

# Suspension Basics

## Part II: Hitting the Twisties

### Modifying Your Suspension for Improved Handling

**S**uspension and handling are, without a doubt, among the greatest mysteries in performance cars, and yet the components that affect these characteristics are often the first to be changed to make the car look cooler or in hopes that it can be made to handle better.

In the last issue we reviewed the basics of suspension and handling, and discussed how each variable affects overall handling and how they interact with one another. So now you want to make your Mini handle even better. Let's discuss the whys and hows, and some of the why-nots of suspension modification.

#### But Why Change Anything?

Before getting into specific suspension issues, you need to ask yourself one general question: Why modify your suspension at all? To me, this question divides owners into two camps: The enthusiast camp wants to get better performance handling and they are willing to "pay" for the improvement in handling with some degradation in ride comfort as well as with bucks invested. The second camp wants to build a show car with a particular look, and handling performance isn't the overriding priority. Let's assume you're in the first camp.

Now, after reading this article to this point, I know everyone has put their suspension purchases on hold while they work out the tire pressures that give the best combination of handling and comfort. (I haven't met anyone who's really done this well, so don't feel bad if you didn't do it, either.) So now that we're working with an optimal baseline, it's off to mod land! I'll go over most of the more common suspension modifications and point out the pros and cons of each. Here we go!

#### The Chassis: Where it All Starts

The chassis, or more properly the unibody, is the basic suspension item. All the bits of the suspension are attached to two sub-frames that are bolted to the unibody. These fixed attachment points define the car's suspension geometry, and are the constraints around which suspension design and modification have to operate. If these attachment points move relative to each other, it becomes impossible to optimize suspension motions as there's no fixed base from which to tune. While the MINI has a very stiff chassis for a street car, it's not perfect. And this is one of the benefits (other than safety) from adding a roll cage: it stiffens the chassis to allow for better control of the suspension.

I'm not advocating we all bolt in roll cages, but this area (chassis stiffening) is an area where strut tower bars, under-car bracing and improved bushings all come into play. They all are involved in holding the basic geometry constant, so that the suspension can do what it's designed to do well. This issue is especially important for convertible owners, as there is no fixed top to "close the box" and it's just a less rigid shape.

One example of the under-car strut system is that offered by M7, shown in Figure 1. The reinforcements bolt across the chassis under the car and

increase the chassis stiffness. It's an upgrade that many track day enthusiasts are installing, but may make the car a bit more responsive than the average street driver would want.

In addition, keep in mind that the stock bushings that separate the chassis from the suspension are rubber, and chosen more to improve ride quality than handling performance. The bushings are often forgotten pieces of the suspension, and on older cars can be particularly sloppy. While going to stiffer bushings will hold the geometry much better, you'll feel the difference over every bump.

There are also bushing replacements that can help tune the suspension geometry. Alta just introduced the JSRS front control arm rear bushing replacement that has an eccentric, and allows for more caster (shown in Figure 2).

#### The Rear Anti-Sway Bar

Increasing the stiffness of the rear anti-sway bar (also called, not quite as accurately, a "sway bar") is the most popular suspension modification among enthusiast drivers for the MINI, and one we've recommended here. This is true because a stiffer rear sway bar fixes a suspension condition that's present in pretty much every production car built today: understeer.

But if understeer is a condition that the enthusiast driver wants to fix and a different sway bar can fix it, why does the MINI come that way?

Understeer is when the car takes more turning input from the wheel to turn the car than ideal, and the car starts to plow as it reaches the limits of adhesion (shown in Figure 3). Pretty stupid, right? Well, not really.

While understeer is not the ideal steering behavior, if you go into a turn too fast, you tend to swing wide, and if you go off the track or off the road, the front of the car tends to leave first. That's not good, but it's a lot better than oversteer.

