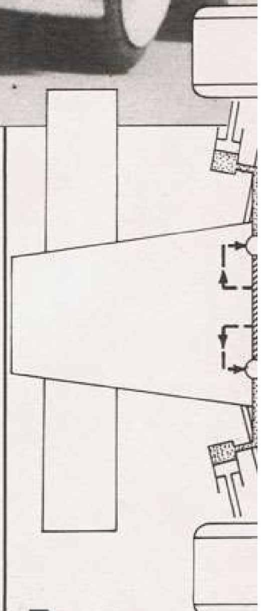
Understanding active su



Active suspension is the next big leap forward in car technology, yet few practical systems exist. Dave Bulman has been looking at the problems

Vehicle suspensions, as the majority of us understand them, rely on springs and dampers, the characteristics of which cannot be dynamically changed to suit various driving conditions.

Dynamically changed? To explain this statement, consider a vehicle which is set up for fast tarmac, which would have relatively high suspension rates (stiff springs and dampers). Now if this vehicle were driven over a very rough road the ride would be unbearable, but what would happen if we could sense the motion of the vehicle, say the vertical acceleration of the driver's seat, and immediately reduce the damping and spring rates if that acceleration was above a certain level? This is what is meant by dynamically changing the suspension parameters.

When we have a suspension which changes its characteristics to suit the conditions, we term it an active suspension. A standard suspension, as fitted to all production cars, is known as passive.

Strictly speaking, a simple self-levelling suspension may be termed as being active, so in this case we might include the Rover 3500 or Range Rover, which uses Boge Nivomat dampers to achieve self-levelling. The Nivomat works by using the motion of the suspension to produce a pumping action, and when the working level is reached, a bleed hole dumps the excess oil.

Another possible example of 'active' suspension could be the Citroen system which uses gas as the suspension medium coupled by hydraulic oil to pistons which act on the suspension arms. The suspension arms are connected to valves which control the flow of oil into the system, but flow is restricted to only provide self-levelling and the response is slow and produces little or no effect with suspension movements caused by the vehicle hitting a bump.

Neither of these two systems are really classified as active these days. Generally, for a true active system we expect the suspension to react quickly, and as stated earlier, react to sensors which detect some important characteristic of the vehicle motion.

Before we explain the possible suspension variations we might have, we'll look at the various characteristics which *could* be required from the suspension.

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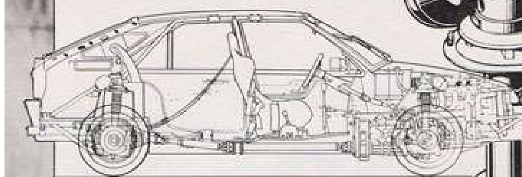
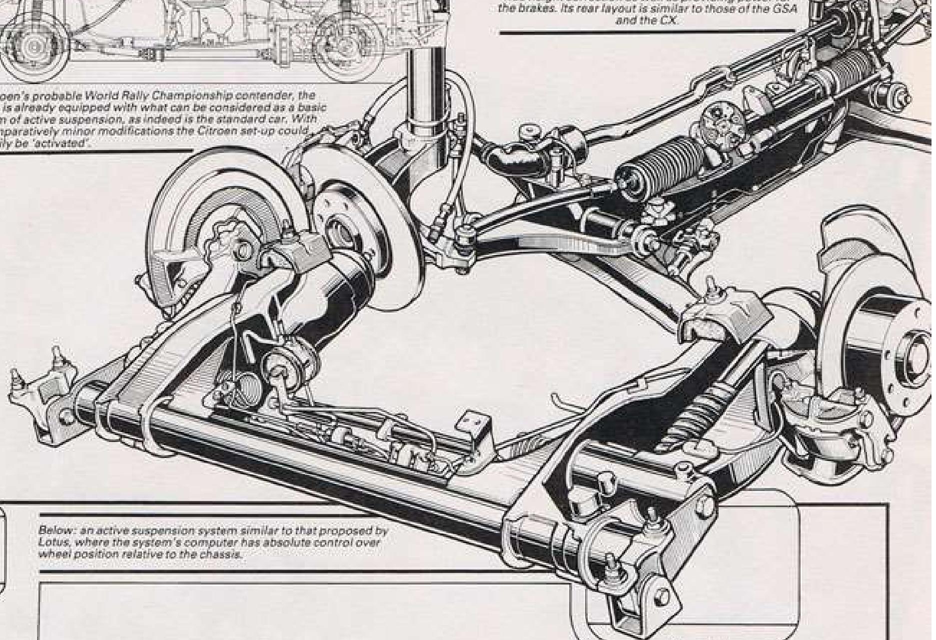
The first essential is to maintain the car at a particular ride height, and this is why active suspensions have recently hit the limelight with the Lotus system. When Formula One was allowed to use ground effect, the aerodynamic downforce could be as high as twice the weight of the

