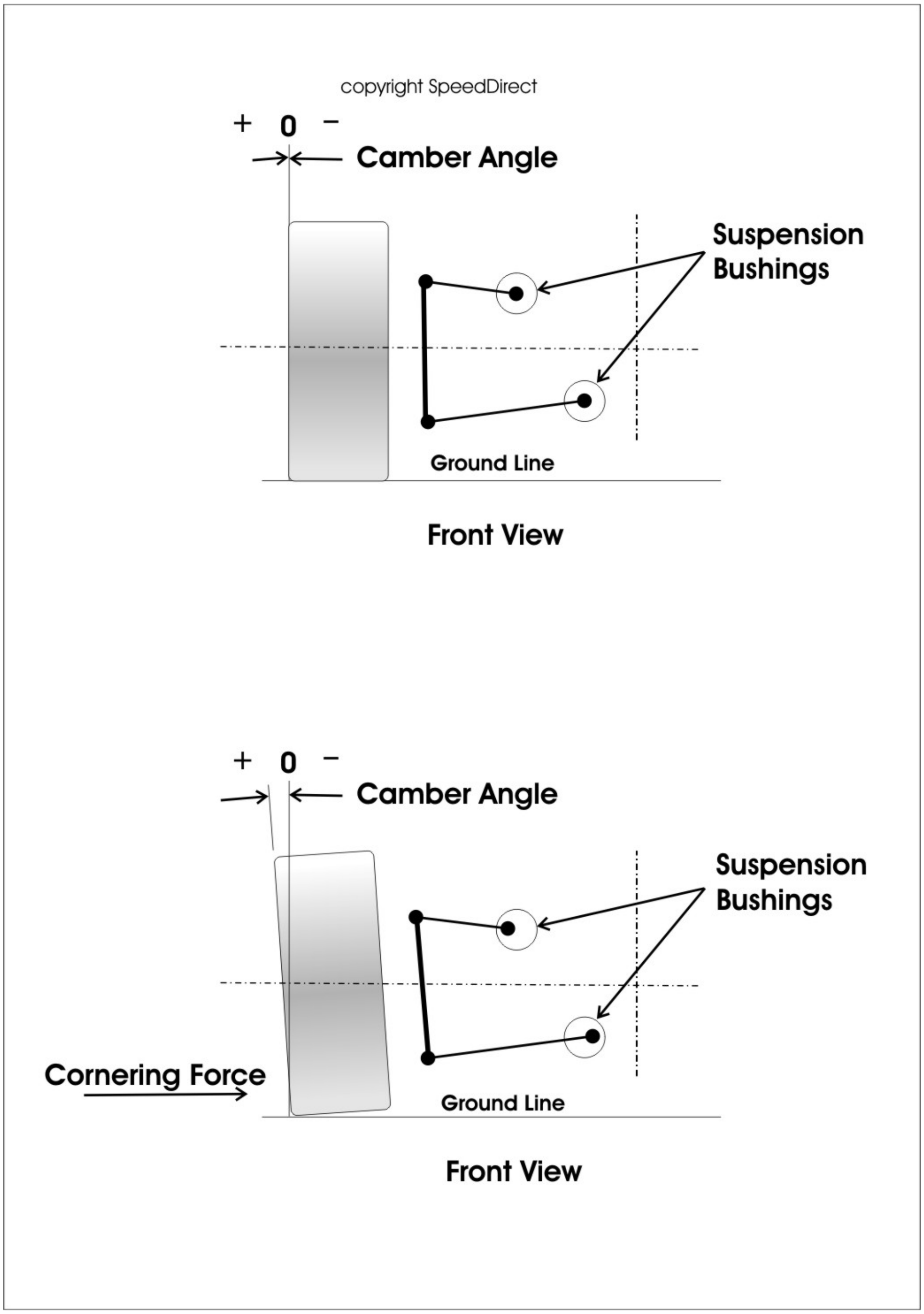
Most muscle cars and classics have rubber suspension bushings at the point where the a-arms attach to the uprights or frame. When these rubber bushings became available in the '50s they were seen as a significant improvement over the metal of their metal predecessors which required lubrication and suffered wear as the suspension moved. Rubber was maintenance free – no greasing - and they offered isolation from road vibration and most important; they were CHEAP. Auto makers could not resist and most suspensions from that time forward have rubber bushings.

All of the benefits mentioned would be great if you never cornered your car. I don't know about you but I like cornering my car. Once we rack it into a turn the load on the bushing dramatically increases. Remember, these bushings are rubber, and rubber flexes, compresses, stretches and in doing so changes the suspension alignment which can do bad things to handling. The images below show a drawing of a loaded and unloaded suspension bushing as would occur when your car enters a turn.

