DISCOVERY SERIES II

Suspension

04-03-LR-W
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Preface

This document has been issued to support the Discovery model range. The information contained within this document relates to the features and specification of this model.

Every effort has been taken to ensure the information contained in this document is accurate and correct. However, technical changes may have occurred following the date of publication. This document will not necessarily have been updated as a matter of course. Therefore, details of any subsequent change may not be included in this copy.

The primary function of this document is to support the Technical Academy training programme. It *should not* be used in place of the workshop manual. All applicable technical specifications, adjustment procedures and repair information can be found in the relevant document published by Rover Group Technical Communication.

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Front Suspension

Radius Arms

The suspension fitted to the New Discovery has been enhanced to improve handling, stability and ride characteristics. With the addition of the optional Active Ride Control (ARC) system, the on road ride is improved as the suspension stiffness to single wheel inputs is reduced, leading to a more supple suspension. The front and rear suspensions have been designed to allow maximum wheel travel and large axle articulation angles, vital for off-road performance.

The front two radius arms fitted to the front axle are longer than those fitted to pre 99 MY discovery. They provide longitudinal axle location and allow large axle articulation. The geometry has been designed to give the driver greater feedback under braking by tuning the level of dive. Too much dive and the driver thinks the vehicle is braking harshly. Land Rover engineers have designed the suspension so that the amount the vehicle dives is kept to a minimum, whilst still giving the driver feedback as to the level of braking. Dive is noticeable when the vehicle brakes are applied and the front suspension compresses as a result of weight transfer. The driver notices this movement by viewing the front edge of the bonnet relative to the horizon. 100% ‘anti- dive’ is when the vehicle brakes are applied but the driver does not see the vehicle lower at the front edge of the bonnet due to the force within the front suspension acting against the weight transfer forces associated with braking.

The chosen geometry provides good ride comfort, with the axle moving in the vertical direction on inputs from the road surface. The forged steel radius arms are fitted with two ferrule rubber bushes, the characteristics of which improve the vehicle handling. The bushes are used to fix the radius arms to the front axle via mounting brackets fabricated on to the axles. To fix the end of the radius arm to the chassis frame, a third ferrule bush is used. Each radius arm has a notch on its lower edge which provides location for the vehicle jack.

A Panhard rod is fitted to ensure that the axle remains centrally located to the chassis and resists cornering forces. It is fitted transversely between the axle and chassis and also utilises ferrule bushes at both axle and chassis locations.

Front and rear anti roll bars

The anti-roll bars fitted differ between ACE and non-ACE vehicles. On non-ACE vehicles a conventional ‘passive’ anti-roll bar is used. On ACE vehicles an ‘active’ torsion bar is used. Both types are attached to the front chassis cross member with mounting rubbers and clamp plates. The end of the anti-roll bar is attached to a anti-roll bar link. Each link has a spherical bearing attached at each end. On ‘active’ torsion bars, the RH anti-roll bar link is attached to a long arm which in turn is attached to the torsion bar. The ‘passive’ anti-roll bar is a conventional anti-roll bar which opposes axle movement, reducing the effects of lateral forces on the vehicle body. With the conventional ‘passive’ anti-roll bar, axle movement is opposed by the anti-roll bar through links attached to the axle casing and each end of the anti-roll bar.

Front and rear dampers

Conventional telescopic dampers are used to assist with control of the body and axle movement. The fronts are secured to the chassis frame by bolt on damper towers. The front upper fixing utilises a ferrule rubber bush with a single bolt fixing to the damper tower. The front lower end is fixed to the axle by another ferrule bush, which has a cross pin and is secured by two bolts. The upper and lower fixings of the rear dampers use a ferrule rubber bush with single bolt fixings to the chassis and axle.

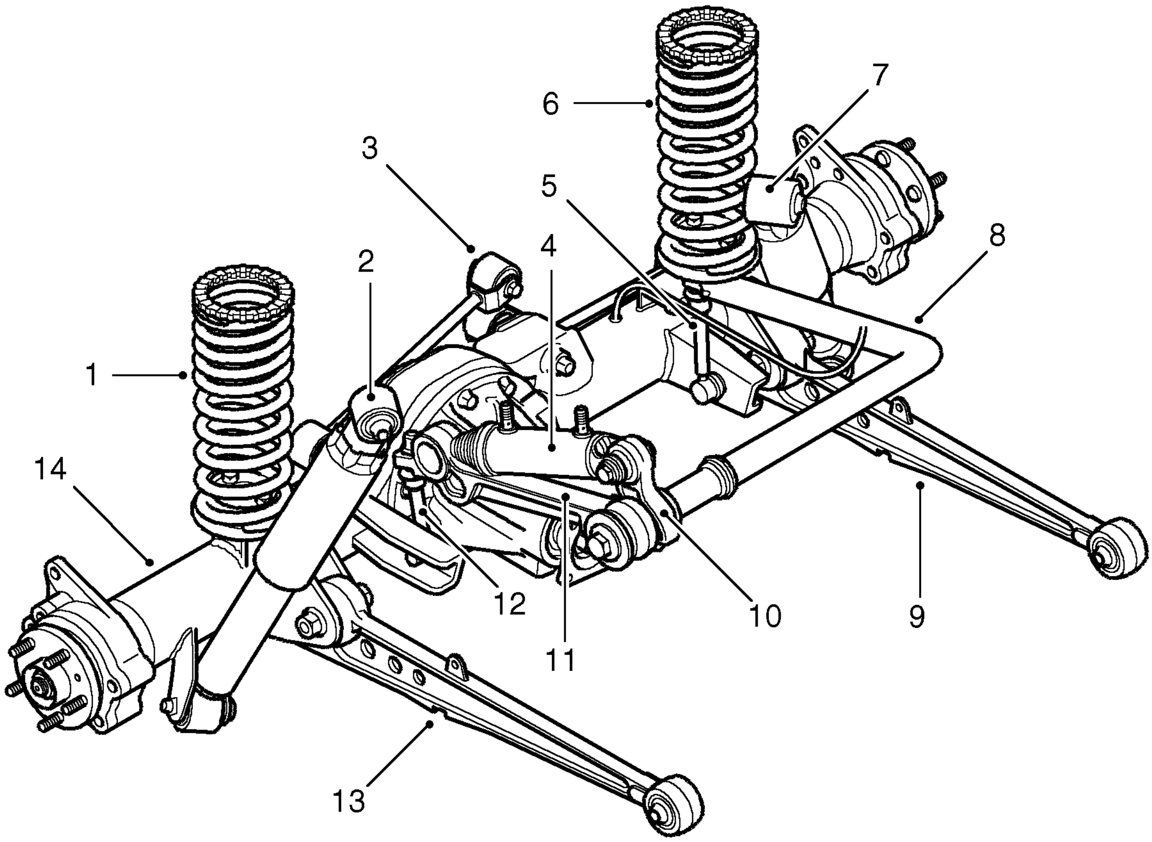
Bush rate characteristics have been designed to provide reduced noise, vibration and harshness (NVH) and improved axle control. The dampers are tuned to each of the suspension options offered to the customer, to ensure optimum comfort and control. Therefore, dampers are not interchangeable.

