FRONTAL ATTACK

Fighting With Your Front Suspension? Here Are Some Strategies for Making It Your Friend Instead of Your Foe

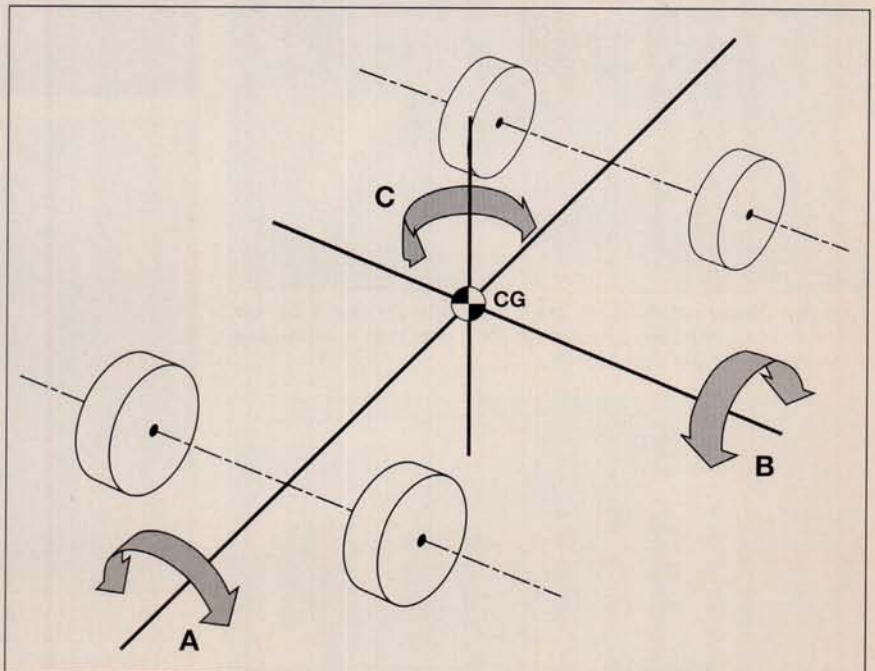
By Bob Egginton

Choosing the proper front suspension setup for a kit car is never easy. Unless you have a firm understanding of the principles involved, it's easy to take a wrong turn. Before covering the various systems available, we should take a look at what the suspension has to do and what the kit car builder should consider when planning a project car.

The obvious function of any suspension is to protect the vehicle's occupants from the bumps in the road and to cushion the vital mechanical and electrical components from shock. In modern terms, however, these obvious requirements pale into insignificance when compared to the greater number of functions that today's systems must undertake.

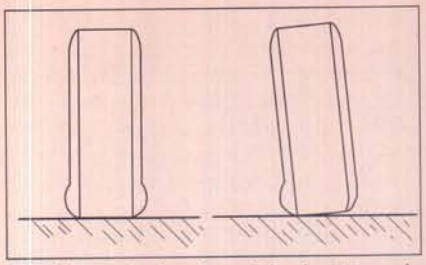
Keeping a Grip

Let's start by considering an obvious but rather sobering thought. The only things that connect any four-wheeled motor vehicle to the road surface are the four tire contact patches, each one not much larger



This diagram shows the axes around which a car moves and must be controlled. The crossing point of the axes is the center of gravity (CG) of the sprung mass; that is, the part of the vehicle supported by the springs, excluding the wheels, axles and suspension components. The resistance to movement in planes A and B (roll and pitch) comes from the vehicle's springs, while C (yaw) is controlled by tire grip.

ILLUSTRATIONS: BOB EGGINTON



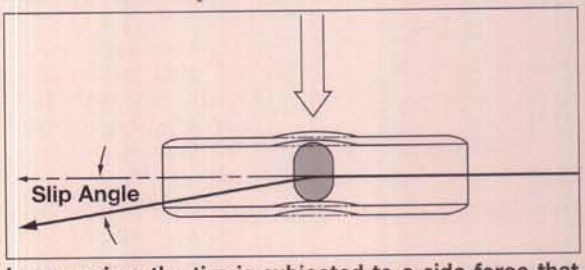
The tire and wheel must be kept nearly vertical for the tire contact patch to remain on the road surface and provide its maximum grip.

than the palm of your hand. If one of the tires leaves the road for any reason, fully one-quarter of the potential grip is instantly lost, or conversely, only three-quarters of the grip is now present. Similarly, if a tire partially loses contact area, a proportion of the potential grip is also lost.

