

CAR SUSPENSION

WHAT DOES IT DO?

Apart from your car's tyres and seats, the suspension is the prime mechanism that separates your bum (arse for the American) from the road. It also prevents your car from shaking itself to pieces. No matter how smooth you *think* the road is, it's a bad, bad place to propel over a ton of metal at high speed. So we rely upon suspension. People who travel on underground trains *wish* that those vehicles relied on suspension too, but they don't and that's why the ride is so harsh. Actually it's harsh because underground trains have no lateral suspension to speak of. So as the rails deviate side-to-side slightly, so does the entire train, and it's passengers. In a car, the rubber in your tyre helps with this little problem, while all the other suspension parts do the rest.

In it's most basic form, suspension consists of two basic components:

SPRINGS

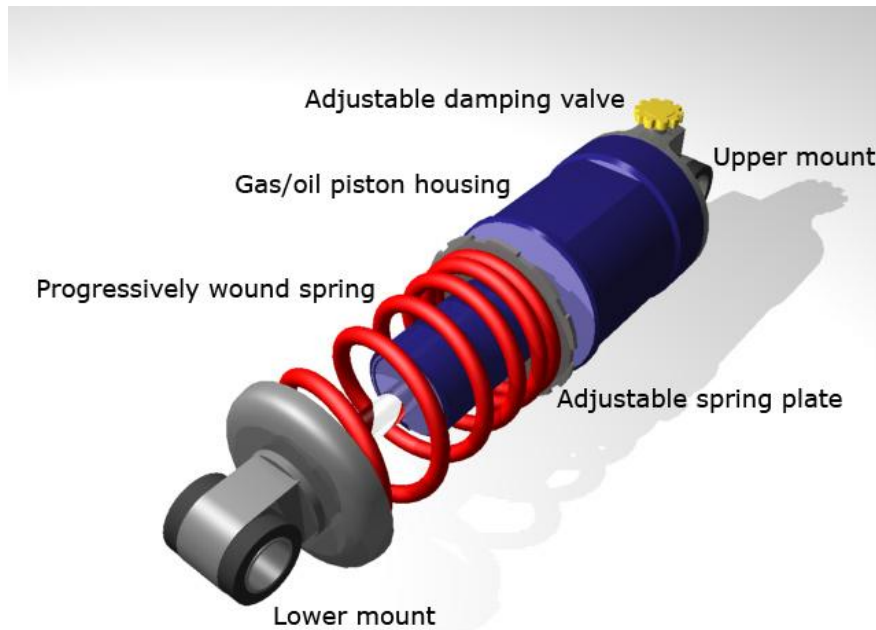
These come in three types. They are coil springs, torsion bars and leaf springs. Coil springs are what most people are familiar with, and are actually coiled torsion bars. Leaf springs are what you would find on most American cars up to about 1985 and almost all heavy duty vehicles. They look like layers of metal connected to the axle. The layers are called leaves, hence leaf-spring. The torsion bar on its own is a bizarre little contraption which gives coiled-spring-like performance based on the twisting properties of a steel bar. It's used in the suspension of VW Beetles and Karmann Ghias, air-cooled Porsches (356 and 911 until 1989 when they went to springs), and the rear suspension of Peugeot 205s amongst other cars. Instead of having a coiled spring, the axle is attached to one

end of a steel shaft. The other end is slotted into a tube and held there by splines. As the suspension moves, it twists the shaft along its length, which in turn resists. Now imagine that same shaft but instead of being straight, it's coiled up. As you press on the top of the coil, you're actually inducing a twisting in the shaft, all the way down the coil. I know it's hard to visualise, but believe me, that's what is happening. There's a whole section further down the page specifically on torsion bars and progressive springs.

SHOCK ABSORBERS

These dampen the vertical motion induced by driving your car along a rough surface and so should technically be referred to by their proper name - dampers. If your car only had springs, it would boat and wallow along the road until you got physically sick and had to get out. It would be a travelling deathtrap until the incessant vibration caused it to fall apart. Shock absorbers (dampers) perform two functions. As mentioned above, they absorb any larger-than-average bumps in the road so that the upward velocity of the wheel over the bump isn't transmitted to the car chassis. But secondly, they keep the suspension at as full a travel as possible for the given road conditions - they keep your wheels planted on the road. You want more technical terms? Technically they are velocity-sensitive hydraulic damping devices - in other words, the faster they move, the more resistance there is to that movement. They work in conjunction with the springs. The spring allows the wheel to follow the road, moving up and down. The kinetic energy of that moving unsprung mass is transmitted to the damper where it is dissipated. The damper does this by forcing gas or oil through a constriction valve (a small hole). Adjustable shock absorbers allow you to change the size of this constriction, and thus control the rate of damping. The smaller the constriction, the stiffer the suspension. Phew!....and you thought they just leaked oil didn't you?