Progressive rate rubber bump stops are fitted under the chassis, adjacent to the front springs, to prevent possible damage which could occur should there be excessive axle to chassis travel, whilst maintaining ride comfort when large road wheel inputs are encountered.

Front road springs

Single rate coil springs are fitted to the front axle. These differ between diesel and petrol derivatives as the weight difference has to be counterbalanced to maintain the correct ride height. Tuned isolators are fitted between the spring and chassis frame. Isolators are fitted to improve NVH and ride performance.

Rear suspension



1.Coil spring RH
2.Damper RH
3.Watts linkage
4.ACE actuator (if fitted)
5.Anti-roll bar link LH
6.Coil spring LH
7.Damper LH
8.Torsion/Anti-roll bar
9.Radius arm LH
10.ACE short arm (if fitted)
11.ACE long arm (if fitted)
12.Anti-roll bar link RH
13.Radius arm RH
14.Rear axle

Radius arms

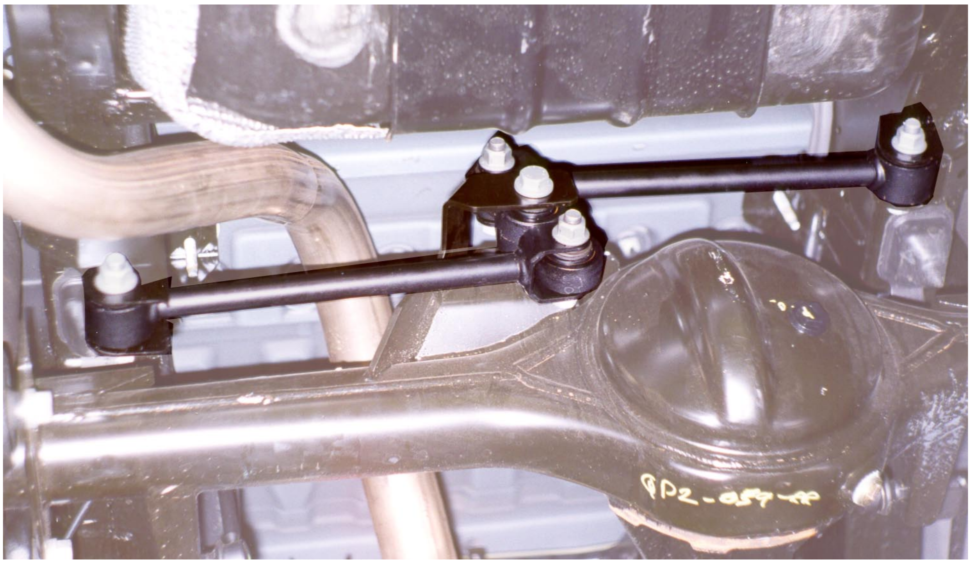
The rear suspension fitted to the New Discovery has long radius arms which provide longitudinal axle location and allow large axle articulation. The front and rear radius arms are not interchangeable.

The geometry has been designed to provide a level of anti-jacking. This reduces the amount of rear end lift when the vehicle brakes, thereby improving braking stability. The radius arm comprises a forged steel link with two ferrule rubber bushes used to attach the arm to the rear axle mounting brackets (see figure 1). The radius arm is attached to the chassis frame by means of a third ferrule bush.

Rear road springs

Standard derivative vehicles are fitted with multi-rate rear coil springs designed for good ride comfort over a wide loading range and, as with the front springs, tuned isolators are fitted between the spring and chassis frame to improve the NVH and ride performance.

Watts linkage



Fitted to all derivatives of the New Discovery rear suspension is the Watts linkage, which provides lateral location of the rear axle. This gives near vertical travel of the axle, and provides good body roll control via a high roll centre. The linkage offers good ride and NVH performance as the two chassis mounting bushes are relatively soft, needing only to provide lateral location of the axle as the radius arms provide longitudinal location and brake reaction.

The Watts linkage comprises two links, fitted with chassis mounting bushes, and a centre pivot assembly. The centre pivot has two spherical ball bushes and a centre bearing (all sealed for life) fitted into a machined casting. The linkage is fitted to the centre of the axle utilising a nut and bolt. A further two nuts and bolts secure it to either side of the chassis frame.

Self levelling suspension

Overview

A optional new feature for the New Discovery is Self levelling suspension (SLS). This incorporates air springs for the rear axle and conventional springs fitted to the front of the vehicle. It is similar visually to the air suspension fitted to Range Rover but it is different physically. There is no air reservoir fitted to New Discovery and no air springs are fitted to the front of the vehicle. The system comprises:

- Air distribution unit
- Silencer
- Two height sensors
- Two air springs
- Air intake filter
- Air suspension height switch
- Air suspension warning lamp
- Off-road mode warning lamp
- Self Levelling Anti lock Brakes (SLABS) ECU

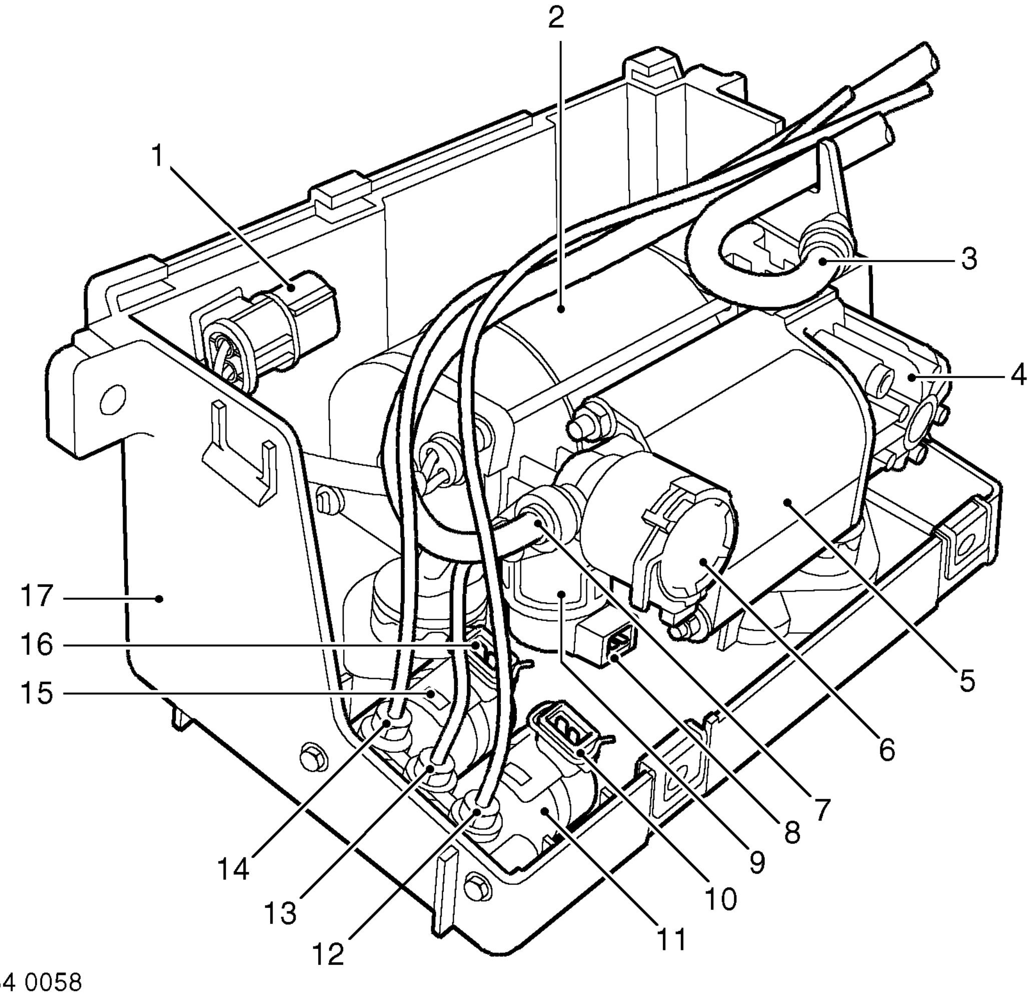
The function of the rear self levelling suspension is to keep the vehicle level under all loading conditions. It is not designed to give rapid height adjustment. The suspension system keeps the vehicle level even if there is an unevenly distributed load in the rear of the vehicle, or the vehicle is towing.