From this basic point, we can see that any suspension's primary function must be to keep the wheels on the ground and at an attitude that is without large camber changes, thus enabling the tires to keep as big a contact patch as possible. The contact patch should also be kept stable, without any tendency toward side deflection, in order to reduce tire wear and keep as much gripping potential as possible. (Of course, if the chassis is so flexible that it functions as a giant undamped spring, then the best suspension system in the world will be rendered virtually useless, but that's another subject entirely.)

Weighty Matters

"Unsprung weight" is another important yet often misunderstood concept. Basically, unsprung weight refers to any part of the vehicle not actually supported by the springs—wheels, hubs and suspension components, and usually the springs, shocks and brakes. When a vehicle's wheel hits a bump, it is deflected upwards from its intended path and is forced in a new direction, taking with it the hub and suspension components. Once on this new path, they are reluctant to change direction again and re-establish their original condition (recall Newton's laws of inertia). It is up to the suspension springs to push the wheel back into its rightful position. The heavier the wheel assembly, the more inertia it will contain and the harder it will be to control.



In cornering, the tire is subjected to a side force that deforms the sidewall and deflects the tire from its path. The amount of deflection is called the slip angle. If a vehicle's front tires have a larger slip angle than the rear ones, the result is understeering.

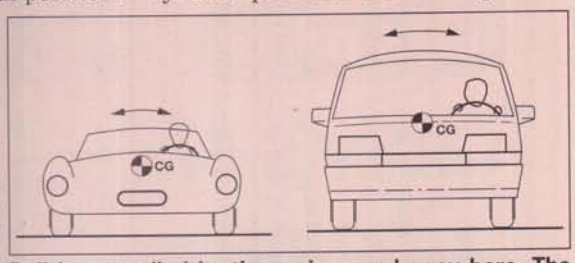
As we have already established, it is essential to maintain the tires' contact area, and the less unsprung weight the suspension components have, the more chance the springs have of controlling them and keeping the tires on the road. This applies not only to bumps, but also to hollows and ripples in the road surface, as well as changes of direction during steering movements. Heavy wheels and hubs also have a greater tendency to steer the wheel from its chosen direction if it hits a bump even at relatively low speeds.

Rock 'n' Roll Center

The linkages that form the suspension of a vehicle and through which its wheels are attached produce an invisible but definable point around which the vehicle's sprung mass laterally rolls during cornering. This point is called the roll center, and there is one for both the front and rear suspensions. The center of gravity of the sprung mass is usually located above the roll centers, and it is the leverage of the sideways movement around the roll center which produces the state of roll in a corner.

The height of the roll center is of vital importance—too low, and the vehicle will have excessive roll, thus requiring over-stiff springs or sway bars to correct it, along with all the disadvantages of a bad ride and wheel-lifting that they bring. If it's too high, the car will feel dead, with a tendency to slide with little or no warning. It will also have a tendency to try to jack itself over its outside wheel if cornered hard. At the front, a height somewhere between 2 and 4 inches above the ground, and a couple of inches higher at the rear, would seem to be the best for the average good-handling sports car. In reality, though, each vehicle has to be treated on its own merits.

The suspension must also be designed in such a way that the roll center will remain as static as possible in relation to the center of gravity. This prevents the leverage from changing between the sprung mass and roll center during motion, which otherwise will cause twitchy and unpredictable handling.

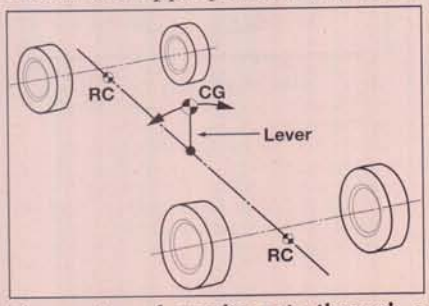


Roll is controlled by the springs and sway bars. The lower the center of gravity (CG), the better the potential control and road holding. While a simple solution for controlling roll is to increase the stiffness of the springs and sway bars, this approach can make the ride rough and unstable. A far better solution is to lower the CG so that it exerts less leverage on the suspension.