A MODERN COIL-OVER-OIL UNIT



The image here shows a typical modern coil-over-oil unit. This is an all-in-one system that carries both the spring and the shock absorber. The type illustrated here is more likely to be an aftermarket item - it's unlikely you'd get this level of adjustment on your regular passenger car. The *adjustable spring plate* can be used to make the springs stiffer and looser, whilst the *adjustable damping valve* can be used to adjust the rebound damping of the shocks. More sophisticated units have adjustable compression damping as well as a remote reservoir. Whilst you don't typically get this level of engineering on car suspension, most motorbikes do have preload, rebound and spring tension adjustment. See the section later on in this page about the ins and outs of complex suspension units.

SUSPENSION BUSHES



These are the rubber grommets which separate most of the parts of your suspension from each other. They're used at the link of an A-Arm with the subframe. They're used on anti-roll bar links and mountings. They're used all over the place, and from the factory, I can almost guarantee they're made of rubber. Rubber doesn't last. It perishes in the cold and splits in the heat. Perished, split rubber was what brought the Challenger space shuttle down. This is one of those little parts which hardly anyone pays any attention to, but it's vitally important for your car's handling, as well as your own safety, that these little things are in good condition. My advice? Replace them with polyurethane or polygraphite bushes - they are hard-wearing and last a heck of a lot longer. And, if you're into presenting your car at shows, they look better than the naff little black rubber jobs. Like all suspension-related items though, bushes are a tradeoff between performance and comfort. The harder the bush compound, the less comfort in the cabin. You pay your money and make your choice. If you have an off-road vehicle like a Jeep Wrangler, suspension bushings are an important part of your suspension system.

SUSPENSION TYPES

In their infinite wisdom, car manufacturers have set out to baffle us with the sheer number of different types of suspension available for both front and rear axles. The main groupings are dependent and independent suspension types but this naming convention really only applies to traditional or analogue suspension systems. Even independent systems are typically joined across the car by an anti-roll bar and so are not truly independent.

From about 2006 onwards, the concept of fully independent suspension systems started to appear on cars where the anti-roll bar was replaced by sophisticated computer software connected to some form of electronically-controlled suspension. See the section later on dealing with digital suspension systems for more information.

If you know of any not listed here, e-mail me and let me know - I would like this page to be as complete as possible.

FRONT SUSPENSION - DEPENDENT SYSTEMS

So-called because the front wheel's suspension systems are physically linked. For everyday use, they are, in a word, shite. I hate to be offensive, but they are. There is only one type of dependent system you need to know about. It is basically a solid bar under the front of the car, kept in place by leaf springs and shock absorbers. It's still common to find these on trucks, but if you find a car with one of these you should sell it to a museum. They haven't been used on mainstream cars for years for three main reasons:

- Shimmy - because the wheels are physically linked, the beam can be set into oscillation if one wheel hits a bump and the other doesn't. It sets up a gyroscopic torque about the steering axis which starts to

turn the axle left-to-right. Because of the axle's inertia, this in turn feeds back to amplify the original motion.

- Weight - or more specifically unsprung weight. Solid front axles weigh a lot and either need sturdy, heavy leaf springs or heavy suspension linkages to keep their wheels on the road.
- Alignment - simply put, you can't adjust the alignment of wheels on a rigid axis. From the factory, they're perfectly set, but if the beam gets even slightly distorted, you can't adjust the wheels to compensate.



I frequently get pulled-up on the above statements from people jumping to defend solid-axle suspension. They usually send me pictures like this and claim it's the best suspension system for off-road use. I have to admit, for *off-road* stuff, it probably is pretty good. But let's face it; how many people with these vehicles ever go off-road? The closest they come to having maximum wheel deflection is when the mother double-parks the thing with one wheel on the kerb during the school-run.....