spension

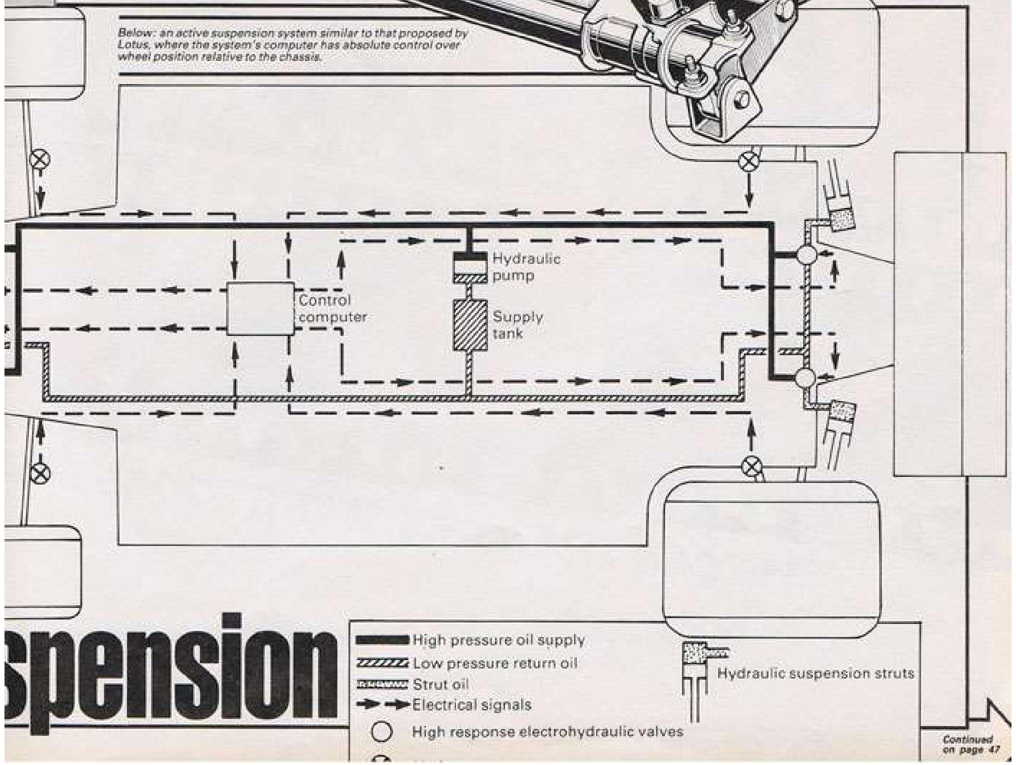


Citroen's probable World Rally Championship contender, the BX, is already equipped with what can be considered as a basic form of active suspension, as indeed is the standard car. With comparatively minor modifications the Citroen set-up could easily be 'activated'.



The BX's low-rate hydropneumatic suspension has unique vertical struts at the front which consist of an integral pneumatic spring and damper with no moving parts, in conjunction with the traditional Citroen high-pressure hydraulic system which ensures automatic ride height correction as well as providing power for the brakes. Its rear layout is similar to those of the GSA and the CX.

Below: an active suspension system similar to that proposed by Lotus, where the system's computer has absolute control over wheel position relative to the chassis.



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Understanding active suspension

Active suspension is generally accepted to involve hydraulics

car. This meant that if the spring rates were chosen for good handling on slow corners, by the time the car reached maximum speed (and hence maximum downforce), the springs would be bottoming out. Just imagine the effect if you took your own car and loaded it so that it weighed three times its kerb weight!

To get over this problem, Formula One designs ran extremely high wheel rates, which were sometimes stiffer than the tyres. This was highly unsatisfactory and very wearing for the drivers, and the teams looked for a way out.