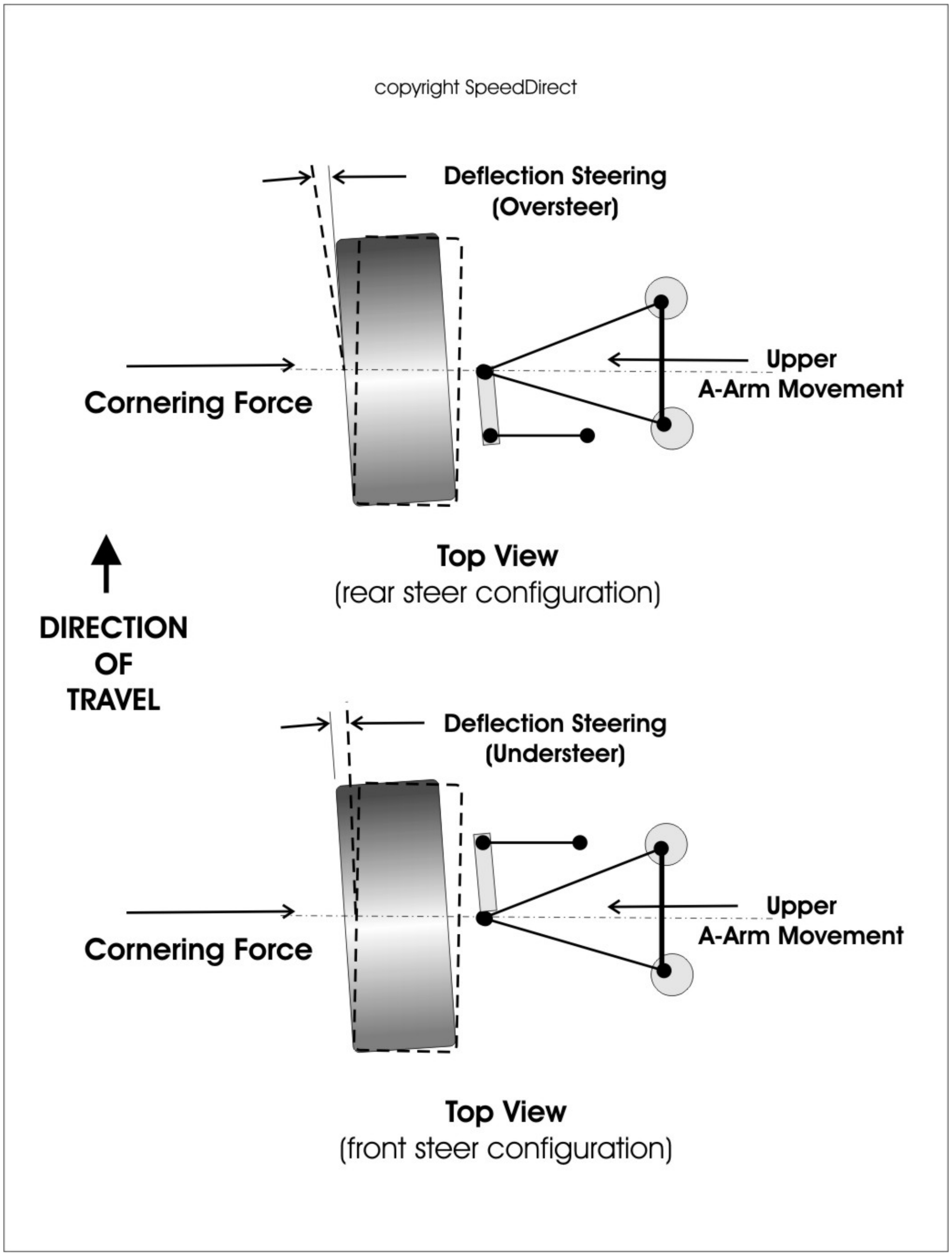
Shifting of Camber

As you can see the hole center of the bushing moves to one side as it is loaded. This movement results in camber loss on the front suspension as you corner. Why do you care? Camber is the angle of the tire to the road. Ideally you want the tire perpendicular to the road / track surface, this is where the tire can produce maximum grip or traction. If the camber angle changes to positive it means loss of traction in the turn.

The illustration of camber angle shows how soft rubber bushings allow the suspension to dynamically change camber to the positive (bad) side which lifts the contact patch and reduces traction.

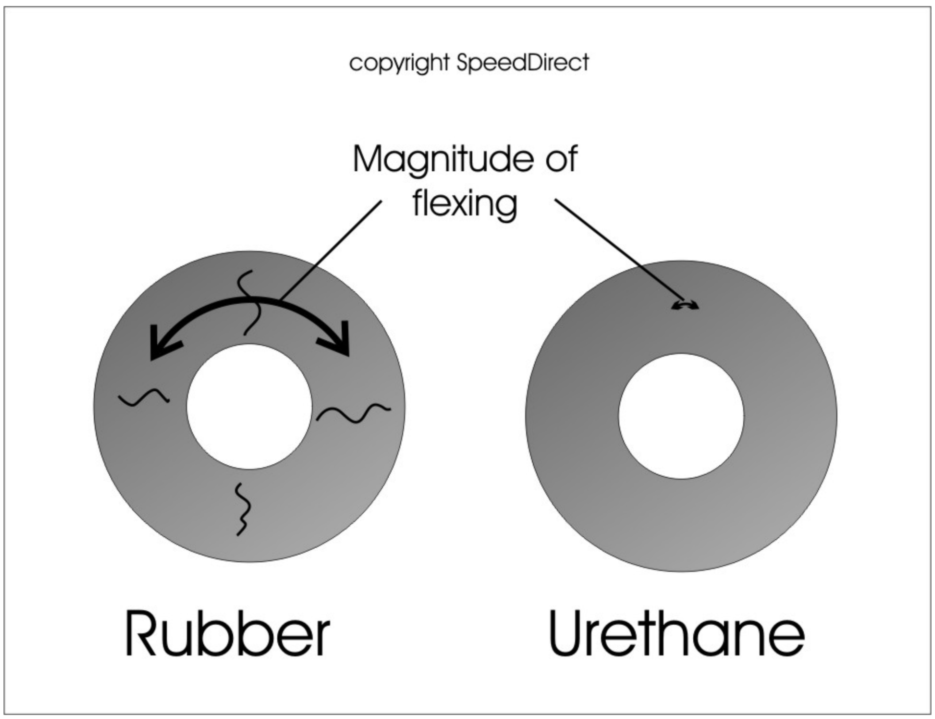


Another steering input in which squishy bushings can change steering angle as you enter a corner is deflection steering. This is a bad side effect of having a flexible bushing in the system. Deflection steering can take two forms; deflection oversteer or deflection understeer depending on how your car's steering is designed. If the steering link in front of the axle (front steer) it can cause understeer or the tendency to widen the radius of the intended steering path. The other condition occurs if the steering link is behind the front axle it can cause oversteer or the tendency to decrease the radius of the intended steering path. Either way your car is not doing what you wish or expect as you take a corner.