FRONT SUSPENSION - INDEPENDENT SYSTEMS

So-named because the front wheel's suspension systems are independent of each other (except where joined by an [anti-roll bar](#)) These came into existence around 1930 and have been in use in one form or another pretty much ever since then.

MACPHERSON STRUT OR MCPHERSON STRUT



This is currently, without doubt, the most widely used front suspension system in cars of European origin. It is simplicity itself. The system basically comprises of a strut-type spring and shock absorber combo, which pivots on a ball joint on the single, lower arm. At the top end there is a needle roller bearing on some more sophisticated systems. The strut itself is the load-bearing member in this assembly, with the spring and shock absorber merely performing their duty as oppose to actually holding the car up. *In the picture here, you can't see the shock absorber because it is encased in the black gaiter inside the spring.* The steering gear is either connected directly to the lower shock absorber housing, or to an arm from the front or back of the spindle (in this case). When you steer, it physically twists the strut and shock absorber housing (and consequently the spring) to turn the wheel. Simple. The spring is

seated in a special plate at the top of the assembly which allows this twisting to take place. If the spring or this plate are worn, you'll get a loud 'clonk' on full lock as the spring frees up and jumps into place. This is sometimes confused for CV joint knock.

ROVER 2000 MACPHERSON DERIVATIVE



During WWII, the British car maker Rover worked on experimental gas-turbine engines, and after the war, retained a lot of knowledge about them. The gas-turbine Rover T4, which looked a lot like the Rover P6, Rover 2000 and Rover 3500, was one of the prototypes. The chassis was fundamentally the same as the other Rovers and the net result was the the 2000 and 3500 ended up with a very odd front suspension layout. The gas turbine wasn't exactly small, and Rover needed as much room as possible in the engine bay to fit it. The suspension was derived from a normal MacPherson strut but with an added bellcrank. This allowed the suspension unit to sit horizontally along the outside of the engine bay rather than protruding into it and taking up space. The bellcrank transferred the upward forces from the suspension into rearward forces for the spring / shock combo to deal with. In the end, the gas turbine never made it into production and the Rover 2000 was fitted with a 2-litre 4-cylinder engine, whilst the Rover 3500 was fitted with an 'evergreen' 3.5litre V8. Open the

hood of either of these classics and the engine looks a bit lost in there because there's so much room around it that was never utilised. The image on the left shows the Rover-derivative MacPherson strut.

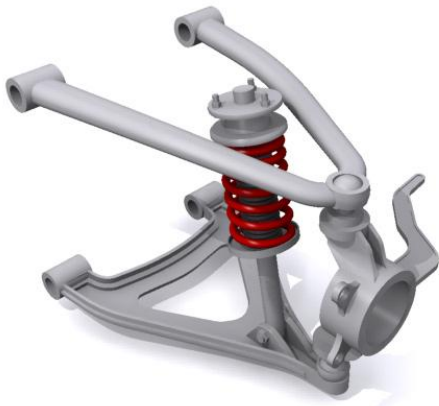
Potted history of MacPherson: Earle S. MacPherson of General Motors developed the MacPherson strut in 1947. GM cars were originally design-bound by accountants. If it cost too much or wasn't tried and tested, then it didn't get built/used. Major GM innovations including the MacPherson Strut suspension system sat stifled on the shelf for years because innovation cannot be proven on a spreadsheet until after the product has been produced or manufactured. Consequently, Earle MacPherson went to work for Ford UK in 1950, where Ford started using his design on the 1950 'English' Ford models straight away. Today the strut type is referred to both with and without the "a" in the name, so both McPherson Strut and MacPherson Strut can be used to describe it.

Further note: Earle MacPherson should never be confused with Elle McPherson - the Australian über-babe. In her case, the McPherson Strut is something she does on a catwalk, or in your dreams if you like that sort of thing. And if you're a bloke, then you ought to....

DOUBLE WISHBONE SUSPENSION SYSTEMS.

The following three examples are all variations on the same theme.

COIL SPRING TYPE 1



This is a type of *double-A* or *double wishbone* suspension. The wheel spindles are supported by an upper and lower 'A' shaped arm. In this type, the lower arm carries most of the load. If you look head-on at this type of system, what you'll find is that it's a very parallelogram system that allows the spindles to travel vertically up and down. When they do this, they also have a slight side-to-side motion caused by the arc that the wishbones describe around their pivot points. This side-to-side motion is known as scrub. Unless the links are infinitely long the scrub motion is always present. There are two other types of motion of the wheel relative to the body when the suspension articulates. The first and most important is a toe angle (steer angle). The second and least important, but the one which produces most pub talk is the camber angle, or lean angle. Steer and camber are the ones which wear tyres.