Oversteer is when the car turns too much for small amounts of steering input. In simpler terms, the back end of the car tries to pass the front end (Brits would say the rear end is stepping out and good ol' boys would say it's gettin' loose). If you



**M7 Under Strut System:** The suspension can only do its job if the geometry is fixed. Stiffening aids, like this chassis brace system, up to and including a full cage, make the car much more rigid. This is especially an area of concern for convertibles, that don't have the top to form a full boxed shape.

don't gather it up fast, a spin results. This is not good at all, as the average driver really can't cope with this too well. So the manufacturers build in the understeer so that typically unskilled drivers don't spin the cars when they're surprised by a situation and induce oversteer.

So how does the stiffer rear sway bar decrease understeer? Understeer is caused by not having enough weight on the front tires when you are turning. Increasing the stiffness of the rear sway bar increases the coupling between the inner and outer rear wheels, so that in a turn weight is transferred from the inner rear to the outer tires (illustrated in Figure 4). Some of this weight transfer goes to the outer front tire, which helps it do its work turning the car. If you look at photos of Minis at autocrosses and on road courses, you'll see them lifting the inner rear wheel completely off the ground!



Understeering is when the car continues to plow forward even when the front wheels are turned into the turn because the car is set up to keep more weight on the rear wheels than on the front wheels. Oversteering is when the car's rear end rotates around the front wheels in a turn because the car has more weight on the front wheels than on the back wheels. Because oversteering is more dangerous than understeering, most cars are set up by their manufacturers to understeer.



**Alta PSRS:** This is a front control arm rear bushing replacement. Besides reducing compliance over the stock rubber, it allows for slight geometry modification as well, increasing caster for improved steering return to center.

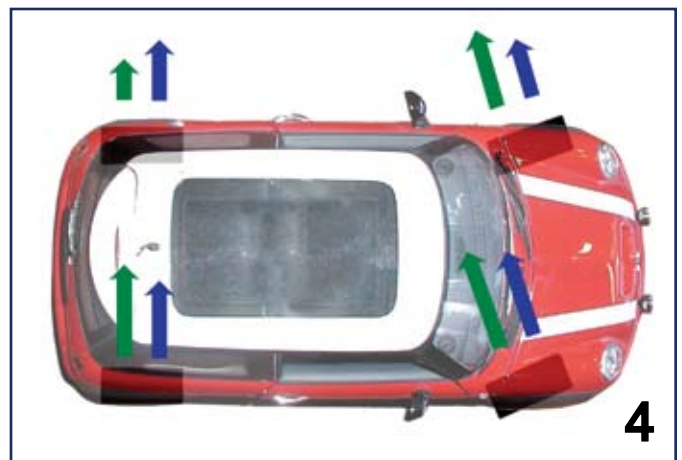
But there is a more dangerous side to stiffening the anti-sway bar. The risk is that you can wind up going backwards due to what's called "induced oversteer." Huh? Didn't I say earlier that the stiffer bar reduced understeer, and that's a good thing? So what's up here?

The answer to this apparent conundrum lies in the fact that braking and acceleration affect weight distribution as well. And if you're in a turn and you hit the brakes (because of a decreasing radius, or someone pulling out of a driveway as examples) you can wind up with the rear end spinning out.

After all the fun, and your car stops sliding, you get out to survey the (hopefully) minimal damage and wonder what happened. What happened was that when the brakes were applied, weight transferred from the rear of the car to the front of the car. More weight on the front tires increased turning force, while the rear suspension unloaded, lost traction, and slid out.

There is a very important lesson buried here: you have to match your suspension to your driving skill. So if your first reaction is always to "hit the brakes," then maybe this isn't the mod for you, at least not until you've got a little advanced driver training under your seat belt.