What can be done?

There are aftermarket urethane bushings which greatly reduce the deflection of the suspension caused by soft bushings. This is because they are extremely rigid, almost like metal, but do not have the disadvantage of metal to metal contact with regard to wear. Like any solution they have some draw backs. Since they are so much stiffer than rubber they do not flex as a rubber bushing does. As you can see from the suspension motions in the drawings, bushing are subject to flexing in multiple planes. In addition to this there is also the applied torque of the a-arm as it rotates on the cross shaft causing the factory rubber bushing to flex by twisting. Urethane bushings flex only slightly, in stead they slide on the cross shaft. Even if you grease them when you install them over time the bushing will start to bind. This binding is slightly detrimental to the free movement of the a-arm and usually results in annoying squeaks and squawks as the bushings dry out. Just keep a bottle of rubber lubricant or Armor All handy.



On the SpeedDirect upper a-arm alloy a-arm for C2-C3 Corvettes we chose rigid composite bushings which are Teflon impregnated to eliminate all of the described problems of bushings. They are stiff, do not flex, they run smooth on the cross shaft, and need no lubrication for the life of the installation.

If you are serious about improving the ability of your suspension to stay aligned during hard cornering then definitely consider urethane bushings. The advantage of controlled alignment and steering is well worth the effort of installing these inexpensive bushings on all of your moveable suspension parts.

Body Roll Factors

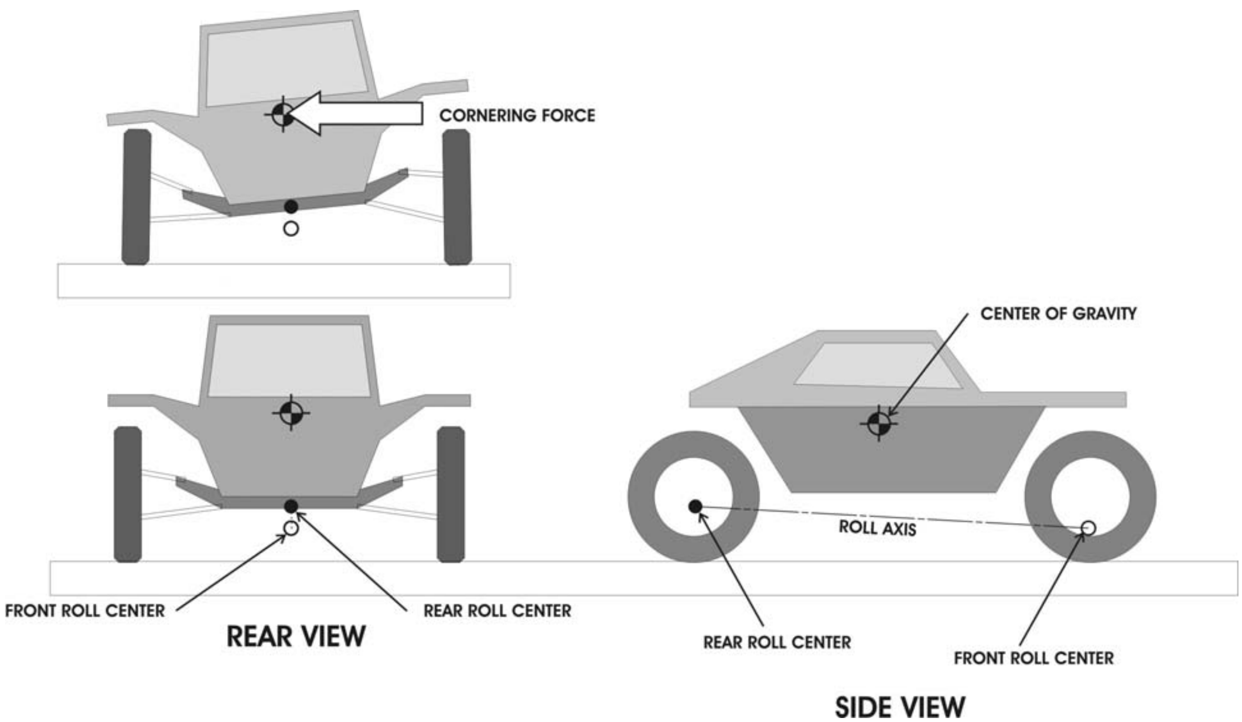
Center of Gravity & Roll Center

There are several basic terms that need to be explained in order to understand what affects body roll. They are center of gravity and roll center.

Center of Gravity: The center of gravity (CG) is that point that all the masses in the vehicle can be considered to be concentrated.

Roll Center: The roll center (RC) is a point where the car pivots. There is one in front and in one in the back and the car pivots about a line (roll axis) between the two roll centers. When the car is in a corner, it will lean (roll) about the roll axis.