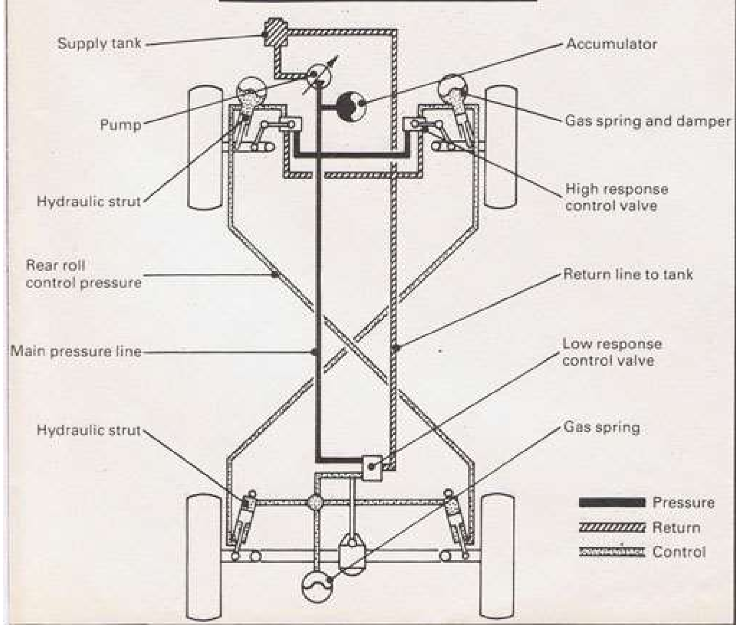
The obvious approach was to have a self-levelling system which acted quickly enough to respond to changes in ground reaction (bumps, curves, etc) as the speed changed. Just about every Formula One team investigated such a system, but before they could be put into operation the rules were changed. Most systems that we heard of involved a lot more than just self-levelling, because once there is the capability of dynamically changing the suspension there are a whole host of other ideas which can be introduced.

The obvious ones for the **CCC** enthusiast are to introduce an anti-dive and anti-roll capability. There is even the possibility of making the car roll *into* bends. This is not so daft as it may seem, because it could put the tyres at a better angle to the road and achieve maximum adhesion and hence a higher cornering speed. It also might give a more comfortable ride and so reduce driver fatigue in a long race or rally.

Of course the major benefit for a car manufacturer in active suspension is an improved ride, particularly for a relatively light vehicle. This is going to be more important as vehicle weights are reduced, and manufacturers try to improve the ride comfort. This is perhaps the only reason why

Screwed into an Esprit, the Lotus active suspension system can provide roll-free cornering if desired, but because of the on-board computer, driver vehicle attitude preferences can be dialled-in as required.

The hydraulic circuit for an Automotive Products system which assists in improving stiffness both in roll and pitch.



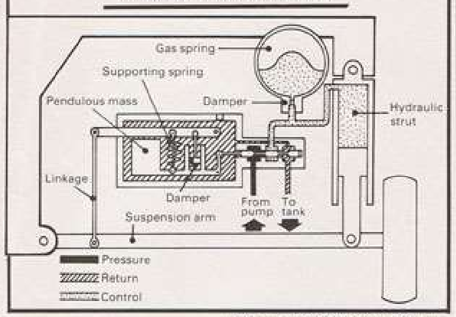
we may see a mass produced active suspension system. In the meantime the major interests lie within competition circles, research and academic institutions, the military, and one or two far-sighted automobile manufacturers.

At the moment, the method for trying to achieve an active suspension is generally accepted to involve hydraulics. But working from this basic assumption there are many possible variations.

The Lotus system uses hydraulic actuators (struts) in place of the spring/damper units, and the flow of oil into or out of the actuators is controlled by very fast acting electro-hydraulic valves. These valves respond to signals which are derived from sensors on the car, with a computer taking the signals from the sensors and using the information to control the valves, and hence the suspension.

As an example, the computer may detect a high upward acceleration of the body at one corner of the car caused by one wheel hitting a bump. To reduce this acceleration the computer could open the valve and dump some oil from the suspension strut only at that corner. This would allow the wheel to move upward over the bump but it cannot dump too much oil, ▶

The control valve for the Automotive Products system is rather more complicated in operation than it may at first appear.



One big disadvantage is that the Lotus system has no spring to take over

otherwise the strut might bottom out.

To prevent this happening the computer also needs to know the displacement of the wheel relative to the body. It can then combine the two signals and limit the upward velocity of the wheel relative to the body by closing down the valve. Once the upward acceleration of the wheel is reduced to a safe level, the computer then notes the position of the wheel relative to the body and the system pumps oil back into the strut to level the car.

