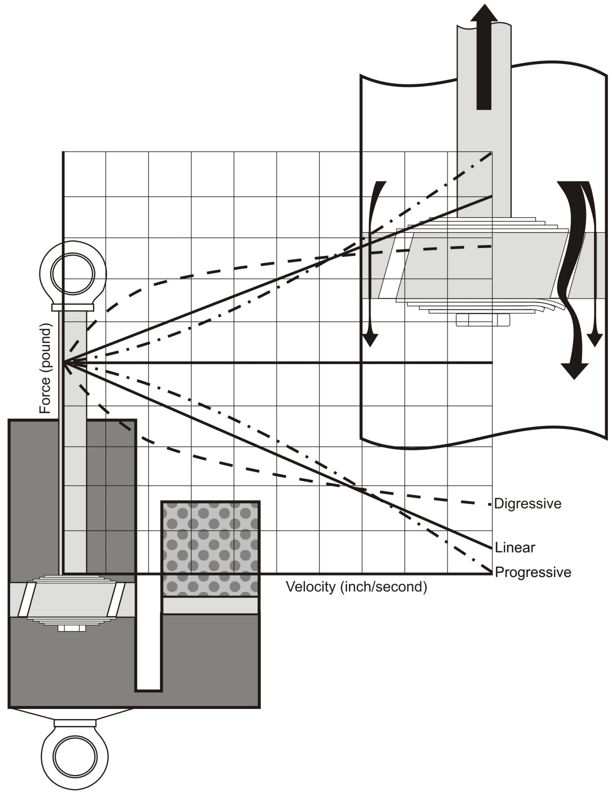
Shocks For Drivers



by Ross Bentley

SPEED SECRETS
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Legal-type Stuff

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Finally, have fun. Oh wait, that's not a legal-type thing. No worries! Have fun anyway (I'm pretty sure the lawyers will allow that)!

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INTRODUCTION

Among racers and performance drivers (and their team of engineers, mechanics, wives, friends and even themselves), the most talked-about component when it comes to tuning and developing the car are the shock absorbers. They really are the "in" thing, with most professional race teams having their own shock engineer; most track day drivers have their own theories, but typically no one to help to ensure they're right or wrong.

Why is this the case? Why are shocks such a big thing? Because practically all of the other systems and components of most race cars have been optimized to the point where there is very little to be gained through further development, and the shocks are the last area where big improvements in performance can be found. Oh, and because they have knobs on them that can easily be twisted and turned by anyone with an idea or theory!

"A little knowledge can be dangerous" is the saying that motivated me to write this eBook. My goal is to give you a little more than a little knowledge since I've seen far too many drivers do just about the exact opposite of what they should with their shocks in hope of making their car handle better.

Obviously, for race engineers, understanding the operation and tuning of shocks is critical. For the serious race driver, that understanding is less critical, but still very important. In fact, most people would agree that a race driver that does not understand shocks today will never be a consistent winner, nor make it far in a professional racing career.

For the performance driver - the HPDE or track day driver – a basic understanding of how shocks work and what to do with them may be even more important since they rarely have an engineer to rely on. When you're both driver and engineer, at least the debrief from one to the other is much quicker!

This eBook, then, is written for both the amateur performance driver and serious race driver. And while there may be big differences between an open-wheel race car with aerodynamic downforce and street car driven on a track, the basics that I cover here all apply.

So, let's begin our discussion on shock absorbers with a correction. The term "shock absorber" really is a misnomer. The correct term is "damper." Dampers do not absorb shocks, they dampen the effects of bumps, or irregularities in the track surface; they dampen the forces of the car's springs. Having said that, in North America at least, dampers are most commonly referred to as shock absorbers, so I will as well to avoid confusion.

One of the things you must not lose perspective of is that the shocks do not act in isolation or independently of the springs, anti-roll bars, suspension geometry, aerodynamics, or even the driver. It is easy to get caught up in only tuning the shocks, and forget the rest. But if the other components are not in line with the shocks, or vice versa, the car will never perform at its peak. You should never focus only on the shocks to solve a handling problem. Look at the overall package.

Shock absorbers are a kind of "helper spring" during Bump (when the suspension and shock are being compressed), and an "energy absorber" in Rebound (extension) as they control the "spring back" of the springs. They also control the speed at which the car rolls (leans) in corners, dives under braking, and squats under acceleration.

We need to look at the function of the shocks from two separate perspectives. First, what they do when the car goes over bumps in the track surface, which I'll put under the heading "Dampers"; and second, how they effect the handling of the car, which I'll refer to under the heading "Handling Tuners."

DAMPERS

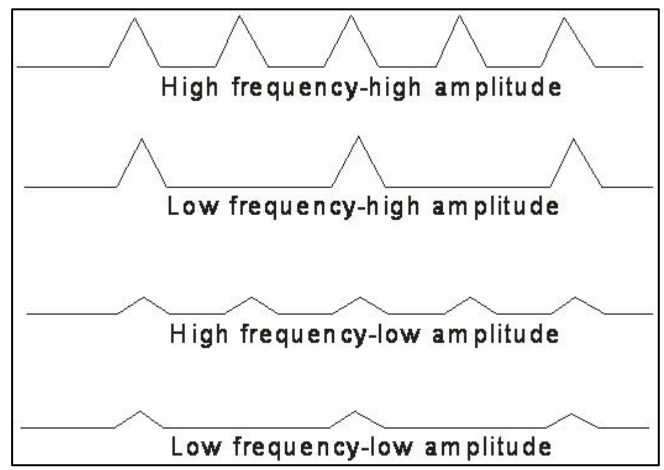
As I said, shocks dampen the effects of irregularities in the track surface. That is, as the car hits a bump, for example, and the suspension/spring compresses, the shock does two things:

1. It acts as an auxiliary spring, slowing down the compression of the spring.
2. It controls the resulting extension, or rebounding, of the spring after it has compressed.