Springs and Shocks

A brief mention should be made at this point about the choice of springs. We have experienced a number of otherwise well-constructed vehicles that suffer from the problem of using springs from a much heavier donor vehicle. The result is that the kit is perched up in the air, and, instead of the springs being deflected by road-surface irregularities, the body is pitched about, the car is very unstable and, in some cases, the chassis is actually twisted.

Generally speaking, the springs should be as soft as the car will accept, and any excessive body roll incurred should be controlled by the use of the appropriate sway bars.



The center of gravity acts through a lever upon the roll centers, causing the car to roll when cornered. Roll centers that are too low will cause excessive roll and wheel lifting; those that are too high make for numb handling with a sudden tendency to slide.

However, this is a very complex subject in itself, and is really too extensive to be considered here in depth.

On the subject of shock absorbers—they are badly named, and should instead be called dampers. Actually, the springs

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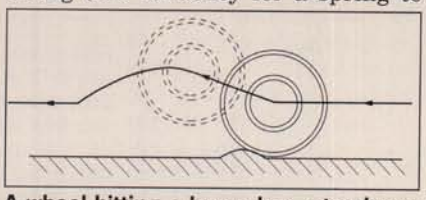
should absorb any shock, while the dampers are left to control the springs and prevent them from oscillating (the tendency for a spring to

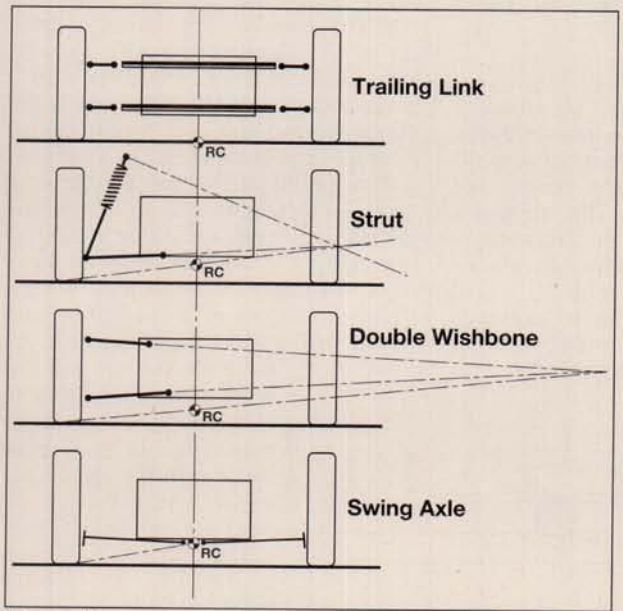


A wheel hitting a bump has a tendency to keep going in the direction it is deflected until the suspension returns it. The less the unsprung weight, the easier it will be to maintain the maximum tire contact patch.

open and shut on its own after being violently compressed and then released—for a crude comparison, think of a jack-in-the-box toy).

Suspension Types

Double Wishbone (A-Arm)—This setup is now probably the most common system in use and, for kit applications, the most useful. The components are lightweight, easy to fit to modern chassis configurations and low in height, thus enabling the frontal area of the vehicle to be kept to a minimum. In addition to these factors, the components are generally not too difficult to manufacture. However, the most important factor of all is that wishbone systems can be designed to give very good camber characteristics; i.e., they keep the wheel nearly vertical during cornering and straight-line movement. Also extremely important is the fact that the roll center can be accurately located, and designed to stay nearly static.



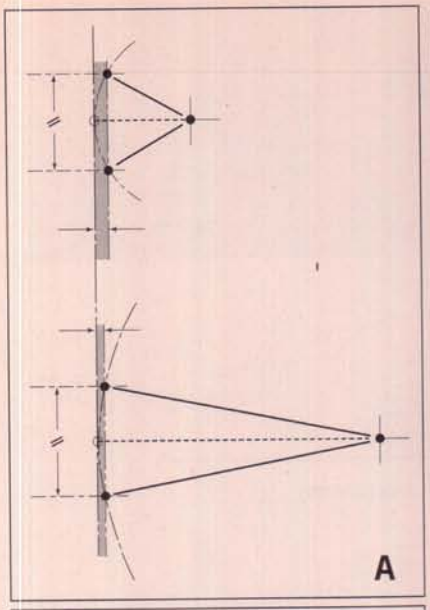
These diagrams outline the various types of front suspension systems and their respective roll centers.