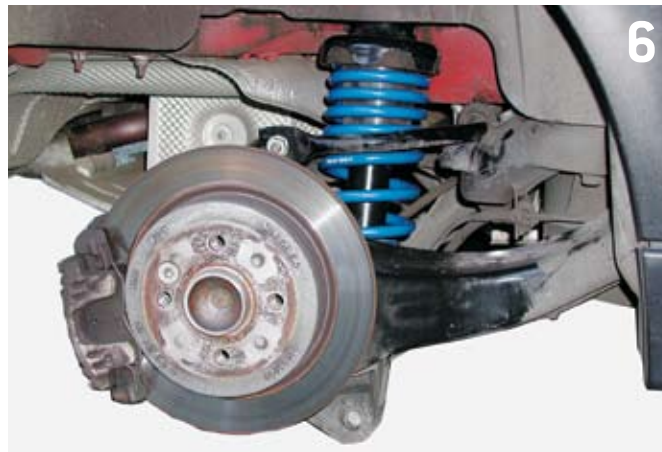
Most race cars are pretty "twitchy," as they are tuned for nearly immediate turning response, and they're being driven by experts who are focused 100 percent on their driving and whose reactions are fast and almost subconscious. While a twitchy car can be fast around a track, it's not the best set-up for most street drivers. Bottom line here: don't install a stiffer rear



The blue arrows show turning force with no sway bar, and limited weight on the front wheels. A rear anti-sway bar will "pick up" the inside (left) rear wheel, effectively transferring weight onto the other three wheels, as the green arrows show. This increase in weight on the front tires increases the turning force, reducing understeer.



**Hotchkis Camber Plate:** The MINI suspension comes with too little negative camber in front. Fixed or adjustable camber plates can address this. These Hotchkis plates don't affect ride height, and can give up to four degrees of negative camber if the right springs are used. Improving the front camber will decrease understeer, improve turn in and in my case, has increased tire life.



**H-Sport Progressive Spring:** A good compromise between comfort and handling is a progressive rate spring. These H-Sport springs lower the car a bit. You can recognize a progressive spring by the different pitches. At first, all the coils flex and the spring is soft. When the tighter coils bind, then only the remaining coils contribute to flex, and the spring gets stiffer

sway bar until you've gotten a chance to take an on-track driving school, preferably with a little skidpad training, gotten some autocross experience, or learned how to control skids by some other means (A large, empty snowy or gravel parking lot can be fun and educational.).

### Camber Plates

Adjustable front camber plates (one example shown in Figure 5), which mount on the top of the shock tower and allow modification of the camber (and caster with some models) angle of the front struts, are a more sophisticated method of suspension modification. While this isn't on the top of everyone's mod list, I think it should be and I bring it up here to illustrate a point. And that is there's more than one way to skin a cat!

Earlier I said that the stock MINI suffers from too little negative camber (the front wheels don't have much inward tilt at the top), and that aggressive handling will wear the outer edge of the tire pretty quickly. That's because the contact patch isn't being held parallel to the road as the turning gets more aggressive. (The MacPherson Strut doesn't have enough camber gain, or increase in negative camber with suspension compression.) This reduces the lateral forces the tire can use for turning, which in turn feeds into more oversteer. (To be fair to MINI, I think the stock setting is to maximize tire lifetimes for cars that aren't driven hard and see a lot of freeway miles.) Increasing the camber up front allows the tire to stay in better contact with the road during turning. Increasing the front camber also reduces understeer, and does so without shorting out the independence of the suspension. So what's the downside?

Camber plates can't eliminate understeer, even though they can reduce it. They also cost more than most rear bars, but installation is about the same level of difficulty. Some versions raise the car a bit (I had early RDR camber

plates, and they raise the front about a bit over a half an inch), but not all do (the new Hotchkis competition camber plates don't change ride height). And after installation, you need to get an alignment, preferably from a shop with race tuning experience.

So while camber plates help improve the geometry, they don't solve all the understeer issues and they're not cheap to buy and install. But even with all these drawbacks, camber improvement should be on the list for any serious suspension plans.