Air distribution unit

The Air distribution unit is the box which contains the:

- Compressor
- Air dryer
- Air valves
- Pressure limiting valve
- Electric motor

It is mounted on the left hand chassis rail, beneath the left hand floor panel. No routine maintenance is required.



1.Compressor electrical connector
2.Electric motor
3.Air intake hose
4.Compressor
5.Air dryer
6.Pressure limiting valve
7.Exhaust hose
8.Exhaust valve electrical connector (black harness connector)
9.Exhaust valve
10.LH air valve electrical connector (natural harness connector)
11.LH air valve
12.LH air spring supply pipe
13.Air supply/exhaust pipe
14.RH air spring supply pipe
15.RH air valve
16.RH air valve electrical connector (blue harness connector)
17.Housing

Compressor

The compressor provides compressed air to pressurise the rear springs. The compressor receives its power from a relay in the under bonnet fuse box, which is controlled by the self levelling anti lock brake system (SLABS) ECU. The air supply unit comprises a 12v electric motor, a compressor and air dryer unit, a pressure limiting valve, an exhaust valve and two air supply control valves (see figure 2). The Exhaust and control valves are solenoid operated responding to signals from the SLABS ECU.

The electric motor drives a crank with an eccentric pin to which a connecting rod is attached. The connecting rod has a piston which fits into the bore of the compressor. When the motor is operated it rotates the crank, moving the piston in the bore of the compressor.

Air Pressure Limiting Valve

The air pressure limiting valve is attached to the end of the air dryer unit. The limiting valve protects the air springs from over inflation. When the exhaust valve is opened, the pressure limiting valve also opens. The valve is pneumatically operated, responding to air pressure applied to it.

Air dryer

The air dryer is built into the compressor. The dryer contains a silicate box which removes moisture from the compressed air entering the system. All air exhausted from the system passes through the dryer in the opposite direction. The air dryer is regenerative in that exhaust air absorbs moisture in the dryer and expels it into the atmosphere. The air dryer is designed to last the life of the vehicle and is non-serviceable.

Air Intake Filter

The air intake for the compressor is located behind the LH rear light cluster in the ‘E’ post. The plastic moulded housing contains a felt and foam air filter and is replaceable (refer to workshop manual). For the correct service intervals refer to the service maintenance check sheet. The filters remove particulate matter from the air drawn in by the compressor.

Air valves

The self levelling suspension air valves control the operation of the air springs at the rear of the vehicle. There are three solenoid actuated valves incorporated within the air distribution unit. These are the:

- Left spring valve
- Right spring valve
- Exhaust valve

For the left hand side of the vehicle to rise, the left spring valve is opened and the compressor run. The same operation with the right spring valve raises the right hand side.

To lower the left hand side of the vehicle, the left hand valve is opened along with the exhaust valve. The same operation with the right hand valve lowers the right hand side.

The L/H an R/H spring valves are located at the forward end of the housing. Each valve is connected to the compressor/air dryer unit through a shared single pipe which directs air to and from the air springs. Each control valve can be individually operated by the SLABS ECU.

The exhaust valve is located with the pressure limiting valve and is solenoid operated by the SLABS ECU. The exhaust valve directs air from the air springs and control valves to atmosphere when required.

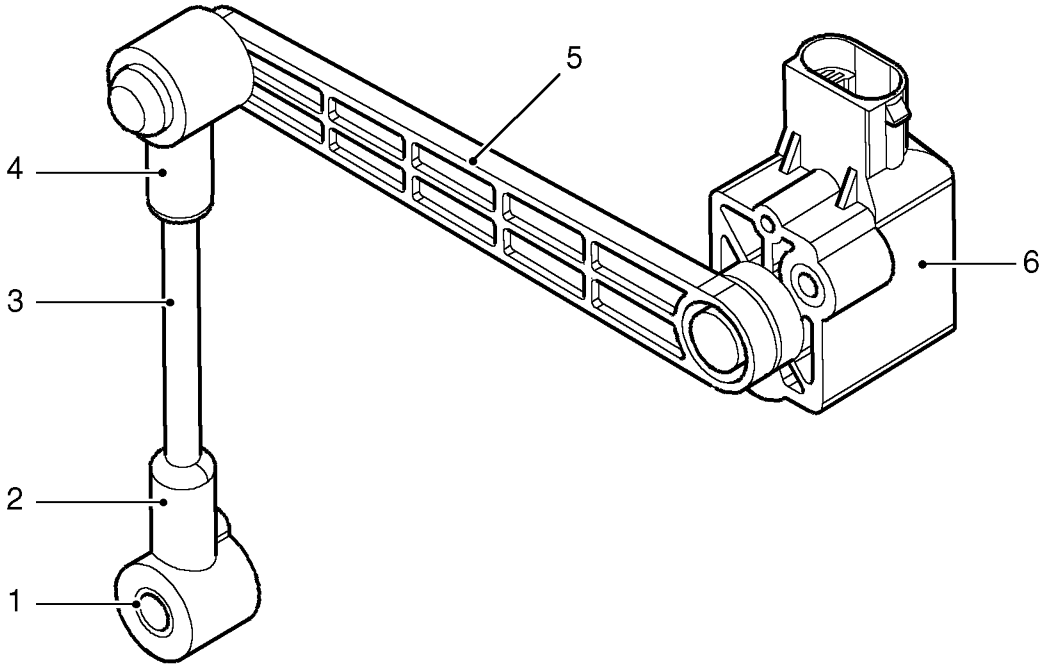
Silencer

The silencer is connected into the air lines behind the air distribution unit. It has two chambers, one to reduce compressor pulsing noises at the intake filter, the other to minimise exhaust noise.