These two duties of the shock are referred to, appropriately, as Bump (or Compression) and Rebound (or Extension).

As a driver, to be able to accurately communicate what the car is doing over the bumps in the track, you must have an understanding of the types of track surface irregularities. Track irregularities can be divided into four types based upon their size (amplitude), and how closely spaced apart they are (frequency):

- High frequency/high amplitude: Many large, severe (high amplitude) bumps spaced closely together (high frequency).
- Low frequency/high amplitude: Large, severe (high amplitude) bumps spaced far apart (low frequency).
- High frequency/low amplitude: Many small (low amplitude) bumps space closely together (high frequency).
- Low frequency/low amplitude: A few small (low amplitude) bumps spaced far apart (low frequency).



In tuning the car's shocks to help over the track's bumps, dips, hills and undulations, think in terms of these four different types of surface irregularities. Doing so will help you and/or your engineer decide what type of change the shocks require.

The ultimate goal in tuning the shocks for track irregularities is to help keep the tires in full contact with the track surface as much as possible. Obviously, if the car hits a bump, causing the tires to bounce or skip across the tops of the bumps, the car has lost traction. The result is you cannot drive as quickly as if the suspension was more compliant, allowing the tires to follow the undulations in the track surface.

Of course, you can make the springs and shocks very soft, allowing much suspension travel, to follow the bumps and dips. If you did that, though, the car may hit one bump and then continue to bounce. That is not good when you hit the next bump, and the next bump, and the one after that. Also, if the springs and shocks are too soft, the car's ride height will have to be high enough to avoid bottoming out (raising the center of gravity, and reducing the effectiveness of the aerodynamics of the underside of the car), and the responsiveness of the car will suffer (it will feel slow to react and roll a lot in the turns).

The trick is finding the right combination between being soft enough to allow the suspension to absorb the track irregularities, and stiff enough to control the ride height of the car and keep the handling responsive.

HANDLING TUNERS

When looking at shocks from the point of view of a component to tune the chassis, and therefore the handling of the car, understand that they only play a role in transient situations. In other words, they are only a factor when the car is changing from acceleration to braking, from braking to acceleration, from straightline to cornering, from cornering to straightline, or any and all combinations of these dynamics. Although a car on a race track is almost always doing some combination of these dynamics, there are some moments when a car is in a steady-state situation. Shocks play no role whatsoever in steady-state situations.

For example, when you reach the end of a straightaway and begin braking, the shocks play a role, and can be used to tune the drivability and handling. When you turn in to a corner, the shocks play a role. When you finish braking and your foot eases off the pedal, the shocks play a role. When you begin to accelerate, the shocks play a role. But, if the corner is quite long, where you are holding the steering wheel in one place and not accelerating or deccelerating – you are in a steady-state situation with no speed or direction change – the shocks are no longer a factor. At that point, it is the chassis' center of gravity, anti-roll bars, springs, suspension geometry, aerodynamics, and driver inputs that are going to determine the car's handling characteristics. Making changes to the shocks to attempt a change in the steady-state handling of a car is a waste of time and effort.

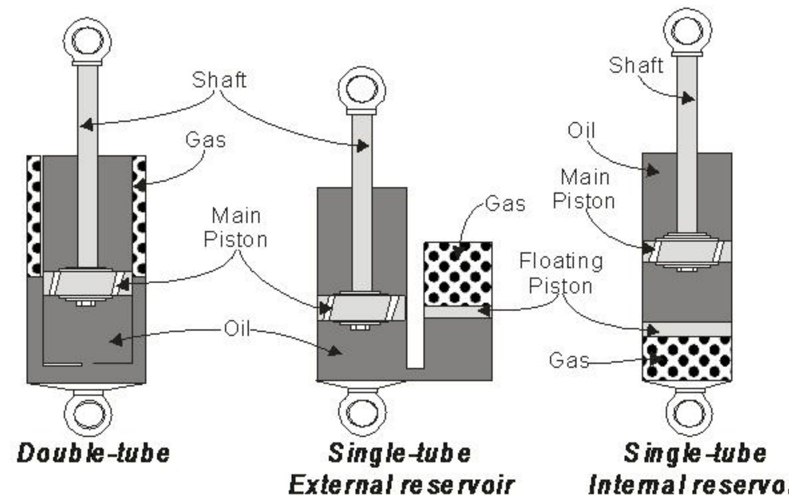
As a car turns into a right-hand corner, weight transfers from the right to the left side of the car, causing the car to lean, or roll, to the outside of the turn. As the car rolls, the springs on the outside (the left side) of the car compress and the springs on the inside (the right side) of the car extend. Ultimately, the amount the car rolls – and the amount of weight that transfers from one side of the car to the other – is determined by the spring rate (their stiffness), the anti-roll bars (their stiffness), and the suspension geometry (roll center). The shocks have no effect on this. However, they do effect the **speed** at which the weight transfer and roll occurs. Shocks are a "timing" tool, not a "quantity" tool – they can only slow down or speed up the handling characteristic, not the degree or amount of it.