COIL SPRING TYPE 2



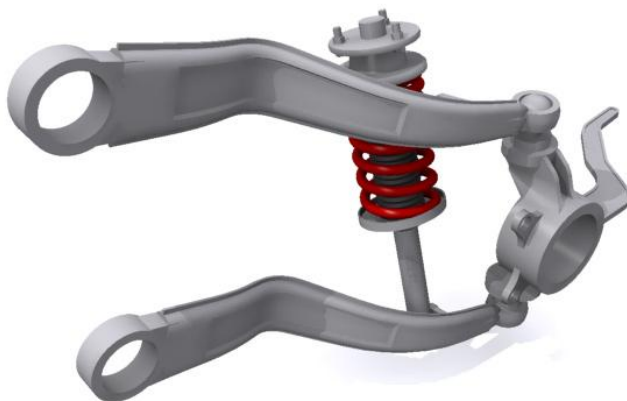
This is also a type of *double-A arm* suspension although the lower arm in these systems can sometimes be replaced with a single solid arm (as in my picture). The only real difference between this and the previous system mentioned above is that the spring/shock combo is moved from between the arms to above the upper arm. This transfers the load-bearing capability of the suspension almost entirely to the upper arm and the spring mounts. The lower arm in this instance becomes a control arm. This particular type of system isn't so popular in cars as it takes up a lot room.

MULTI-LINK SUSPENSION



This is the latest incarnation of the double wishbone system described above. It's currently being used in the Audi A8 and A4 amongst other cars. The basic principle of it is the same, but instead of solid upper and lower wishbones, each 'arm' of the wishbone is a separate item. These are joined at the top and bottom of the spindle thus forming the wishbone shape. The super-weird thing about this is that as the spindle turns for steering, it alters the geometry of the suspension by torquing all four suspension arms. They have complex pivot systems designed to allow this to happen. Car manufacturers claim that this system gives even better road-holding properties, because all the various joints make the suspension almost infinitely adjustable. There are a lot of variations on this theme appearing at the moment, with huge differences in the numbers and complexities of joints, numbers of arms, positioning of the parts etc. but they are all fundamentally the same. Note that in this system the spring (red) is separate from the shock absorber (yellow).

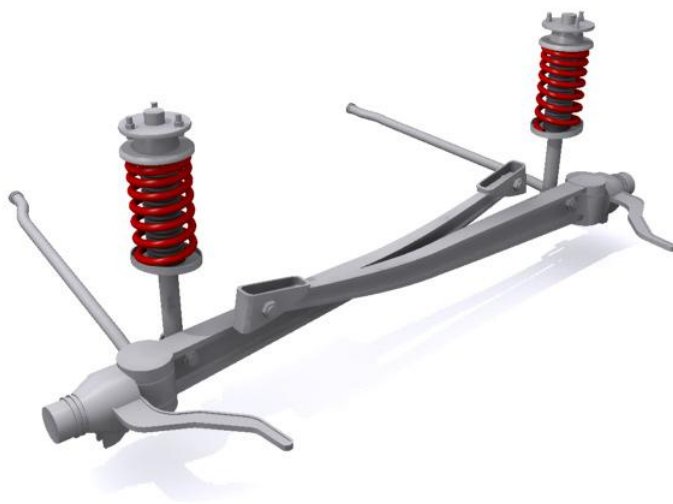
TRAILING-ARM SUSPENSION



The trailing arm system is literally that - a shaped suspension arm is joined at the front to the chassis, allowing the rear to swing up and down. Pairs of these become twin-trailing-arm systems and work on exactly the same

principle as the double wishbones in the systems described above. The difference is that instead of the arms sticking out from the side of the chassis, they travel back parallel to it. This is an older system not used so much any more because of the space it takes up, but it doesn't suffer from the side-to-side scrubbing problem of double wishbone systems. If you want to know what I mean, find a VW beetle and stick your head in the front wheel arch - that's a double-trailing-arm suspension setup. Simple.