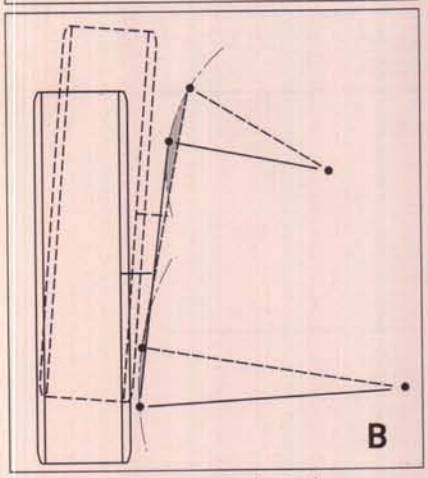
Usually, springs and dampers are attached to the longer bottom wishbone and pass up through the shorter top one before bolting to the chassis, but there are variations on this setup. For example, the spring may be attached to the top wishbone, or, like the Jaguar E-type, a torsion bar can be attached to the inner end of the bottom wishbone and run rearward parallel to the car's axis. There are also systems where the spring/damper unit is operated by a push- or pullrod via a crank, as well as systems that use a single spring, but those are other stories.

Strut Suspension—This system can be applied to both the front and rear of a vehicle and consists of a single lower link or wishbone with a spring-damper unit passing nearly vertically from the link and attaching to the chassis at the top. The hub, bearings and wheel are attached at the bottom end of the spring-damper unit near the pivot at the outer end of the bottom link.

Struts have a lot of advantages. The moving components are very lightweight and can be easily fitted into a modern unitary-construction type of chassis. They are more difficult to fit into the ladder or spaceframe types commonly found in the kit car field. Struts allow for proper placement of the roll center, and their camber-change characteristics are good, but they take up a lot of room vertically, so they do not lend themselves particularly well to sports car applications. In the past, attempts have been made to reduce the height of struts by compressing their design, but this has never proved particularly successful.

Trailing Link—Used for many years on the Volkswagen Beetle, at one time the trailing-link setup was probably the most common kit car front suspension to be found. It must





On an A-arm suspension, the reason for using a longer bottom wishbone or link is basically very simple. The shorter the link, the tighter the arc it will prescribe when moved and the greater the lateral travel at any point on the circumference *(A)*. If this analogy is transferred to a suspension system *(B)*, it can be seen that the lateral movement of the shorter top wishbones will pull the top of the wheel in toward the vehicle center more than the longer bottom one. If carefully designed, this phenomenon can be used to ensure that a wheel will remain nearer to vertical when the car is rolling laterally under hard cornering. Keep in mind that the permutations allowed by varying the link lengths and angles are endless, so this is an area better left to a design engineer.

now be considered out of date when compared with modern trends. As the name implies, it consists of two arms that protrude backwards from two pivots, with the wheel/hub assembly attached between the arms. In the case of the VW, torsion bars are attached to the arms at the front pivot and provide the springing medium, although this is not always

the case. The advantages are that this type of suspension takes up little space, attaches to most chassis types readily and is cheap to mass-produce. It does, however, offer poor camber-change characteristics that do not lend themselves to today's wide, low-profile tires. Also, the roll center is far too low.

Swing Axles—In the past, swing axles have been tried at both ends of automobiles, and in most cases have proved to be inadequate. Basically the system consists of a beam divided and pivoted in the center, the wheels being attached at either end. In fact, most swing-axle systems that have been tried on the front of kit cars consisted of a beam axle cut in two and modified with pivots, trailing arms and coil-over shocks.

A swing axle has a number of disadvantages, despite its relative simplicity. It is rather difficult to fit into a modern chassis and it has excessive camber change. The roll center is also too high, which causes the car to try to climb over its outside wheel in hard cornering, a rather alarming phenomenon at best.