Height sensors

The height sensors are located on the chassis, with the sensor arms, a link and two link ends attached to the radius arms (see figure 3). The link ends allow articulation of the arm to allow for suspension travel. The lower link arm is attached to a lug on top of the radius arm. Each sensor is connected to the main chassis harness by a multiplug. The three pin multiplug provides an earth, a 5 volt supply voltage and a output signal voltage to the SLABS ECU. Each sensor operates on the hall-effect principle. A magnet is attached to the shaft and rotates with the movement of the arm. The magnetic flux generated acts on a hall effect sensor and depending on its position varies the current across the sensor. This current is measured and amplified and passed to the SLABS ECU as a linear output voltage signal, which varies depending on the angular position of the sensor. The signal information is processed and the SLABS ECU can determine the vehicle height.

If, for any reason, the sensors are replaced, or removed and refitted, a calibration process must be completed to ensure that the SLABS ECU knows the correct height of the vehicle. This process involves using TestBook and a set of special setting blocks (LRT 64-003). The blocks differ from those used on Range Rover.



M64 0059

1.Spacer
2.Link end
3.Link
4.Link end
5.Arm
6.Sensor body

Air Springs

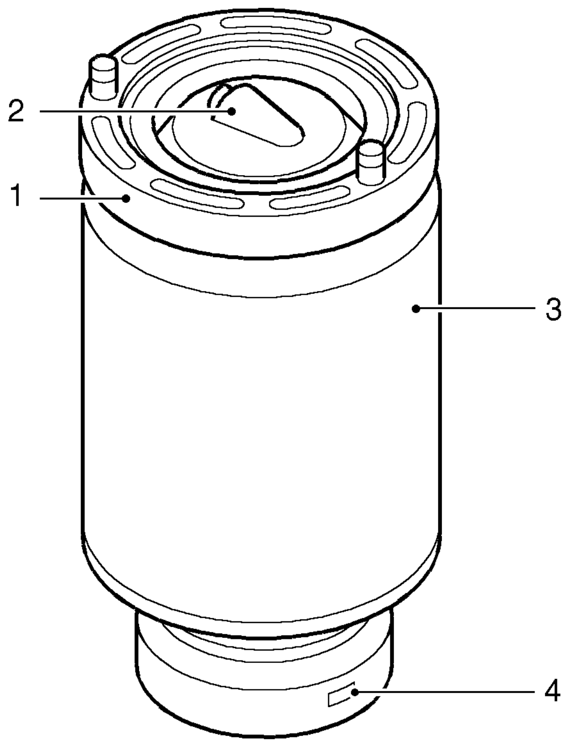
The air springs located on the rear axle differ from those fitted to Range Rover. They have a new construction and are made from new lighter materials. This gives the vehicle an improved secondary ride. Secondary ride is the term used to describe vibrations/oscillations caused by the vehicle reacting to minor road surface imperfections.

Each air spring is located at its base on a fabricated platform on the rear axle. The top of the spring locates in a fabricated bracket attached to the outside of each chassis.

The plastic base piston is recessed with a boss with two lugs moulded in the centre for attachment to the axle. The piston is secured by locating lugs in a slotted hole in the axle platform and rotating the spring through 90, locating the lugs in the slot. The plastic top plate has two grooved pins which locate through holes in the chassis bracket (see figure 4). Two spring clips locate on the grooved pins and retain the top of the spring in position.

Each air spring comprises a top plate, an air bag and a base piston. The airbag is attached to the top plate and the piston with crimped rings.

The airbag is made from a fibre reinforced flexible rubber material which allows the spring to expand with air pressure and deform under load. The top plate comprises the two bonded grooved pins and female Voss connector in the centre. The Voss connector allows for the attachment of the air supply pipe from the air supply unit. The piston is also plastic and is shaped to optimise the springs characteristics.



M64 0060

1.Top plate
2.Voss connector
3.Air bag
4.Piston

SLABS ECU

The SLABS ECU is mounted on a bracket behind the passenger glovebox and is identified from the other ECU’s by its five connectors. The five connectors are located on the lower face of the ECU. The twelve, six and eighteen pin connectors are used to supply inputs and outputs to and from the ECU. The remaining connectors are used for the ABS operation.

The SLABS ECU receives a continuous battery supply from fuse 11 in the engine compartment fusebox. An ignition ‘ON’ signal is supplied from the ignition switch via fuse 28 in the passenger compartment fusebox. The ECU has the ability to control when it requires power and is not reliant on the ignition signal for it to power up.

Incorporated within the ECU is a counter which times the operation of the SLS system and prevents the compressor exceeding its duty cycle. The ECU can remain powered up for up to 1.5 hours after ignition off is sensed to allow the counter to continue running to avoid an ignition cycle resetting the counter.

If any of the doors are opened, this will power up the ECU irrespective of the ignition switch position. The door open signal is sensed by the door switch completing an earth path which is sensed by the ECU. The door open signal powers the ECU for up to 30 minutes to allow the vehicle to re-level when a load is removed or passengers leave the vehicles.

Self levelling suspension operation

Basics

Self levelling is accomplished automatically when the engine is running (the engine ECU sends an engine speed signal to the SLABS ECU to indicate when the engine is running). The height sensors inform the SLABS ECU at what height the vehicle is currently set. If the rear suspension is too low, the SLABS ECU switches on the compressor by actuating the compressor relay. The left hand and right hand spring valves will open simultaneously (providing the vehicle is on flat ground), allowing compressed air to the air springs. The exhaust valve will remain closed. The height sensors then inform the ECU that the target height has been reached, the compressor stops and the spring valves are closed. If the air suspension is too high, the left and right hand spring valves will open, along with the exhaust valve, purging air until the height sensors inform the ECU that the target height has been reached.

If the LH and RH rear corners of the vehicle are at different heights, then the height sensors will inform the SLABS ECU that the distance between the axle and chassis is uneven. The SLABS ECU can then actuate the individual spring valves, along with the compressor or the exhaust valve, to level the rear suspension. The compressor does not need to be powered to deflate the air springs.

Other operation features

The levelling system is capable of lowering the rear suspension to within 20mm of the target height for up to 30 minutes after a door has been opened. This allows the suspension to be levelled as the vehicle is unloaded. With the exception of this unloading function, all other levelling functions are disabled if the doors are open while the vehicle is stationary.

The SLABS ECU will disable all levelling activities if the height sensors indicate that the rear suspension is articulated more on one side than the other by more than 100mm above its target ride height.

The SLABS ECU monitors the signals from the height sensors while it is changing the rear ride height. If the rear ride height is not changing as the SLABS ECU expects it to, then all valve (and compressor) activity is halted. If the vehicle is moving at greater than 5 kph (3 mph) when this happens, a fault will be logged in the ECU. Full functionality will be re-enabled when the expected movement is seen, or when the target ride height is changed e.g. by selection of off-road mode or by use of the plip function.