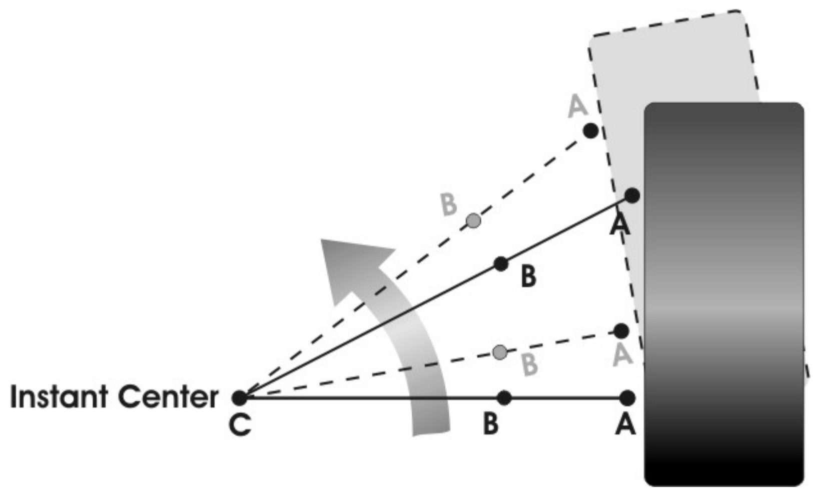
The most dramatic impact to body roll is center of gravity height. This is affected by the CG distance from the roll center height. The greater the distance between them the more body roll. Consider the example below. This simplified vehicle has a high center of gravity and is offset considerably from the roll centers and roll axis. When a cornering force is applied the body will lean. You can see that if the CG was closer to the roll axis, in the same corner the body lean would be reduced.



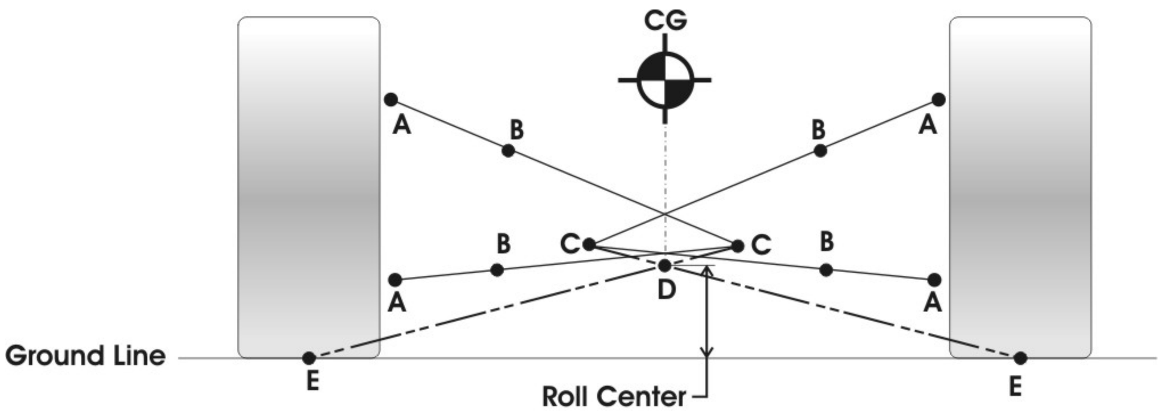
Why is This Important?

From this discussion you would think that just lowering the vehicle by using shorter springs would result in an improvement to handling. While it is true that you will lower the CG by lowering the car, you can also adversely impact the roll center, steering geometry or both. Even if the ride height is not changed the roll center can be a problem that needs to be understood

We are only going to address the front roll center because it is the easiest to change and will provide the most amount of improvement. The RC of a symmetrical, independent suspension is determined by utilizing a front view of the suspension pivot points and drawing imaginary lines to connect the ball joint, point B and inner pivot, point A of each control arm and extending them to the point where they intersect, point C. This point is called the instant center and is the point at which the wheel (if attached with a single bar) will move about in an arc.



Drawing another line from the centerline of the bottom of the tire, point E to the instant center, point C and still another set for the other side of the suspension will give you the roll center. It is the point where these two lines meet. The height of the roll center is measured from ground level.



Front View

While we can't completely eliminate body roll without causing other problems, if the RC is changed to reduce these effects we can still improve things significantly. Example: Raising the roll center from 1.28" to 4.21" above the ground will reduce the roll couple by 17% (assuming a theoretical CG of 18"). You don't want to raise it too far because that gets into other issues, such as jacking, that can have a negative effect on performance.

What's Next?

If you are a Corvette owner we have our Shark Bite TM aluminum control arms. These a-arms raise the roll center on the C2-C3 Vette's from 0.29" below ground level to 3.31" above ground level.

Stock Roll Couple Moment Arm = 16.79"

Shark Bite TM arms installed = 13.19"

This translates into a 21% reduction in roll couple moment arm thereby vastly improving the tendency to roll!

Other Advantages: They are 8.5 lbs lighter that the stock steel a-arms, and they improve the caster and camber over OEM. Overall, a good contribution to improved handling that is truly a bolt on modification.

Sway Bars & Handling

Yearn to Turn?

Driving a stock car highlights the fact that its design was a compromise between the average driver's capabilities, the average road surface, the average turn; do you see a trend? Let's see a show of hands, how many want to drive a car rated "C" in overall handling? When we buy a car it is now up to us to improve handling performance to somewhere way above average, to match our expectations and abilities. The anti-roll or sway bar is a very reasonable way to vastly improve how the car feels. Upgrading your ride will loose its nasty habits like understeer or body roll or both.

Understeer is a condition where the car seems to “plough” or “push” through the corner. Believe it or not this is done by design. The auto manufacturers look at the skills of the “average” driver and set the car up to understeer, that’s right, to understeer! This is because they assume that you are incompetent at handling your vehicle up to and beyond the limit of traction. The conventional wisdom goes something like this: If the car understeers and pushes around a corner the rear end will still have traction so the pointy headed little driver will not get in trouble swapping ends; spinning out. In the corporate world of paranoia concerning lawsuits makes total sense.