For what it's worth, I run minus-two degrees front camber, minus-one rear, zero toe both ends, and a 19mm Alta rear bar on the stiffer setting. This is a pretty good street set up, with decent tire wear and most of the understeer removed. It's not as aggressive as some of the set-ups I've seen, but it's well-suited to my skill level and driving needs (I enjoy twisty roads, and participate in an occasional track day, but don't race my MINI.)

### Springs

Another common mod that we often see on modified high-performance cars is lowering springs. There are two types of springs sold to the MINI market, linear-rate and progressive-rate springs.

Linear springs are called that because the restoring force is equal to a constant (the spring rate) times the distance the spring is squished or stretched. Cars are heavy, so you may hear rates like 350 lbs per inch of travel (my Mustang was running with 620 lb/in springs for a while).

Progressive springs start softer for improved ride, but after a certain amount of deflection, the spring rate gets much higher.

I had some H-Sport springs (shown in Figure 6) on my car before I moved to fully adjustable coil-overs. What I found with progressive springs (and this is purely a personal taste, your

opinions may be very different) is that while the ride is improved in street driving, I didn't like the transition from soft to firm spring rates when I was on the track. It's a bit harder to "take a set" (find and hold a constant lean angle and turn angle) with the progressive springs, at least for me. But for many who want improved comfort on the road, and don't track the car too often, they are an excellent choice.

I'm sure some of you are asking if you're changing springs, why not just run stiffer springs in the back instead of installing a stiffer rear sway bar; after all, that's pretty much the same thing, isn't it? Well, yes and no, but mostly no.

The stiffer springs will make your ride stiffer all the time. Even when driving straight on a flat road. This will decrease ride comfort, even when it provides no benefit. The sway bar is only "in play" when the two sides of the suspension are doing different things: i.e. turning.

The rear becomes much more responsive (think of the rear bouncing more quickly than the front when you hit a bump) and tends to skip over rough surfaces. There's also some tail chasing in this scenario (figuratively as well as literally); because you have stiffer rear springs you will need more dampening. So you go to a stiffer shock as well. Now the fronts are too soft and you have to stiffen it up to match the front and rear, and next thing you know, you've stiffened the front up to match the rear and now you've got your understeer back. So you go to an even stiffer rear spring..... And on and on. Finally you end up with a suspension that might as well be bolted directly to the chassis, and you will *still* have understeer.

### Lowering Ride Height

Lowering is another topic that definitely affects handling as much as it affects the car's appearance. There are lots of driver who like that slammed look, with larger wheels and really



**Leda Adjustable Coil-Over with Camber Plate:** This is an entry-level competition suspension. It allows for camber, height and dampening adjustment. To get full advantage of parts like this, adjustable end-links and a full alignment with corner balance will be required. Figure to spend about \$2000-plus to step up to entry-level full adjustability. This particular combination, with Ledas, camber plates, end-links and alignment (with their brothers for the rear) represent about a \$3000 investment. You can spend much, much more as you get more hard-core.

low profile tires, and the bottom of the car right down on the deck. If you're one of them, more power to ya', but your car's suspension has been modified for looks, and not for handling. Some of the reasons are pretty obvious. Severely lowered cars have less suspension travel, requiring stiffer springs and firmer shocks which increases the costs and makes day-to-day driving rough, to say the least.

But there's a more complicated reason why this isn't such a good idea, and it has to do with the MINI's suspension geometry. As you lower the car, the rear suspension has rather large camber gain (the tops of the wheels are tilted in, reducing the effective contact patch).

So to correct this, you need adjustable control arms. No big deal; this can just be fixed with money. In the front, lowering the car causes the suspension geometry to deviate significantly from the ideal, and the contact patch will move sideways with suspension motion. This is called "scrub" and can really degrade cornering ability.