It doesn't take too much thought to realise that the control system becomes very complex to take account of all situations. In the case of the Lotus system it is even more important because there is effectively no 'spring' to take over, one big disadvantage of the Lotus suspension.

It is effectively a total loss system, and so requires relatively large amounts of power. Everytime the wheel moves up, oil needs to be pumped into the strut to move the wheel back down. In a normal suspension, if the wheel is pushed upwards, the energy is stored in the spring and this is recovered when the wheel moves the other way. The only loss is a small one from the dampers, although under severe conditions even this can be appreciable. Lotus have of course realised this, and some sort of conventional springing may be added.

Another active suspension idea, which incidentally has been around for many years, is the Automotive Products system. This is a conventional hydraulic suspension similar to that used by Citroen, but in addition has a special valve which either dumps oil or adds oil to the system.

It uses an ingenious mechanical control system. A small mass is supported on one end of an arm, the other end of which is fastened to a pivot on the vehicle body. Movement of the arm causes a spool valve to either dump oil or add oil to the suspension. A small spring connects a point on the arm to a link which detects the position of the suspension relative to the body. Everything is arranged so that with the vehicle stationary, the centre of gravity of the mass is to one side and either slightly above or below a horizontal line which passes through the pivot.

The operation of the valve relies on the fact that when the vehicle accelerates upwards, the mass (because of its inertia) wants to stay where it is. Also, when the wheel moves relative to the body, there is an additional force on the arm through the small spring. A combination of these two produces a movement of the spool and consequent oil flow either into or out of the suspension strut. Obviously for successful operation the correct combination of mass and spring is essential, but the system doesn't end there.

First, the rear suspension struts are made to be double-acting. This means that oil can be applied to either side of the piston. An hydraulic connection is then made diagonally from the front struts to the under side of together across the vehicle.

In this way, pitch and roll stiffness can be controlled. The next step is to adjust the size of the mass and the spring in such a way that the system is tuned for the best possible performance. When this is done correctly the gas springs can be made very soft, and the flow of oil through the valve becomes reduced, keeping power consumption to a minimum.

The result is a very soft suspension rate in bump, but high roll and pitch stiffness. The roll stiffness is increased still more if the mass on the valve is above the pivot. The centrifugal effect causes the spool to move, dumping or adding oil as necessary, and hence keeping the vehicle level. Usually two valves are used, mounted on either side of the front of the vehicle. A further slow response valve controls the level of the rear suspension.

While the operation is not as simple as might first be thought, it has already been tried on a number of saloon cars, an ambulance, and a couple of special research vehicles. The ride it gives is excellent, but it requires careful calculation during the design stage to make sure the response to ground inputs is correct.

Up to now we have not actually mentioned the use of damping within the suspension systems. In the case of the Lotus system this is all done within a computer which can control the velocity of the wheel relative to the body. The Automotive Products system does incorporate damping valves, but these remain fixed, once set.

A further idea, this time suggested by Lucas, is to have a relatively conventional suspension, but have the damping varied actively.

This is done in practice by using an hydraulic suspension (like the Citroen) and replacing the standard damping valves by electronically controlled ones. Sensors detect the position and velocity of the wheels relative to the body, and also the acceleration of the body itself. A computer then takes over and adjusts the damping according to certain criteria laid down by the designer, depending on the use of the vehicle.

In its favour, the Lucas system does not necessarily need an hydraulic supply and therefore does not need any engine power, so it could conceivably be added to the Hydragas suspension as used on the Metro. However it does not give the self-levelling required to cope with changes in load, and this is one of the important reasons for an active suspension. Self-levelling could be added, but then we come close to the other systems.

It will remain to be seen if active suspensions actually become a commercial reality on private cars, but on vehicles such as coaches, heavy goods vehicles and trains we believe it will happen.

Certainly some competition cars will benefit, but it is unfortunately not something that the private individual could tackle with ease.

However, for the inspired CCC enthusiast, a good starting point would be a Citroen. Most of what is needed is there, and all that is required is the correct valving, an improved oil supply, plus the control system.

Somebody ought to try it. ■

The Lotus system can result in some startling cornering visuals, (see below, with and without) but it has a big disadvantage in that it is a total energy loss layout, and there's no energy storage medium like the spring in a conventional suspension.