One other very important function of the shocks is to help control the ride height of the car. This is critical on ground effect cars, or cars with large flat-bottoms where pitch, roll and track-to-undertray clearance effects the aerodynamic efficiency of the car.

SHOCK CONSTRUCTION

Although there are very big differences in the detail design and construction of the various shocks used in racing and performance driving (Dynamic, JRZ, Koni, Ohlins, Penske, Sachs, Tokico, and the original equipment that came with the car, etc.), the basic layouts are similar. There are two different types of shocks: single-tube and double-tube.

A shock is simply a cylinder with a piston attached to a shaft inside that telescopes up and down. Inside this cylinder is a fluid (oil). The ends of the tube and shaft are connected to the suspension, its movement forcing the shaft and piston to slide up and down in the tube. Obviously, as the piston moves, it tries to compress the oil. Because oil is very difficult to compress, instead of compressing it, the oil is allowed to flow through holes in the piston.

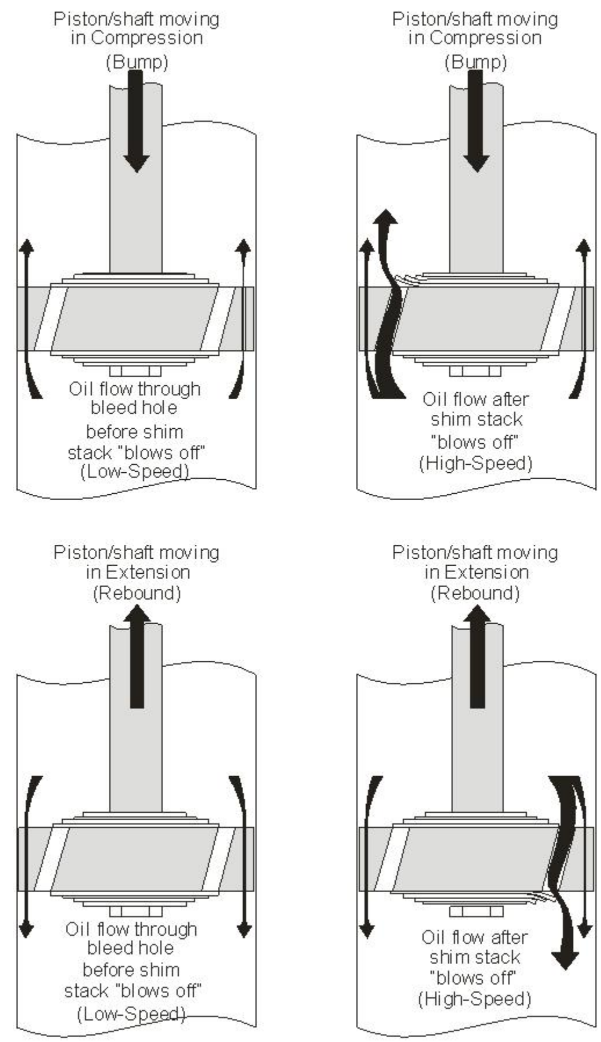


The piston, in a common shock design, has a number of holes, or orifices, that are partially covered by a number (sometimes as few as one) shims (flat steel washers). As the pressure of the flow of oil through the piston increases – from an increase in force applied to the shock shaft (from a bump in the track, for example, pushing up on the tire/wheel, through the suspension) - these shims flex enough to allow the oil to flow through the orifice. The thickness and number of these shims determine the force required for the oil to open them and allow the flow through that particular orifice. The overall combination of the size and layout of the orifices in the piston, along with shims covering the holes, determines the force developed by the shock, and therefore the characteristics of the shock.

As you can see in the illustration on the next page, in both the Bump and Compression direction, during low piston speed (I'll explain low and high-speed piston movement soon) the oil is forced through small orifices in the piston. These orifices are called "bleed holes." Some shocks do not use bleed holes, relying instead on oil "leaking" past the piston seals (this tends to make the Low-Speed characteristics of the shock to be quite stiff or harsh). When the velocity of the piston movement becomes high enough, the oil has enough force to "blow off" the valve shim stack, opening up a larger hole in the piston.

The exact layout and design of the shock piston, bleed holes and valve shims will be different than that used in the illustration. In fact, each shock manufacturer has their own specific design, each with their own pros and cons. Some shocks use bleed holes - actual holes drilled in the piston. Others use a needle and jet system to allow adjustment of the bleed size externally. These two systems can and are sometimes used together.

The size of the metering orifice of the bleed holes are usually adjusted by way of needle valves. This is what you are doing when you adjust the external Low-Speed Bump or Rebound adjuster – you are increasing or decreasing the size of the orifice in the bleed holes.