Race cars or autocross cars are set up to be neutral steer or slight oversteer. Neutral steer is self explanatory, neither over nor under steer. Oversteer is where the front end stays planted, with plenty of traction but the rear tires tend to loose traction first and the car has a tendency to swing the tail end out in a hard corner. Obviously you have much better directional control with neutral steer or slight oversteer because the front tires have traction. They are not sliding like an understeer setup.

With a neutral or oversteer car now the driver is responsible for keeping the car headed through the turn in the track, road, or course. It is then possible to control up to the limits of traction and negotiate the turn as fast as possible under the prevailing conditions, and your skill. Isn’t that better than to accept a compromised vehicle that an engineer and corporate lawyer decided was good enough for you?

“But my car has a sway bar.” That may be true, most modern factory cars have cute little paper clip sway bar that add spring rate, just not enough, and many have no rear sway bar. While bigger is better is good up to a point, most factory suspensions are whimped out to meet the lawsuit requirements of corporate management.

Here are some guidelines for achieving improved results:

Understeer: Increase rear sway bar diameter or decrease front sway bar diameter to restore balance.

Oversteer: Install either a smaller rear bar or a larger front bar.

Match Bars with Springs

Selecting a sway bar should be done in conjunction with your springs. I you are planning to upgrade to stiff springs, then you probably wont need to increase the sway bar diameter since the added spring rate will handle body roll. A larger diameter bar is required if you have softer springs. Many people prefer a softer ride, but want to limit body roll and opt for softer springs. Here are some helpful generalities:

Stiff springs, small sway bars.

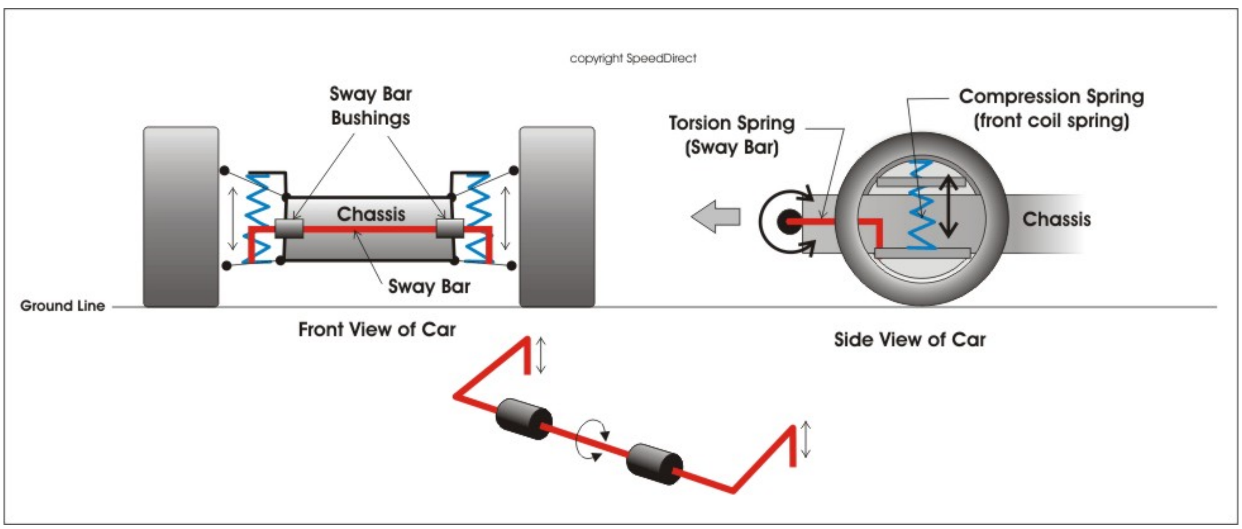
Soft springs, large sway bars.

With all generalities there are tradeoffs. The stiff spring / small bar arrangement is generally better for overall handling because it reduces front to back weight transfer. This is because the spring rate is higher and helps resist the tendency for a car to "dive" in breaking, or "squat" during acceleration. Both conditions will upset the vehicle by changing suspension geometry and can make handling worse.

Rock & Roll Control

Driving a car that is a "leaner" is no fun. You wonder if the door handles are going to scrape off negotiating a tight corner. Even if your car has stiff suspension a properly sized anti-roll or sway bar will improve its stance in a corner. That is because the bar adds spring rate as the vehicle tries to roll. On the straight away or when not maneuvering the spring rate is not there. To add the additional spring rate needed to stay relatively flat in a corner would mean a really stiff, uncomfortable ride.

How is it possible to just selectively add spring rate? The diagram shows the ingeniousness of a sway bar in that it is a torsion spring which is tied to the suspension and body through the sway bars bushing and the vehicles moveable suspension parts like the lower a-arm in front or the differential housing (non-independent cars) in the rear. The net result is that it is affective only when the vehicle tries to lean. Consider it spring on demand. The more the vehicle tries to lean the more it resists leaning. On the other hand when you go over a bump that is across the entire road the bar rotates in its bushing with no addition of spring rate. This directional bias makes it perfect for reducing body roll.



Body roll is also connected to whether a car has bad habits like oversteer previously discussed. That's because the more the body rolls the more is messes with the steering geometry (mostly camber) causing the car to do things you would not expect when you corner. We have shown the front suspension but the rear can use the same treatment only with a much smaller bar diameter since front engine vehicles have so much more mass to affect the front suspension.

How Much is Too Much?

With this knowledge you would think you would want to bolt on the biggest, baddest sway bar you could find. Not a good idea, you see the suspension needs to be able to react to the irregular surface of the road or track in a straightaway and in a corner. If you put a huge sway bar on when you start to corner the spring rate (stiffness) of the suspension will go way up disproportionately to the weight of the vehicle. The suspension becomes so rigid that it can not do its job of properly following the surface to keep the maximum contact patch (tire footprint) against the surface. You will loose traction, reduce the maximum speed you can take the corner, and it will ride just like a go-kart when you hit a bump in a corner - like it had no suspension at all - ouch! From this you can see that properly sizing the sway bar is essential if you expect to improve the handling, reduce body roll and retain the ride characteristics.