The SLABS ECU monitors use of the compressor and the valves. If these components are being over-used then they are disabled to allow them to cool down, and an event code is stored in the ECU for interrogation by TestBook. If the SLABS ECU decides that the compressor or the valves are being over- used, the levelling behaviour of the system may become erratic.

Information lamps

The SLS system has two information lamps in the instrument pack. Situated in the bottom left of the instrument pack is the first amber warning lamp (see figure 5). If it is continuously illuminated, this indicates that a malfunction has been detected or that the transit function is set. If it flashes, then the plip function is being used or the transit function is raising the rear suspension.

Malfunction / remote function lamp

The second amber warning lamp is situated in the top right of the instrument pack. This is the off-road warning lamp (see figure 6). The warning lamp, if continuously illuminated indicates that the self levelling suspension is in off-road mode. If the lamp flashes, this indicates that the SLS is between the standard ride height and the off-road mode, or that the vehicle is in its extended mode.

Off-road warning lamp

The SLABS ECU controls the operation of the SLS audible warning, the SLS warning lamp and the ‘Off road mode' warning lamp. When the ignition is switched to position ll, the ECU performs a three second bulb check and illuminates the SLS and ‘Off road mode' warning lamps in the instrument pack to check for operation. The audible warning is operated by the Body Control Unit (BCU) when it receives a signal from the SLABS ECU. The audible warning is emitted from a speaker at the rear of the instrument pack.

Modes of operation

The self levelling suspension has several different modes of operation. These are:

- Standard ride height.
- Off road mode.
- Extended mode.
- Transportation mode.

Off Road Mode

To give the vehicle extra height off-road, there is an off-road mode. To activate the off-road mode, press the self levelling switch on the fascia for a minimum of 0.5 second. A single audible warning will be given and on release of the switch the off-road warning lamp on the instrument pack will flash, indicating a change of ride height. When the vehicle is at the off-road mode target height, the lamp will stop flashing and remain illuminated. To exit the off-road mode, press the self levelling switch for a minimum of 0.5 second. The audible warning will sound once. On release of the fascia switch, the warning lamp will flash and the system returns the rear suspension back to the standard height.

Off-road mode can only be selected if the vehicle speed is lower than 30 km/h (19 mph), all doors are closed (if the vehicle is stationary), the engine is running and the rear axle has less than 100mm of articulation. If any of these conditions are not satisfied, the audible warning will sound three times and the off-road warning lamp will extinguish when the switch is released.

The off-road height setting is 100mm from the bump stops on the chassis to the axle. The vehicle will return automatically to the standard setting (60mm from the axle to the bump stops) if the vehicle speed exceeds 30 km/h (19 mph). Again, this height transition will be accompanied by an audible warning and lamp flashing. Off-road mode can only be deselected if all doors are closed (if the vehicle is stationary) and the rear axle has less than 100mm of articulation. If either of these conditions are not satisfied, the audible warning will sound three times and the off-road warning lamp will remain illuminated when the switch is released.

Extended mode

The extended mode operates only under the SLABS ECU control and is not selected by the driver. This will happen only when the ECU senses a grounded chassis, the rear wheels are spinning and the vehicle speed is lower than 10 km/h (6 mph). This function is intended to increase the rear suspension height to clear an obstacle. Under these conditions, the compressor will operate for 25 seconds. The self levelling warning lamp will flash at a different rate, 75% on, 25% off. This function is cancelled if the vehicle exceeds speeds of more than 13 km/h (8 mph) or if the fascia switch is pressed for a minimum of 0.5 second.

Transportation mode

The self levelling suspension has a transportation function. This function should be used whenever the vehicle is to be transported on a trailer and is to be lashed down by its chassis frame. The transportation function can only be enabled and disabled using TestBook. The transportation function lowers the rear suspension onto the bump stops, when the engine is not running. In this condition, the malfunction warning lamp will be illuminated continuously if the ignition is in position II. When the engine is running, the transportation function raises the rear suspension until the gap between the chassis mounted bump stops and the axle is 25mm. In this condition, the malfunction warning lamp will flash while the suspension is rising, then it will be illuminated continuously when the 25mm bump stop gap has been achieved.

Headlamp adjuster

All New Discovery derivatives feature a headlamp levelling switch situated on the vehicle fascia. The switch adjusts the headlamp setting to the driver preference. When the system has levelled the rear suspension, the driver can then set the headlamps to suit. This is especially useful when towing, as the vehicle's pivot point will cause the headlamps to rise at the front due to the weight pulling down on the rear of the vehicle.

Remote function

An additional option available as an accessory, is a dedicated air suspension remote transmitter which allows the driver to stand outside the vehicle and adjust the height to match that of a trailer hitch for hitching/disconnecting. This enables the rear vehicle height to be controlled between standard ride height and bump stop height. This option is purchased from the dealer and has to be configured by TestBook.

The remote transmitter transmits RF signals which are received by the same RF receiver used for the alarm/remote door locking system. The RF receiver passes this data as a 25 Hz PWM signal to the BCU. The BCU then transmits this data to the SLABS ECU as raise or lower data.

Operation

To operate the remote transmitter the ignition must be in position II and all doors must be closed. The vehicle must be stationary and the self levelling suspension should be at the standard ride height.

Pressing the lower button on the plip will allow the suspension to be lowered up to 60mm below standard ride height. Pressing the raise button on the remote transmitter will allow the suspension to rise up to the standard ride height. If either button on the remote transmitter is released during the remote operation then the suspension height will freeze in whatever position it is positioned currently.

Whilst undertaking the operation of modifying the suspension height in response to the remote transmitter signal, the fascia warning lamp flashes (see above) and the audible warning is activated.

The rear suspension height will return automatically to standard ride height if the vehicle speed exceeds 5 km/h (3 mph) for longer than 5 seconds, or instantly if it exceeds 12 km/h (7 mph).

Door switches

The driver, passenger and rear entry door switches are important in the operation of the self levelling system. The levelling system will not operate if the SLABS ECU, detects that the vehicle is stationary and a door is open. Within the SLABS ECU, the driver's door switch and the passenger door switches are connected together. Therefore, the SLABS ECU cannot determine which door is open, or if more than one door is open.

Diagnostics

The SLABS ECU can be interrogated via TestBook to:

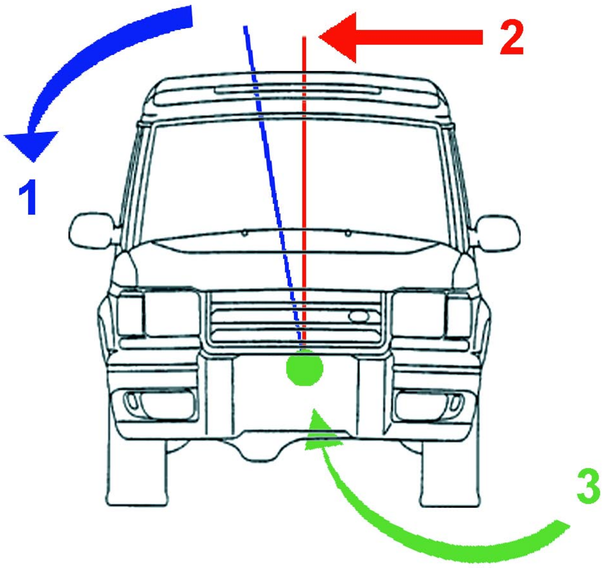
- Diagnose faults stored in the ECU memory, current or historic.
- Test individual parts of the system.
- Initialise a new SLABS ECU for operation and configuration of functionality.