If you think about it, as the piston strokes into the tube and oil flows through it to the other side, more and more of the shaft is also entering the tube. As the shaft enters the tube it takes up some of the volume of the tube, meaning there is less room for the oil. The result is there is no room for the oil to flow to, so the shock would then hydraulically lock up – the piston could not move further into the tube without being able to compress the oil, which takes a very great force. So, shocks are designed so that as the piston moves further into the tube, the volume of the tube essentially becomes larger. How? By allowing the oil to push against another floating piston which compresses a gas (typically nitrogen). This secondary floating piston and gas is either incorporated within the tube, or it has its own separate tube – called an external canister or reservoir - attached and fed by a flexible or solid tube. This is how a single-tube shock is arranged.

In a double-tube shock, the area where the oil is allowed to go and compress the gas is incorporated into another outer tube surrounding the main tube. Double-tube shocks are used a lot on passenger vehicles, but not that often on race cars, as they generally are a little larger and they don't dissipate the heat very well.

Shocks dissipate energy, turning vertical movement into heat. That heat is then dissipated into the air through the body of the shock. The performance of an overheated shock, whether due to an external heat source or lack of cooling airflow around it, will suffer greatly.

As the oil flows through the piston bleed holes, tiny air bubbles can form in the oil. This is called "cavitation," and results in the oil being able to be compressed slightly. It also reduces the viscosity of the oil. This changes the efficiency and characteristics of the shock – they become "softer" - which is certainly not something you want (you want your shocks to behave consistently). Generally, the more gas pressure there is in the shock, the less susceptible the oil is to cavitation. However, too much gas pressure and the shocks will not be compliant enough, resulting in a harsh ride over bumps; and it will be less sensitive to minor adjustments and small piston movement. Most shocks use a gas pressure in the range of 75 to 350 psi, depending on the shock design, the application, and the track. The goal is to run with the lowest possible pressure that still protects the oil from cavitation.

Most good racing/performance shocks today allow you to adjust the Bump without affecting the Rebound, and vice versa. As well, you should be able to change the High-Speed characteristics without affecting the Low-Speed, and vice versa. With less expensive shocks, or ones not made for the track, you can't do this. Obviously, to get the full potential from your car, you need to be able to adjust specific characteristics of the shock without affecting others.

With a proper racing shock these changes are made externally by way of the adjusters and/or the canister gas pressure. The most popular shocks today are three-way adjustables, allowing tuning of the Low-Speed Bump, High-Speed Bump and the Rebound, through three separate external adjusters. Some shocks only allow one adjustment (typically Bump), some two (Bump and Rebound), some three (Low-Speed Bump, High-Speed Bump, and Rebound), and some are 4-way adjustable (Low-Speed Bump, High-Speed Bump, Low-Speed Rebound, High-Speed Rebound). To make a larger change in the shock's characteristics, you will have to disassemble the shocks and change the piston design or the shim stack (the number, order, diameter and thickness, and the pre-load on the shims).

SPRING RATES

Any discussion of shocks must include springs as well, as obviously they (and anti-roll bars) work together – or, at least, they should! So, let's get a brief understanding of springs before we move on.

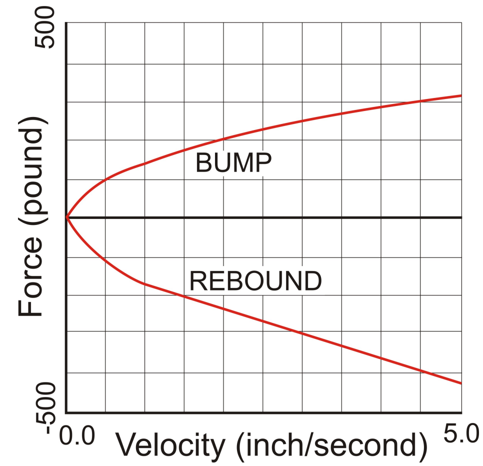
As you know, springs compress and extend. The amount of force it takes to do that determines the spring rate. A spring is measured by compressing it one inch, and measuring the amount of force it takes to do that. For example, if it takes 500 pounds to compress a spring one inch, then that spring has a rate of 500 pound/inch. In most cases, spring rates are linear in the ranges used on race cars, meaning that if it took 500 pounds to compress the spring one inch, another 500 pounds would compress it another inch, and so on. Of course, with a coil spring, once the coils begin to bind as the spring reaches its maximum compressed length, it will require much more force to compress it. In theory, that should never happen with a spring on a race car (unless you're racing in NASCAR, where they use "coil bind" to tune the car's handling).

Now, some springs are designed to progressively get stiffer with more force. For obvious reasons, these are referred to as "progressive springs." In this case, as an example, it may require 500 pounds to compress the spring one inch, but require 550 pounds to compress it the next inch, and 600 pounds to compress it a further inch – it progressively gets stiffer the further the spring is compressed.

The most important point to understand about springs is that they are **displacement** sensitive. In other words, the force they produce is dependent on the displacement of the spring (distance it is compressed).