Solutions

If you are a Corvette C2 or C3 owner SpeedDirect has a tailored package that matches springs, shocks and sway bars for an optimal combination depending on three driving preferences:

Shark Bite TM Cruiser TM Suspension Stage Kit - A smooth ride that handles great.

Shark Bite TM Instigator TM Suspension Stage Kit - Firmer ride, improved handling.

Shark Bite TM Nemesis TM Suspension Stage Kit - Solid ride, maximum handling.

One of these is right for your driving preference and style.

Brakes: An Introduction

Driving a fast car on a good track is a blast. There is nothing more exhilarating than whistling down the straight away into a tight turn. It gets a whole lot more exhilarating and a lot less fun when your brakes mush out on you. Brakes are such an essential component of performance driving, yet most people consider them as one of the last things to upgrade. Let’s look at this important element and what can be done to enhance their performance.

Calipers

These are the most visible through the teeny weenie spokes on alloy wheels. Red seems to be the color of choice for the calipers of most performance brake manufacturers, and why not, you paid a bunch for the upgrade so why not show them off! But the fact they are painted is a good thing; we'll get back to that in a bit.

Factory calipers are typically cast iron, where as aftermarket calipers are aluminum. The material change is excellent for two reasons, weight and heat transfer. Weight because it reduces un-sprung mass allowing the suspension to be more responsive to bumps and dips because of the lower mass.

Better heat transfer is crucial to allow the heat buildup to be dissipated quickly. A caliper loses heat through three methods: conduction, convection and radiation. Conduction is via the surrounding mounting structure or through the brake fluid. Convection is the wind whistling past the hot surface and the last method; radiating heat via the caliper emitting heat in the infrared spectrum to other cooler surrounding components. The first two, convection and radiation, are easy to understand but the emitting or emissivity, as we gear heads call it; can be significant especially when the caliper is hot.

This is where the painting of the caliper is important. A bare aluminum surface has an emissivity of around .10, while a painted surface is more like .95 (irrespective of color). That's a huge difference in its ability to transfer heat in the infrared area of the spectrum. So painting the caliper red is cool on two levels.

Number of Pistons

Why are calipers made with multiple pistons? It is basic physics; more area distributed over more pad area than stock equals more clamping force needed. Large calipers are typically six piston, this is because the pad area is large too. In combination it creates more braking force. Stock calipers are a compromise between the cost to make the part and the duty it is likely to see. What works well in normal driving conditions can be really disappointing on the track where the force needed to slow down from over 100 mph can be staggering. Your factory brakes that really stopped on the freeway are now in a new reality where bigger is better. More piston area, more sweep area, more pad area are things that differentiate high performance brakes from "street" brakes.

Pad Material

There are a lot of choices when it comes to brake pads. It all comes down to how hard you plan on driving your car. Here are some of the factors to consider:

- **Stopping performance when the brakes are cold:** How well does the pad grip during the first use? Some pads need to warm with a couple of hard breaking stops before they start working well.

- **Stopping performance when the brakes are hot:** How well does the pad react in higher temperature such as a windy down hill road, the track or autocross course?
- **Pad Life.** What kind of miles can I drive before they need replacing?
- **Rotor Life.** Do the pads really use up and wear away the rotor fast?
- **Noise.** Some pads squeal which is annoying.
- **Dust.** A lot or a little and can it be easily cleaned off?

All of these choices will impact cost and performance so consider the type of driving you will be doing most and pick the brake pads for the job.

Rotors

The selection of the right rotors for the driving you will be doing has similar considerations just like choosing the right pad material. There are several choices for rotors; un-drilled, cross-drilled and slotted. Rotor diameter is significant too. Increasing the rotor diameter over the stock size is important in that it gives you more brake area and better mechanical advantage. Let’s look at the differences to see what makes sense. (We will be discussing only vented rotors.)

Un-drilled rotors are the most common. Structurally they are the most stable and handle the stresses best. That is because they have no drilling through the rotor or milling done to the surface.

Cross-drilled rotors are slick looking. The purpose of drilling is to allow the gasses that can build up from the hot pad surface to vent. They also reduce the mass for a slight reduction in un-sprung weight (mass) as well as rotating mass. The slight disadvantage of drilling holes is that they provide a potential point where stress can concentrate and possibly cause rotor cracking.

Slotted rotors do a similar function to cross-drilling and that is to provide a surface slot instead of a hole to vent gasses which can be generated during extreme braking. In addition they are less prone to stress concentration and therefore more resistant to rotor cracks. The slots also help to wipe away the pad material that is created through the friction of braking.

Consider an Upgrade

If you are looking to improve the brakes on your C2-C3 Corvette SpeedDirect offers an excellent option. We have adapted the Corvette C6-Z06 brakes to the early Vettes, giving you a number of advantages over the stock brakes, which are:

- Six piston all aluminum Corvette C6 Z06 brake calipers.
- Hawk HP Plus high performance brake pads.
- 13" cross drilled, slotted or plain rotors.
- Aluminum rotor hats (The rotor mounts to these).
- Stainless steel braided brake lines.

All the components have been selected to provide what we feel is the best all around value and performance that will modernize the brakes on an already great car.