TestBook will also be required to calibrate the settings of new height sensors and to configure the remote transmitter (if applicable).

The philosophy behind the system

Active Cornering Enhancement is a system designed by Rover Group engineers to enhance the dynamic handling and suspension characteristics of New Discovery. In essence, it is a system which monitors the lateral forces acting on a vehicle during cornering and makes adjustments to the suspension to compensate for these forces.

When cornering, the lateral acceleration acting on the vehicle body results in the body pivoting about the suspension roll axis (which, on New Discovery is determined by the Panhard rod and the Watts linkage). The lateral acceleration acting on the centre of gravity of the sprung mass results in a torque about the roll axis. This torque on a ‘normal’ passive suspension vehicle is opposed by the road springs and the anti-roll bars.



1.Body reaction
2.Lateral force due to centrifugal effect of cornering
3.Roll axis

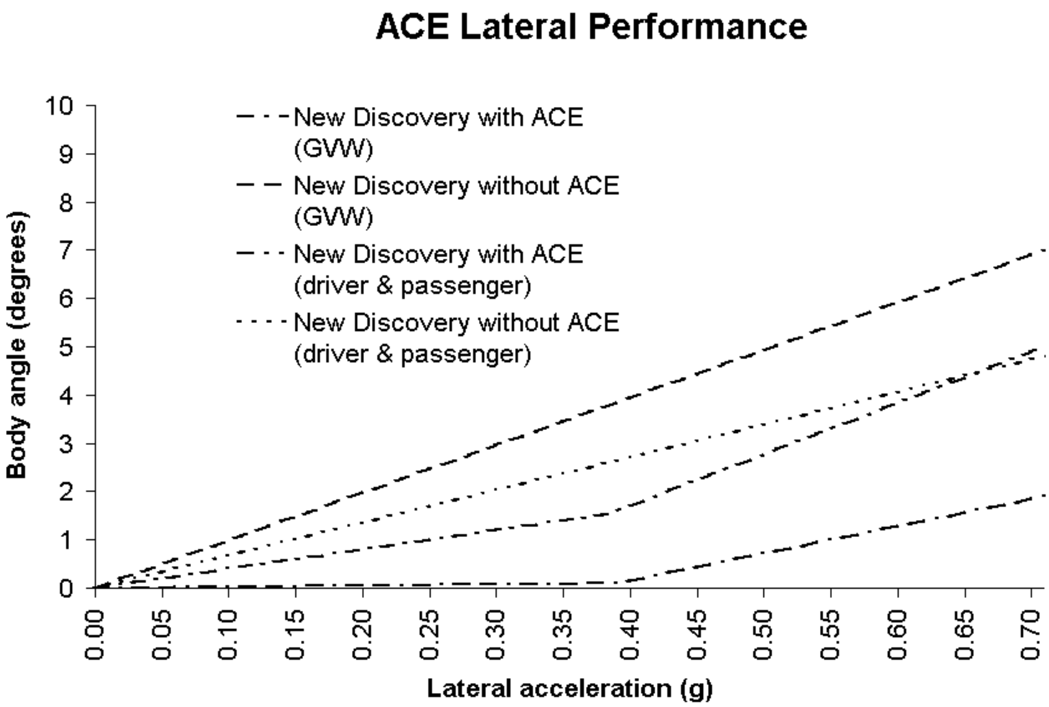
The anti-roll bars (on a conventionally sprung vehicle) are springs which resist any differential movement of the wheels on an axle. This effects the single wheel bump rate but has no effect on parallel movement of the axle.

The Active Cornering Enhancement (ACE) system replaces the standard anti-roll bars with roll control modules. These modules can be considered to be rigid, apart from the hydraulic actuator which connects one end of the bar to the other. The ACE system uses accelerometers to monitor the lateral acceleration of the vehicle (how hard it is cornering) and applies a predetermined amount of hydraulic pressure to the actuators. This pressure is then translated, first, into a force in the actuator and, subsequently, into a torque, which acts between the axle and the vehicle body. This force counters the torque produced by the lateral acceleration of the vehicle when cornering.

The roll control modules are controlled by pressure. If one wheel hits a bump during cornering, no further pressure (force) is applied to that wheel. In this circumstance, it is only the road spring which opposes the bump, unlike passive suspension where the anti-roll bar also opposes the movement of a wheel when encountering a bump. This feature enhances the ’ride' quality of the vehicle when cornering.

This principle enables the ACE system to reduce body roll significantly in all circumstances and to eliminate it altogether in certain circumstances. It also enables the vehicle to be fitted with relatively low rate springs, improving ride comfort and optimising axle articulation for superb off road ability.

Lateral acceleration is measured in m/s^2. Acceleration due to the earth's gravity measures approximately $10m/s^2$ (1g) and is referred to as 1(g). The greater the mass, the bigger the effect (or force) of gravity, though the ‘g' level does not change. When cornering in extreme circumstances, lateral acceleration of up to 1(g) can be felt. The ACE system is designed to virtually eliminate the movement of the vehicle body up to a lateral acceleration of 0.4(g) (unladen) and then to allow a progressively higher amount of body roll as lateral accelerations increases. The graph in figure 2 shows this relationship. The benefit to the driver is that the vehicle feels very stable and responsive under these conditions, while passenger comfort is improved due to significantly reduced body movement. A second benefit is improved steering characteristics. The steering is less susceptible to the normal variations that are felt when the body and chassis move relative to the steered axle.



System components

ACE employs an hydraulic system comprising a reservoir, pipe-work, pump, valve block and two actuators, one on each of the two roll control modules. These actuators apply the required torque to the suspension. To control the hydraulic system, two accelerometers are used which supply the ACE ECU with information on the lateral acceleration of the vehicle. A pressure transducer is incorporated to monitor the hydraulic pressure in the system; its inputted signal is used by the ACE ECU to monitor the effect of applying a controlling electrical current to the proportional pressure control valve. The ACE ECU also uses inputs from other vehicle system's ECU's to determine:

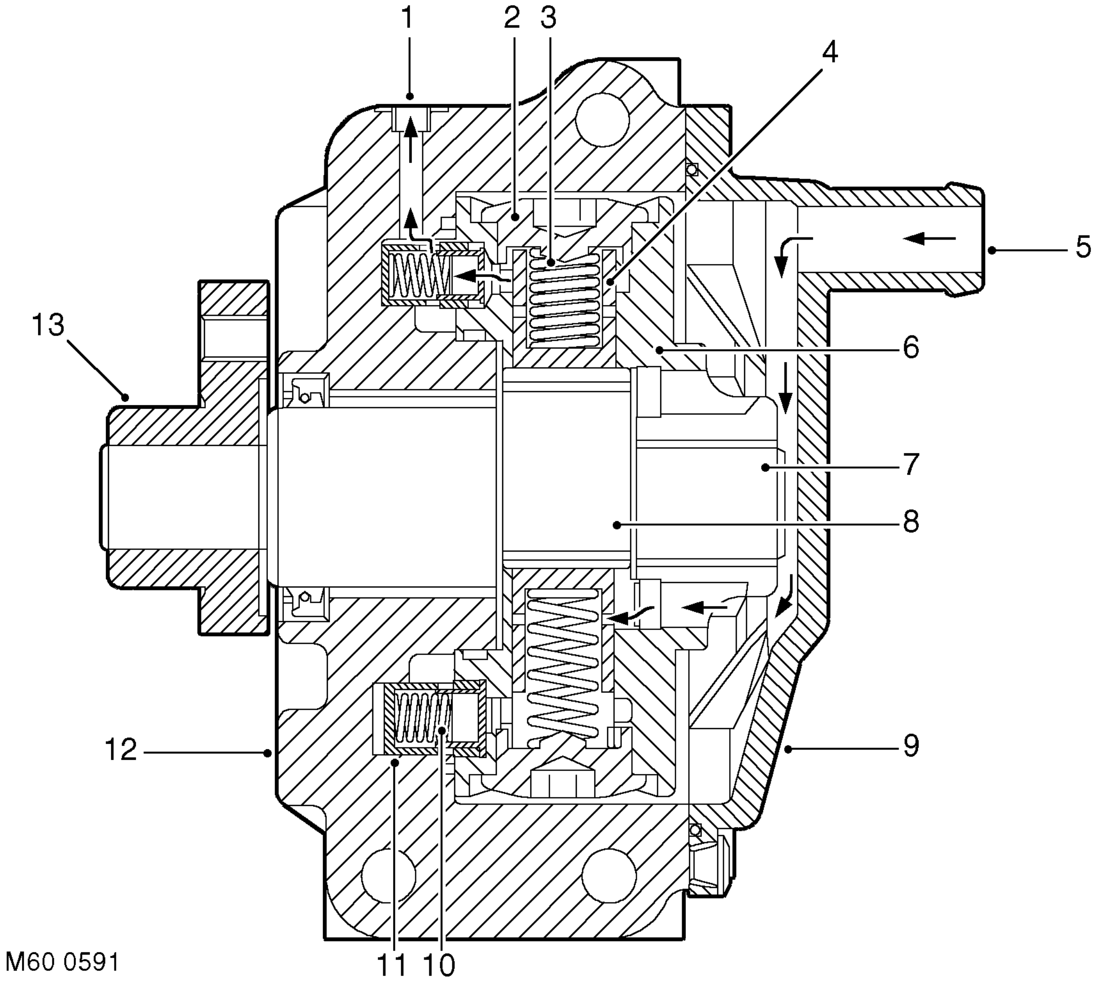
- If the engine is running
- The vehicle speed
- If the driver has selected reverse gear
- The above information is required for system control calculations.

It should be understood that the ACE system works independently of the air suspension self-levelling system, although it does use the road speed input from the Self-Levelling Anti-lock Braking System (SLABS) ECU.

Hydraulic pump

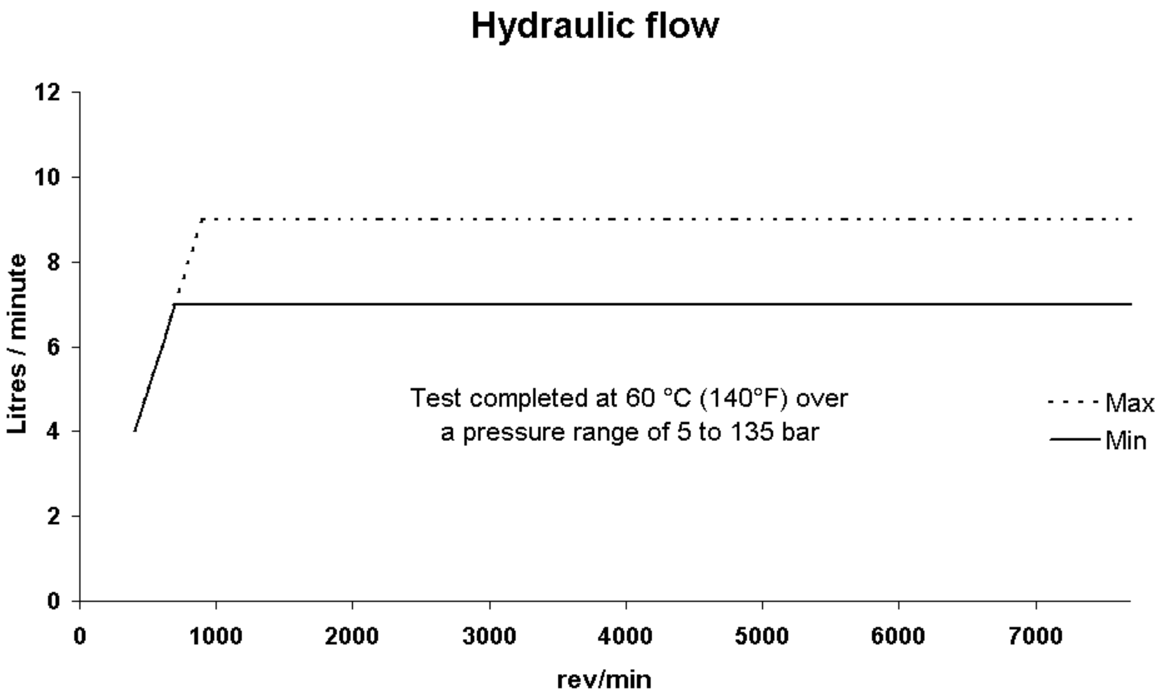
The hydraulic pump is located on the engine and is driven by the auxiliary drive belt. The belt is self-tensioned and must be replaced in accordance with the vehicle maintenance schedule. It is a radial piston pump which differs from a conventional power steering pump because of the unique requirements of the ACE system. Where as a power steering pump requires its greatest pressure at low engine rev/min (due to the need for the greatest assistance when the vehicle is completing parking type manoeuvres). The ACE system works across the complete engine range, and so requires the pump to deliver a constant flow from relatively low engine rev/min through to high engine rev/min. The ACE system also requires the pump to deliver high pressures across the complete engine range. If a power steering type pump were used, it would require up to six times the amount of engine power to drive it.

The ACE pump flow characteristic is a result of `suction control', which is regulated by the size and position of the fluid inlet holes in the piston (see figure 3). If the suction hose between the reservoir and the ACE pump becomes kinked or restricted, it will reduce the pumps output flow characteristic.



1.Outlet port
2.Cap
3.Piston spring
4.Piston
5.Inlet port
6.Cylinder housing
7.Shaft
8.Cam
9.Inlet housing
10.Spring
11.Discharge valve
12.Housing
13.Pulley attchment flange

This condition is difficult to diagnose because there are no obvious changes in noise levels and/ or performance. The driver may, however, be aware that the response time of the ACE system increases when completing extreme vehicle manoeuvres. Flow/engine rev/min characteristics of a typical radial pumps are detailed in figure 4.