SHOCK RATES

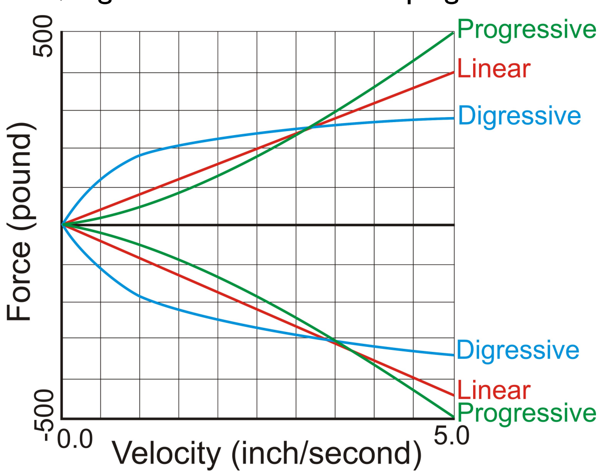
If springs are **displacement** sensitive, then shocks are **speed** or velocity sensitive. Where springs are rated by force versus distance, shocks are rated by force versus speed (velocity). It has nothing to do with the speed the car is travelling; it has to do with the speed the shaft of the shock is travelling. I referred to Low-Speed and High-Speed movements earlier, and this is what I was talking about. Some movements of the shock result in a slow movement of the piston, while others cause it to move quickly. For example, gently turning into a corner would likely cause a Low-Speed movement of the piston, while hitting a sharp bump in the track surface or very quickly turning the steering wheel would result in High-Speed movement of the piston.



Shocks are rated by this speed, in inches per second, that the piston/shaft moves, both in compression (Bump) and extension (Rebound). Their rates are measured on a shock dynamometer, with their shaft speed (velocity) versus force, both in compression (Bump) and extension (Rebound), and displayed on the graph to the right.

Typically, the faster the shock piston moves, the more resistance there is to the movement. In other words, the faster the piston moves, the more force required to move it. However, the relationship between force and piston velocity is not necessarily linear. Sometimes it is progressive or digressive. What does this mean?

A linear characteristic means the damping force increases at the same rate as the piston speed. Progressive means the damping force increases at a greater rate than the increase in piston speed. And, digressive means the damping force increases at a lesser rate than the increase in piston speed.



Through careful use of various piston shapes, orifices layouts and sizes, and shims, a combination of linear, progressive and/or digressive can be achieved. For example, the curve can start out being linear, and then change to digressive; or, start out progressive and then change to digressive. It's all a matter of what you what the shock to do.

Bumps in the track surface cause quick, High-Speed movement or displacement of the shock's shaft and piston. This **bump-induced** shock function is generally in the 1 to 6 inch/second range. **Driver-induced** movement in the shock is considered Low- Speed function, in the range of 0 to 1 inch/second.

By changing the internal valving (piston, piston bleed holes, shims, etc.), and the external adjusters, the shock's characteristics can be changed dramatically. This, in turn, will change the car's transient handling characteristics, as well as the car's ride quality over track irregularities.

BUMP RUBBERS & PACKERS

Bump rubbers were initially used to stop the shock piston and shaft from bottoming out within the shock body and damaging it when the car experienced an extreme bump in the track surface. They allowed the spring and shock to remain relatively soft – compliant, so the car handled the bumps well – while stopping the car, and therefore the shocks, from bottoming out.

Bump rubbers are typically made of a cellular polyurethane in varying densities, shapes and sizes to alter its spring rate characteristics. They go over the shock shaft and are compressed between the shock body and the top eye of the shock as it compresses.

Sometimes, though, bump rubbers are used to create a form of rising-rate spring and shock combination. As the shock reaches a certain pre-determined amount of compression, the bump rubber begins to be compressed. And, as the bump rubber is much stiffer than the spring, it results in an overall increase in spring rate. The bump rubber really becomes an auxiliary spring.

Packers, which are made from hard plastic, are used to adjust the gap between the bump rubber and the shock. This changes the point where the bump rubber begins to compress, and therefore the characteristics of the shock/bump rubber.

The idea in using bump rubbers or packers to tune the handling of the car is to allow the car to be relatively soft through the initial part of the travel, and then to rely on the stiffness of the bump rubber or packer to support the car before the chassis bottoms out on the track surface.

Packers are most often used on very high downforce cars. When these cars are at high speed on the straightaways, the aerodynamics force the car down onto the packers, whose job it is to stop the suspension travel just short of having the bottom of the chassis hit the track surface. When the car begins to slow for corners, the aerodynamic downforce is reduced, the car raises slightly, allowing adequate suspension travel in the turns. In other words, the packers are used as spacers to stop the car from bottoming on the straights.

SHOCK TUNING

Of most concern to you once you've determined which type and brand of shocks you will run on your car is what you can do to adjust and tune them. Let's look at some general shock tuning "rules." But please understand that this is not a complete and all-encompassing list of every change and adjustment you can use – but it will give you the basics.

As a general rule, you would use and adjust low shock shaft speed (in the range of 0 to 1 inch/second) to tune the handling, feel and grip of the car; and high shock shaft speed (from 1 to 6 inch/second) to control the car over track irregularities. Low-Speed damping affects the "feel" of the car when braking, turning and accelerating. High-Speed damping affects the car's grip when travelling over bumps in the track surface.

Most drivers can only feel changes in the 0 to 2 inch/second range – the Low-Speed to just barely into the High-Speed range. This is the range that you mostly work in when trying to change the handling of the car. High-Speed adjustments are primarily used to control the way the car handles track surface irregularities.