All A-Arms Are Not Alike

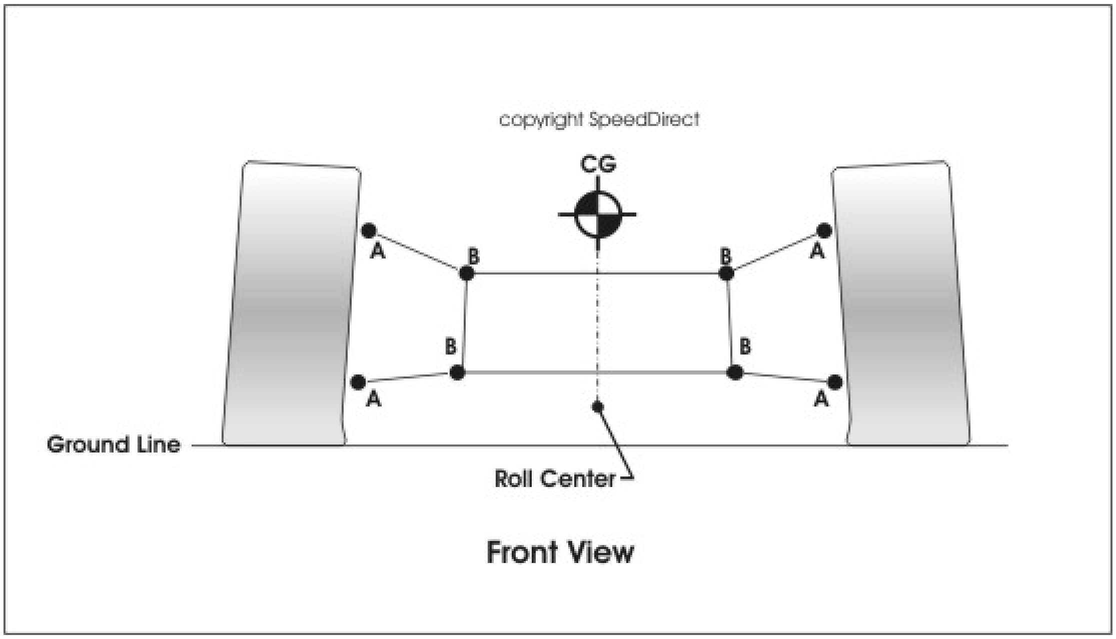
So what’s the big deal with a-arms? Your car already has a set so why replace them? Let’s look at some very good reasons for upgrading.

Geometry

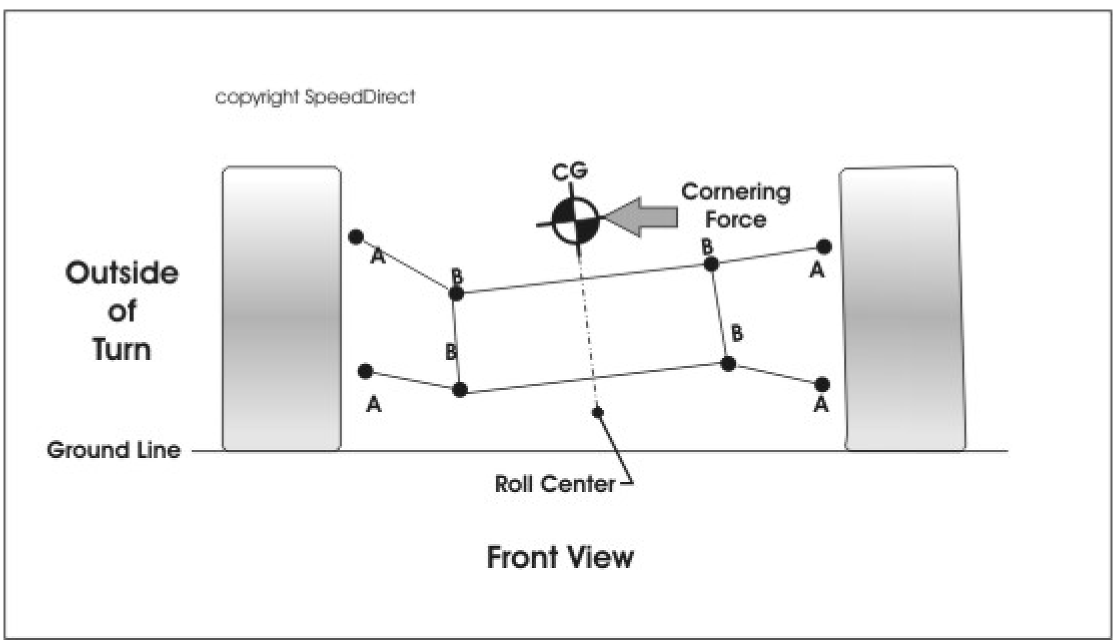
It is just like the stuff you did in high school. A suspension system obeys the rules of geometry with respect to how the wheel moves when you hit a bump, or when you take a hot corner. The travel is predictable because it is controlled by where the suspension pivots, how far it can travel and most importantly the angles that start and stop its travel. These angles are established by design. The suspension engineer looks at the vehicle mass, center of gravity, tire size and width then selects a setup that is a compromise between reasonable handling, and the ability to mass produce the parts at a budgeted price. Let’s look at the C2 and C3 Corvette and see what Zora Duntov and the boys chose for the car.

The frame and front suspension parts are identical on the ’63-’82 Vettes. When the Sting Ray came out in ’63 wide tires were not around, and low profile tires were definitely not available. Tires have come a long way since then and they have an affect on suspension since the contact patch, the “foot print”, of the tire on the ground is so much wider than it was back then.

Camber: The contact patch is so important because you want it as flat to the road / track as you can get it in all conditions; that’s how you get maximum grip necessary for best braking and cornering. This brings us to the first geometry consideration and that is camber, and camber gain. Camber is the angle of the wheel with respect to vertical as viewed from the front of the car. The picture shows exaggerated positive camber. If the top of the wheels were tipped out it would be negative camber. Negative camber is evil and you don’t want that as we will explain.