TWIN I-BEAM SUSPENSION



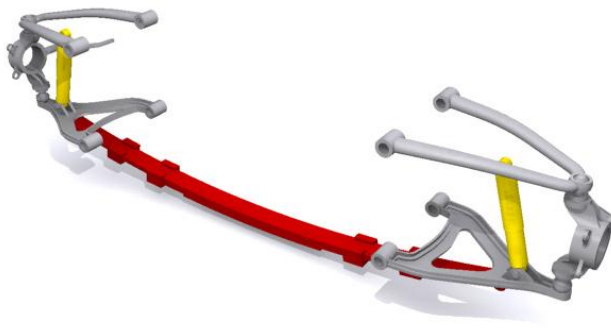
Used almost exclusively by Ford F-series trucks, twin I-beam suspension was introduced in 1965. This little oddity is a combination of trailing arm suspension and solid beam axle suspension. Only in this case the beam is split in two and mounted offset from the centre of the chassis, one section for each side of the suspension. The trailing arms are actually (technically) leading arms and the steering gear is mounted in front of the suspension setup. Ford claim this makes for a heavy-duty independent front suspension setup capable of handling the loads associated with their trucks. In an empty truck, however, going over a bump with twin I-beam suspension is like falling down stairs in leg irons.

MOULTON RUBBER SUSPENSION



This suspension system is based on the compression of a solid mass of rubber - red in both these images. The two types are essentially derivatives of the same design. It is named after Dr. Alex Moulton - one of the original design team on the Mini, and the engineer who designed its suspension system in 1959. This system is known by a few different names including cone and trumpet suspension (due to the shape of the rubber bung shown in the right hand picture). The rear suspension system on the original Mini also used Moulton's rubber suspension system, but laid out horizontally rather than vertically, to save space again. The Mini was originally intended to have Moulton's fluid-filled Hydrolastic suspension, but that remained on the drawing board for a few more years. Eventually, Hydrolastic was developed into Hydragas (see later on this page), and revised versions were adopted on the Mini Metro and the current MGF-sportscar. For a while, Moulton rubber suspension was used in a lot of bicycles - racing and mountain bikes. Due to the compact design and the simplicity of its operation and maintenance, it was an ideal solution, but has since been superseded by more advanced, lightweight designs. If you're interested in further reading, there's a memoir book out now about Alex Moulton and his original designs. [Alex Moulton - a lifetime in engineering](#).

TRANSVERSE LEAF-SPRING



This system is a bit odd in that it combines independent double wishbone suspension with a leaf spring like you'd normally find on the rear suspension. Famously used on the Corvette, it involves one leaf spring mounted *across* the vehicle, connected at each end to the lower wishbone. The centre of the spring is connected to the front subframe in the middle of the car. There are still two shock absorbers, mounted one to each side on the lower wishbones. Chevy insist that this is the best thing since sliced bread for a suspension system but there are plenty of other experts, manufacturers and race drivers who think it's junk. It's never been clear if this was a performance and design decision or a cost issue, but this type of system is very rare.

Historically, Triumph used transverse leaf spring suspension on the front of their small chassis cars (Herald, Vitesse, Spitfire & GT6). In the good old British school of thought, they did this because it was cheap. The spring was bolted to the differential, rather than the chassis, and under (very) hard cornering you got jacking and tuck-under. If you got this whilst driving and panicked enough to let off the gas, or worse, step on the brake, you got massive over-steer, and pirouetted off into the nearest tree. There were plenty of complaints about this suspension system in the late 60's, so Triumph changed to a 'swing spring' system on some cars (no longer

bolted to the diff), and what they called 'rotoflex' on the GT6. Again from the good old British school of thought, the replacement system was unnecessarily complicated and allegedly very fragile.



To compound the issue, the rear suspension used a swing axle system (again - cheap, and also used by Mercedes and Tatra amongst others). The wheel's lower control arm on a swing axle system is pivoted a long way inboard - almost on the centerline of the car. There isn't an outboard pivot so the wheel is always at 90° to the control arm thus the wildly varying camber angles. You can see the 'folded in' look of the rear wheels in the photo above. Note : on rear wheel drive versions of swing-axle suspension, there was no lower control arm - the drive shaft itself was the suspension component.