So, to improve the ride quality over bumps, adjust the High-Speed characteristics. This is done primarily with the High-Speed Bump, but reducing the High-Speed Rebound can also help (to a point). In fact, too much High-Speed Rebound can make the car feel very harsh over low amplitude/low frequency bumps; too little and the car will continue to oscillate for too long after the bump.

The shock canister pressure can also be used to tune the car's ride quality – but it has little to no effect on the handling. Too much canister pressure causes harshness over low amplitude/high frequency bumps (many little bumps); but has little effect on high amplitude/low frequency bumps (a few large bumps).

Low-Speed adjustments control the handling of the car – the transient response and the rate of roll, dive and squat. Usually, an increase in Low-Speed damping will make the car feel more responsive, without affecting the ride quality. Often, that will also make the tires work harder, and raise their temperatures.

As I said earlier, shocks can be thought of as a "timing device" for the handling characteristics, and the springs and anti-roll bars as the "quantity devices." That is, the ultimate behavior of the car may be to oversteer in a corner – due to the springs, anti-roll bars, suspension geometry and aerodynamics – but the timing of where in the corner is determined more by the shocks. If a car has a tendency to oversteer, by adjusting the shocks you may be able to delay the onset of it until later in the corner. The shocks control the timing of the car's handling characteristics.

From a handling point of view, shocks only come into play in transient situations. Remember, they are velocity dependent. They don't do anything on a straight, smooth track. They don't do anything once the car has taken a set in a corner. They don't do anything when the car is in a steady-state situation. Although a race car is not in a steady-state very often on a race track, it is important to be aware of when it is, for there is no point in trying to tune the shocks to adjust a steady-state handling characteristic. You must determine if the handling problem you are trying to change is a steady-state one, or a transient one. If it is transient or track surface related, look towards the shocks. If it is steady-state, look towards the springs and anti-roll bars, or aerodynamics.

In deciding whether you should be tuning the shocks or another component of the car, ask yourself what you and the car are doing during whatever handling characteristic it is you are trying to change. Are you just beginning to turn in to the corner (transient)? Are you just coming off the brakes (transient)? Just getting back on the throttle (transient)? Progressively squeezing down on the throttle (transient)? Driving over track surface irregularities? Or, are you holding the steering wheel and throttle steady, going through a long, sweeping turn (steady-state)?

Shocks and driving style go hand in hand. Shock adjustments will play one of the key roles in tuning to suit one driver or another – one driving style versus another. If a driver is very abrupt with his braking, turning and accelerating, he will require very different shock settings than a driver with a more smooth, flowing driving style. Shock tuning is the main reason why one driver may not be able to go as fast as another driver in the same the car, until adjustments are made to suit his particular style.

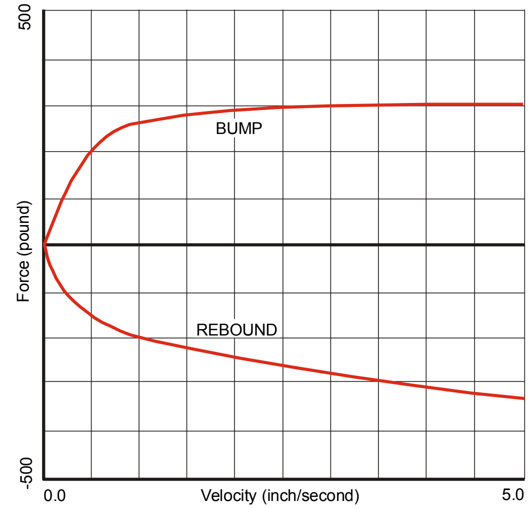
A car with shocks that have too much Rebound may have to be run with lots of static ground clearance – a high ride height. Why? As this car hits a bump at speed, the springs and shocks compress, bringing the chassis closer to the track surface. With too much Rebound, the shocks take a long time to extend after being compressed. Before the shocks and springs are fully extended back to static ride height, the car hits another bump causing the car to sit even lower still. Then it hits another bump, sucking it down even lower again. This continues, with the shocks "jacking" themselves down, the car bottoming out, the driver reporting that, and the crew raising the static ride height. As you can see, it has nothing to do with the car's ride height setting. It has to do with the shocks' Rebound setting.

So, if your car is bottoming, or you want to lower the ride height without it bottoming, try reducing the high speed Rebound. That may be accomplished by an external adjustment of the Rebound setting, or by changing the internal valving or piston type.

When the oil flow through the piston causes the valve stack to open, or "blow off," the shock is going from Low-Speed operation to High-Speed operation. Generally, the **driver-induced** (braking, turning, accelerating) shock movements are in the Low-Speed range, before the valve stack has blown off; and the **bump-induced** movements are in the High-Speed range, after they have opened. How soon - or, more accurately, at what shaft speed – the valve stack opens is determined by the piston design and the amount, size and pre-load of and on the valve stack.

For example, a piston without a bleed hole will cause the car to feel harsh – very hard on small bumps – as it requires a higher shaft speed before the valve stack blows off. A piston with a dish will act similarly - the deeper the dish, the higher the shaft speed before opening. As you can see, the piston design can play an important role in the feel of the car for the driver.