When you barrel into a tight corner the car will rotate about the roll center (an imaginary point explained in another not so imaginary article we have written) that is joined, or coupled, to the center of gravity (CG). When this occurs the camber causes the wheels to change their vertical orientation. This movement is called camber gain. What the Shark Bite TM arms do is to raise the roll center so it is closer to the CG; the closer the better (up to a point.) This is because there is less leverage to roll the car. The effect camber gain has is to keep the wheel more vertical in turns. The more vertical the more contact patch is in touch with the ground the more grip the car will have.

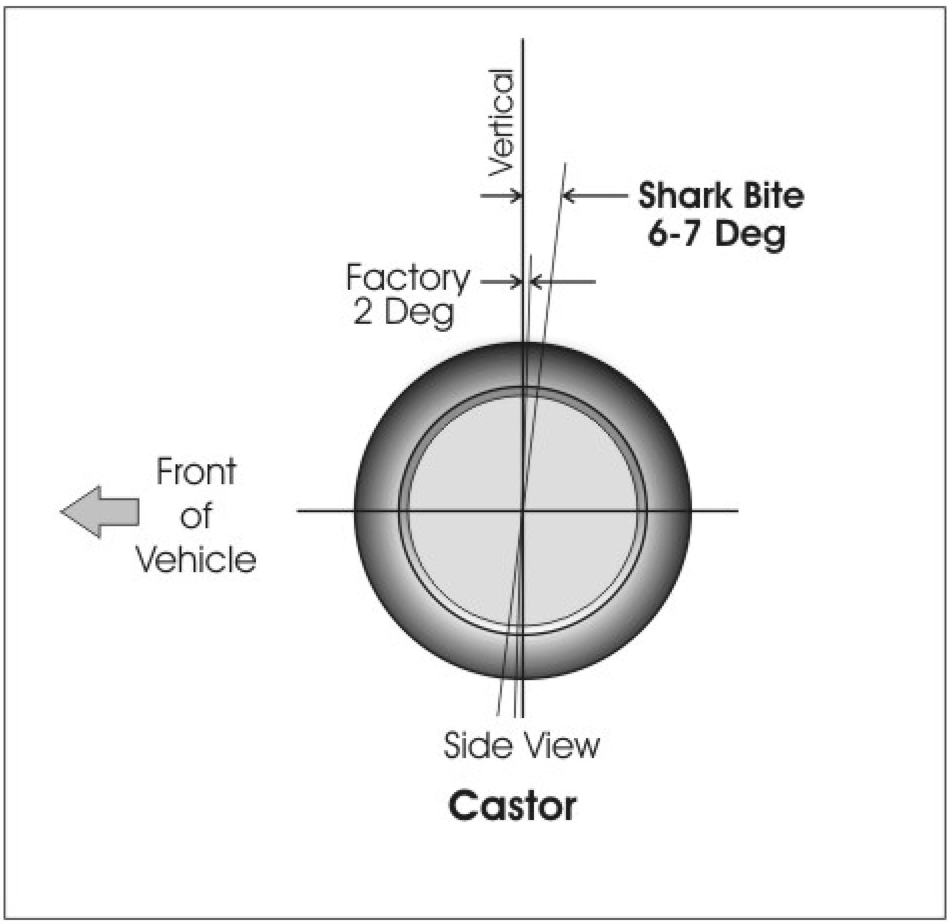


As you can see starting with positive camber sets the car up to maximize contact patch in a turn. The opposite is true if for some strange reason you started with negative camber. With negative camber as the suspension is loaded, and the car rolls (leans) the tire would not remain flat and thereby lower available traction.

We have found that the factory design puts the front roll center below ground line! This is not good since there is more leverage (distance from center of gravity to roll center). The result is more body roll and insufficient camber gain to keep the wheels as vertical as possible. The Shark Bite TM aluminum alloy a-arms raise the roll center by 21%, reducing body roll and greatly improving camber gain.

Castor: This is another important geometric concern worth considering on your suspension. It's what should make shopping cart wheels want to track straight (well, maybe that's not a good example), but it is what makes your steering want to self center after you take a corner. As mentioned earlier, in Zora's day wide tires didn't exist so he and his designers settled on 2 degrees positive castor (tipped back from vertical). Wide tires have more contact area and offer more friction and resistance to centering. The affect on your car is that it will not want to re-center. It produces that kind of vague wandering feeling as you drive and a general reluctance to return to center after you turn.

To improve this Shark Bite a-arms have three times the castor over factory a-arms. This figure is typical of most modern steering systems. You will notice the difference in how the car re-centers, as well as a much more stable modern feel as you cruise.



Weight: A-arms contribute to what is known as un-sprung weight or mass. It is the mass of the suspension the a-arms, spindles, springs; everything attached to it rather than what it supports like the chassis, engine, body and you. Reducing this un-sprung mass allows the suspension to follow uneven ups and downs of the road or track to keep the contact patch on the ground because there is less mass to push around. The less un-sprung mass the more responsive the suspension can be at following bumps, the more traction you will have.

Shark Bite TM aluminum a-arms are 4.3 lbs lighter that the factory steel a-arm. It reduces the un-sprung weight and improves the response of the front suspension.

Smarter is Better

The easy modification of bolting on new a-arms can greatly improve the geometry and ultimately handling of your classic Corvette. Some of the benefits of modernizing your car with this upgrade are:

- Raising the roll center for less body lean and more traction in turns.
- Improved re-centering with more positive castor.
- Reducing un-sprung weight for better suspension response to bumps.
- They look cool, especially the polished ones.