There was also a rare Swedish sports car in the 1990's called JC Indigo which had transverse leaf spring as both front and rear suspension. The composite spring was derived from the Volvo 760 station wagon but Indigo used it both as rear suspension and in a modified form in the front. The car had mostly Volvo running gear but the company had no relationship to Volvo themselves. It went out of business pretty quickly and I'm not even sure if the Indigo ever reached mass production. Interesting factoid for you: Sweden has had over 120 car manufacturers. Only three remain, only two

are really mass producers and it is unlikely that more than one of them will survive to see 2020.

SPEAKING SPECIFICALLY ABOUT CORVETTE LEAF-SPRING SUSPENSION.

The Corvette was not the first car to combine leaf springs with independent suspension. As well as the Triumph Herald, Fiat did something similar in the 50s with steel springs. The recent Volvo 960 Wagon (not sedan) also used fibreglass leaf springs in the rear with independent suspension. The Corvette is, as far as I know, the only vehicle that uses this setup both front and rear.

The system is definitely independent, not like a live axle or a twist beam rear end. With dependent systems, when one wheel moves, the other is forced to move too. The design of the Corvette suspension is such that even though both sides are linked one side can move without affecting the other, hence its classification as independent. But how - what about that leaf spring? Surely if it's attached to both sides, that makes this a dependent suspension system?

On the older Corvettes (C2, C3, C4 rear end) the leaf spring was rigidly clamped to the subframe in the centre. That made it act like two separate leaf springs, one for each side. As two separate leaf springs it, like a torsion bar, was simply an alternative to coil springs.

When considering coil-spring type suspension, the 'third spring' is essentially forgotten - the two visible coils are considered to be the springing part of the suspension. Not so - there's the anti-roll bar too. Whilst not technically a spring, it does act as a transverse torsion bar linking both sides of the suspension together.

So the way GM started using the transverse leaf spring is actually very clever; it lets one spring act as both a traditional spring *and* an anti-roll. Yes - if one wheel moves, spring forces (not geometric displacements like we

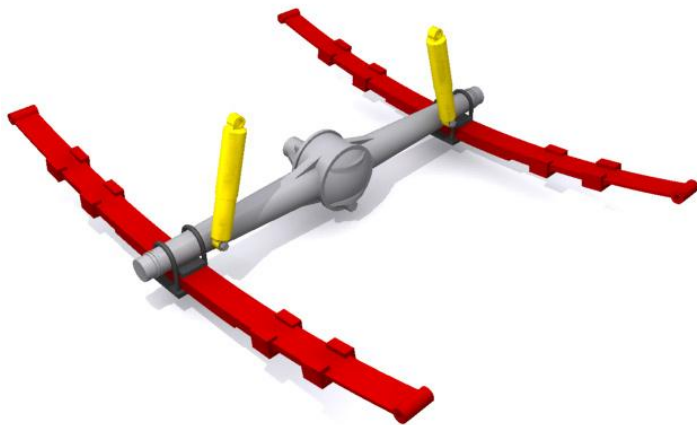
see with a live axle) are applied to the other wheel - however, in a car with an anti-roll bar the same thing happens (see the section on [anti roll bars](#)). The problem was that it worked well as a spring, but not so well as an anti-roll bar, so in the end GM had to add anti-roll bars too.

Typically, aftermarket tuners will tear the leaf springs out and replace them with coil spring systems simply to make life easier. GM left many things on the Corvette with room for improvement. Leaf springs are not really a fundamental problem - typically the view is that Corvettes would be no better from the factory with coil springs. A traditional leaf spring live axle saves money because the cost of leaf springs is less than coils, trailing arms, pan hard rod etc. The Corvette has all the same suspension arms as a system with coil springs, so the only difference is the cost of the fibreglass leaf vs. the cost of the coil spring; leaf springs cost more than a coil so GM didn't do it to save money. It's not immediately clear then why they did it other than perhaps 'because they could'.

To round off this section then, here is an excellent link talking about how this suspension works - it does a far better job than I can

REAR SUSPENSION - DEPENDENT (LINKED) SYSTEMS

SOLID-AXLE, LEAF-SPRING



This system was favoured by the Americans for years because it was dead simple and cheap to build. The ride quality is decidedly questionable though. The drive axle is clamped to the leaf springs and the shock absorbers normally bolt directly to the axle. The ends of the leaf springs are attached directly to the chassis, as are the tops of the shock absorbers. Simple, not particularly elegant, but cheap. The main drawback with this arrangement is the lack of lateral location for the axle, meaning it has a lot of side-to-side slop in it.