If you are driving a car where ride height is critical for aerodynamic reasons, you may want to use the shocks to help control it. In this case, for good mechanical grip while controlling the ride height, try a shock with lots of Low-Speed Bump and Rebound, and little High-Speed Rebound – the High-Speed Bump would be tuned to suit the situation. This shock set-up might produce a dyno graph that looks something like the one just below. Why? First, the Low-Speed Bump and Rebound would make the car feel responsive, and limit the amount of roll and pitch. Second, the lack of High-Speed Rebound would stop the car from "jacking down," keeping the car at an acceptable ride height. And the relatively little High-Speed Bump and Rebound would allow for adequate suspension movement over bumps. Of course, it would be very easy to go too far with the little High-Speed Rebound. With too little, the Rebound will not absorb the energy compressed in the springs after a bump, and the car will continue to oscillate for too long.

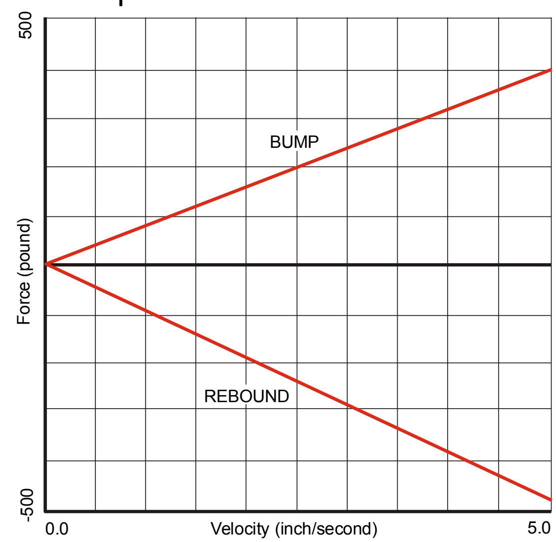


How much is "lots" and "little" in the above scenario? Good question - one that can only be answered with experience and testing. If you're driving a car where ride height control is not so critical (a production-based car, for example), then this approach may not be ideal.

It used to be that shocks always had more Rebound damping than Bump. This was to control the energy stored in the spring from the bumps in the track surface. That is not necessarily the case anymore. Often now, the Rebound and Bump are relatively equal, and sometimes the Rebound is even less than the Bump. One reason for this is that it may be more important to use the shocks to control the roll and pitch of the car than it is to dampen the effects of track surface irregularities.

For most drivers, they like the feel of a shock set-up with relatively lots of Low-Speed damping, and less High-Speed – particularly in Bump. This is a Digressive curve as shown in the graph above. This gives the car a very responsive feel upon initial turn-in to a corner.

Now, some people believe that one of the reasons Michael Schumacher (and Aryton Senna before him) was so fast at Ferrari was because he preferred a shock set-up with a more linear characteristic. The shock dyno graph might look like the one to the right. This means the shock is softer in the Low-Speed range, and stiffer in the High-Speed range. Ultimately, this may lead to the car having more overall grip, but giving the driver less feel, particularly at turn-in – it is less responsive and predictable when you initially turn into the corner. It may also require turning in slightly earlier, and then waiting a little longer for the car to respond (change direction) and then take a set. This, obviously, takes a lot of confidence and experience to be able to "trust" the car to eventually take bite and turn. But, it may require less overall movement of the steering wheel; and in some people's opinion, result in more grip, leading to a higher mid-corner minimum speed.



To control the roll and pitch (dive and squat), adjust the Low-Speed Rebound. If you increase the Low-Speed Rebound, you will reduce the chassis roll and pitch without having to increase the spring or anti-roll bar rates. In fact, the Rebound adjustment is the primary tool in changing the handling and responsiveness of the car. It has a greater effect on the feel of the car than adjusting the Bump.

Sometimes, a car feels as though it is rolling too much at either the front or the rear. If that's the case, increase the Low-Speed Rebound at that end.

Low-Speed Bump is a good way of controlling the feel at corner entry (the initial turn-in), and when putting the power down (accelerating out of a turn). To improve the initial turn-in responsiveness, increase the Low-Speed Bump and/or Rebound at the front – primarily the Rebound. This makes the car feel more stiff when turning into the corners, giving you the responsiveness you're looking for. To make the car put the power down better, reduce the Low-Speed Bump at the rear, which allows a little more weight transfer onto the outside rear tire, increasing its grip level.

When adjusting the oversteer-understeer balance, try to determine if the imbalance is caused by the car being too stiff (not enough roll, feeling like a go-kart), or if the car rolls too much (feels like an old Cadillac).

If the car is understeering too much, and it feels too stiff, try reducing the front Low-Speed Bump and/or increasing the rear Low-Speed Rebound. This will allow the front of the car to roll a little more – much like putting softer front springs in the car or softening the front anti-roll bar. If the understeer feels as though it is caused by too much roll – it feels like a Cadillac, the front end falling over – then increase the front Low-Speed Bump and/or reduce the rear Low-Speed Rebound. This helps support the front of the car, reducing the amount of roll.

If you have an oversteering car that feels too stiff, reduce the rear Low-Speed Bump and/or increase the front Low-Speed Rebound. This has a similar effect as reducing the rear spring or anti-roll bar rates. If the oversteer feels as though it is caused by too much roll, increase the rear Low-Speed Bump and/or increase the front Low-Speed Rebound.