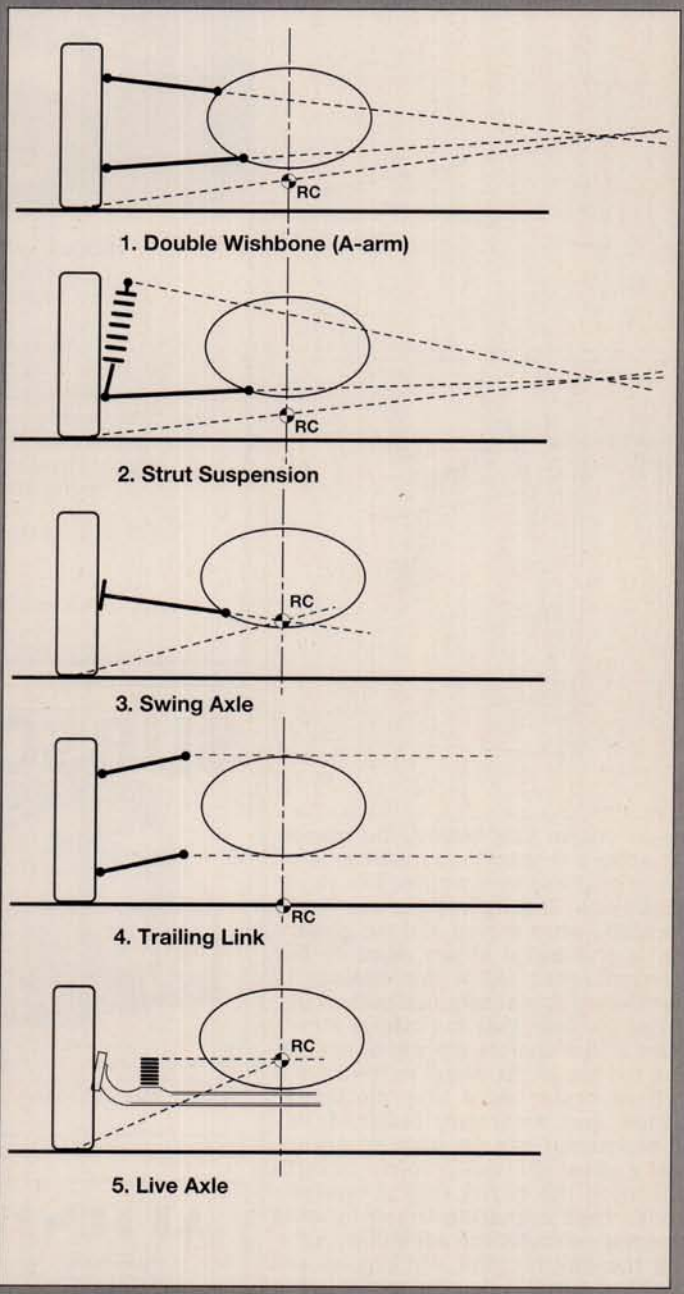
Live Axles—Consisting of a beam with a wheel at either end with either leaf springs, torsion bars or coil springs attaching it to the chassis, front live axles are out of date on most cars (except street rods), but are still prevalent on heavy trucks. The axle's location governs the roll center, which can be designed at an acceptable height. Drawbacks include excessive weight and installation difficulties on modern chassis designs, but by far the worst problem with a live axle is that whatever happens to one wheel affects the other. This characteristic can cause unpredictable gyroscopic effects at high speeds, particularly with wide tires.

This concludes our quick trip around front suspension systems found on the current crop of kit cars. Bear in mind that by its very nature any suspension package is a huge compromise, and by juggling the various components it is possible to emphasize one or more of the advantages at the expense of others. The trick is to emphasize the advantages that you really want and need. ***KC***

How to Calculate Your Roll Center

If you suspect the roll centers on your kit car are either too low or too high, they're fairly easy to determine. The tire-to-pavement contact patch provides sideways resistance, and the suspension linkages produce the point about which the sprung mass of the vehicle rolls when centrifugal force is applied during cornering. To calculate the roll center of an A-arm front suspension *(note drawing No. 1)*, project lines from the suspension linkages that connect the wheel to the chassis, and also from the center of the tire contact patch, to a point in space where they intersect. Find the point at which the tire contact patch's line passes through the vehicle's vertical centerline. That's the roll center. Then simply measure how far above the pavement it is. As mentioned in the main feature, somewhere between 2 and 4 inches at the front, and a couple of inches higher at the rear, is usually right for a good-handling sports car.

On a strut-type suspension, note that the upper line projects from the top mount. On a swing axle, there are only two lines to intersect. On a trailing-link setup (VW Beetle), the upper two lines are parallel, with no intersection point, so the roll center is always at ground level, an inherent drawback that cannot be altered. Note that on the live axle the upper line is projected from the top of the spring pickup, so a dropped-spindle arrangement, typically found on street rods, can improve the roll-center height. However, making changes to the position of a roll center should only be taken after very careful consideration or after consulting a suspension expert, because even minor errors can create unstable handling.



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