The MacPherson Strut also has very low camber gain, and the rear will be in a location with very, very high camber gain, and the motions of the suspension will be even more unmatched than they are at stock ride height! I'll leave it as an exercise to the reader to draw a picture to figure it all out! While this may seem cruel, it's not too hard to do, and is pretty instructive. But this kind of suspension shortcoming can't be

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fixed with anything short of welding equipment plus, so you're really stuck with it.

Now, I'm not saying you shouldn't lower your MINI, but after you drop the car about three-quarters of an inch, these geometric effects start to show up. So you're left with a trade-off: a lower center of gravity, which is good, but increased scrub and reduced suspension travel, which is bad.

What's best? That depends on where and how you use your car, and there is no right answer for everyone. If you're racing or using the car primarily for track days, the reduced suspension travel and cost to replace tires more frequently may be acceptable. I'm currently running a compromise set-up on my car, with about five-eighths-inch of drop.

One last caution on lowering: lowering the car reduces available suspension travel, and as you go lower and lower, the suspension will bottom more often. This can lead to deformation of the strut tower up front (called mushrooming) and it can really destroy the struts, depending on how they are constructed. So if you want a lower ride, go cautiously here, and make sure that the parts you select are compatible with a reduced travel suspension set-up.

### Struts

I use strut, shock absorber and damper pretty much interchangeably, (though to be precise, a "strut" is a suspension component that incorporates the spring, shock absorber, and chassis support, and "damper" is simply the British term for shock absorber).

Anyway, lots of Mini owners have changed struts and once again, the reasons typically fall into two camps. One wants improved ride, without sacrificing handling, and the other wants increased handling, and is willing to sacrifice some ride.

For the first camp, products like the Koni FSD struts are a nice item. They are designed (read tuned) to work with the stock springs, but give a softer dampening initially, firming up after some travel. This is like the progressive springing.

For those who are looking for a more customizable set-up, fully adjustable strut assemblies are available. Here the sky is the limit, in terms of both function and price. I'm currently using Leda adjustable coil-overs, shown in Figure 7.

The basic advantage of more adjustable units is that you can bias the suspension for your current need, and customize the ride height and weight distribution by working with an experienced racing alignment shop.

While this is some serious bling, it's really

not needed for the typical Mini that sees only street duty. And to really get the benefit of height adjustable coil-overs, you need to get adjustable end links (that connect the sway bars to the struts) to take out something called pre-load. (this is when the sway bar is stressed when the car is on a flat surface, not a good thing as the car handles differently turning left or right). So the cost of deploying adjustable coil-overs should really include adjustable end-links, and a full alignment including corner balancing. To not do so is really a waste of time, money and effort, as you can't realize the full benefit of the adjustable coil-overs without them.

### And At the End of the Day

Now I'm sure that there is many a serious racer out there who has rolled his or her eyes at some of the oversimplifications that I've included here. That's okay: if you're that far into the understanding of suspension tuning you don't really need this article. My hope is that the MINI owner who isn't a die-hard racer can learn something about the function and interaction of the suspension systems so that better choices can be made about if and how suspension modifications should be done.

If after you've read these two articles you've learned that the suspension is a pretty complicated interconnected system and you don't just slap this and that on, then I've met my goal. This is just scratching the surface of a subject that takes most of a lifetime to become expert at.

But there is serious benefit to be had from intelligent suspension optimization. It's just not easy to do well. So if you're going to change the set-up on your car, the best advice I can give is to find someone who knows what they are doing to work with you. For me, I look to the guys at a shop like Custom Alignment in Mountain View, California, which specializes in custom suspension tuning. Working with them is an education, and after every visit there, I leave knowing more than when I came in.

And by working with the same shop, I've developed a relationship with the guys, and they are aware of the suspension tuning history of my car and my driving tendencies as we work on improvement.

There are lots and lots of good books out there on the subject as well, so if this has piqued your curiosity about the subject, I suggest you go buy a book and start reading. The suspension is one area where you really can make it much worse by adding a part that isn't well mated to the rest of the set up. And that will take all the fun out of motoring!

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