To reduce chassis roll, and hopefully increase the grip, increase the Low-Speed Bump at the end of the car that needs the improvement.

To give the car a "snappier," more responsive feel, instead of a slow, smooth roll, you can try using a piston with more of a dish. This causes the valve shims to snap open when they blow off in the progression from Low-Speed to High-Speed operation.

To control the ride height of the car - to prevent the chassis from bottoming without having to run too high a ride height – increase the Low-Speed Bump and/or reduce the High-Speed Rebound at the front and the rear. This reduces the shocks' tendency to "jack" the car down.

If you are using bump rubbers or packers, watch for the car feeling "darty," or the cornering grip to suddenly go away. If the suspension suddenly hits a bump rubber that is too solid, or a packer, as the car rolls in a turn, the spring rate on the outer side of the car has increased dramatically. This extreme increase in spring rate can suddenly decrease the cornering grip right when you need it most.

One thing that every driver should do from time to time is what is referred to as a "shock sweep." Start off with all of the adjusters (Bump and Rebound, Low-Speed and High-Speed, front and rear) set at full soft, and then go drive the car for a few laps – enough for you to get a good feel for the car with these settings. Then, systematically go to full stiff with each adjuster, one at a time on the front and then the rear, driving the car for a few laps each time to get a read on it. Make note of how each adjustment changes the handling, the ride quality, and the overall feel to you. It is important for you to write down what each change does so that, later, when you are trying to change a specific characteristic, you can look back at your notes and know exactly what will accomplish what you want.

As I said earlier, the shocks are just one part of the overall package. If you change to much stiffer springs, for example, you will have to change the shocks to match, and vice versa. Stiffer springs typically require less bump and more rebound, and softer springs require more bump and less rebound. Either too much or too little shock control for the springs will mean the car's performance will suffer.

Ultimately, to tune the shocks, and therefore your car's handling, you have to think like a shock. In other words, identify exactly what your car is doing, where it's doing it, and what you're doing to the controls when it's doing it… and then picture what the shock on each corner of the car is doing when that's happening. If you want to slow down the extension of a shock, stiffen the Rebound; if you want the shock to be able to extend quicker and more easily, soften the Rebound. If you want the shock to compress slower, stiffen the Bump; if you want it to compress quicker and more easily, soften the Bump. Mostly, I'm talking about all Low-Speed adjustments here, as again, it's the Low-Speed that is going to have the most effect on the handling of the car; the High-Speed adjustments will have the most effect on the ride of the car. Having said that, High-Speed adjustment will sometimes make a difference to the handling; you may have to try it to see what effect it has on your car.

Finally, the more you understand about how shocks work, and how they interact with other factors and components of the car (springs, anti-roll bars, suspension geometry, and even aerodynamics), the better you'll be at tuning your car's handling. The better you identify what's happening with your car, where, and what you're doing at that time to the controls, the better you'll be at tuning your car's handling. And the more you picture what's happening with the shocks on each corner of your car when all of this is going on, the better you'll be at tuning your car's handling.

ABOUT THE AUTHOR: Ross Bentley

I'm not a shock engineer. But I've worked with a few really good ones throughout my thirty-plus years of driving race cars. I've also spent a few seasons where I was the driver/engineer, doing all of the shock dyno work, tuning, and setup work. I learned a lot from working with the real engineers, and from the mistakes I made – and even from when I got the setup right every now and then!

I've been fortunate to race some pretty cool cars throughout my career, from sprint cars on short ovals to Indy cars, and from club racing in Formula Fords and Showroom Stock cars to GT and Prototype cars. I've won a few races along the way, and when I got a ride with the factory-supported PTG BMW team in 1998 I won the United State Road Racing Championship. And one of my most satisfying wins was the 2003 Daytona 24-Hour race, driving an LMP-2 car.

I've probably learned as much from coaching drivers as I have from my own driving. In that role, I've often played the liaison between driver and engineer, helping interpret and communicate what the driver was feeling. I don't know if I learned more from the drivers or the engineers, but I certainly owe a lot of gratitude for what they taught me.

Some people will tell you that tuning shocks is an art and science, with a little magic thrown in for good measure. If that's the case, Jeff Braun is a master artist, brilliant scientist, and magician all rolled into one. He's the best race car engineer I've ever met or seen, and what I've learned from him is immeasurable and invaluable. I'll never forget the 3-day test years ago at Sebring with Jeff where all we did was work on different shock setups on a prototype car, with me driving non-stop and Jeff showing me dyno graphs and explaining how the art, science and magic works together. I learned more in those three days than at any other time in my life. While Jeff is technically not an author of this eBook, he did take time to read and proof it, giving me the confidence to share it with you. Thank you, Jeff!

For answers to questions or information on the coaching/training services I offer, go to http://speedsecrets.com, or contact me at ross@speedsecrets.com.

You might also be interested in my weekly "inbox magazine," *Speed Secrets Weekly*. Please visit http://speedsecretsweekly.com to learn more about it, and subscribe. And if you're an instructor, check out http://HPDE-Instructor-Tips.com for my **free** eBook, *Brake,* Brake*, BRAKE: The HPDE Instructor Manifesto*. And join the conversation by following my tips for drivers and instructors on Facebook at https://www.facebook.com/DriverCoach.

Have fun!