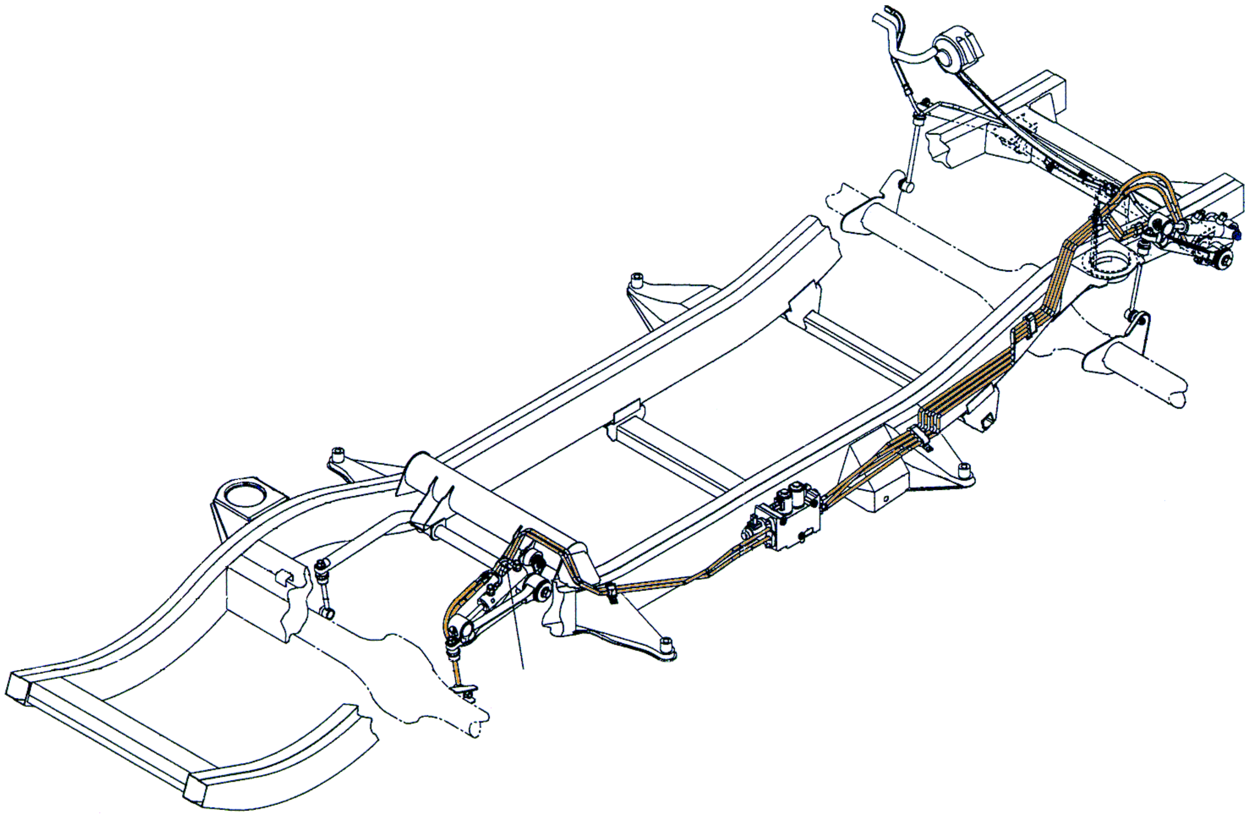


Hydraulic pipes

The flow from the pump goes to the valve block located on the outside of the right hand chassis rail, via a high-pressure hose and pipe assembly. The hose is particularly important as it contains two attenuator springs and a restrictor, which have been tuned in their lengths, positions and diameters in order to minimise the system's noise level and vibration. A multi piston pump generates pulses of flow as each piston forces fluid out of its outlet port. These pulses have been minimised by careful design of the pump, but the pump still produces some pulsations over the complete engine speed range. The pulsation frequency changes with engine speed but the overall flow remains constant. It is, therefore, necessary to have the above devices incorporated into the hose to dampen out these pulsations. The hose specification is also extremely important, as a hose which dilated significantly would result in very poor hydraulic response to system pressure changes, impacting on total system performance. The hose has, therefore, been selected to give the required system response whilst also giving some attenuation to the pulsations.

It is vital that this pipe is serviced as a unit and that no attempt is made to repair it. Both the front and rear pipe assemblies follow a defined route and are secured by several brackets that clamp them to the chassis. The positioning of these brackets is extremely important. The pipes have location features to ensure that both the front and rear pipe assemblies can be located easily on the chassis frame without either 'loading' the isolators and isolator brackets or allowing the pipes to foul other vehicle components. If the pipe or brackets are removed, care must be taken to ensure that the pipe is reattached in the original position.

There are two isolating blocks located on the pipework. These blocks are used to keep a distance between the different ACE pipes and to ensure there is no contact with other vehicle components. These isolation blocks must not be fixed to the chassis, nor should any other fixing be placed onto the pipes, otherwise the noise refinement of the system can be destroyed.



The hydraulic pipes incorporated within the ACE system from the pump to the valve block and from the valve block to the reservoir differ as service replacements from those fitted when the vehicle is manufactured. This is because these two pipes are fitted to the vehicle before the body of New Discovery is attached to the chassis. This allows the use of ‘one piece’ pipes. In service it is not possible to remove the pipes without cutting them. To facilitate an acceptable repair policy, the service pipe from the pump to the valve block, and the pipe from the valve block to the reservoir, will be sold in two parts with a connector to seal the joint. The pipe route along the chassis has a strategically placed enlarged gap to allow for these connection joints.

At no time may the pipes be joined or cut, other than to replace a manufactured pipe with the two pipes supplied for after sales use. It is important that if the pipes are removed from the valve block they are re-fitted to the correct ports. If the pipes are ‘crossed’ the system will be damaged. To facilitate correct fitment, all ports are marked on the connector plate and the pipes are tagged with identifying letters. The letter on the pipe must match the letter stamped on the valve block connector plate. These are:

- ‘A'. There are two ‘A's - one for the front pipe and one for the rear. It is not possible to fix the pipes incorrectly from front to rear
- ‘B'. There are two ports marked with the letter B again one front and one rear
- ‘P'. This pipe is the pressure pipe from the ACE pump
- ‘T'. This pipe is the return and goes back to the reservoir (tank)

The hydraulic pipes that supply pressure to the actuators from the valve block must also never be cut or joined. Each actuator has two pipes which are routed along the chassis with short, flexible hoses (jump hoses) to the actuators. These jump hoses are stainless steel braided and then covered for increased abrasion resistance. This design combines minimum pipe dilation with robust service life. Like the hydraulic pipes from the pump and reservoir, the routing and fixing points of the pipes are critical in assuring quiet and effective operation of the ACE system.

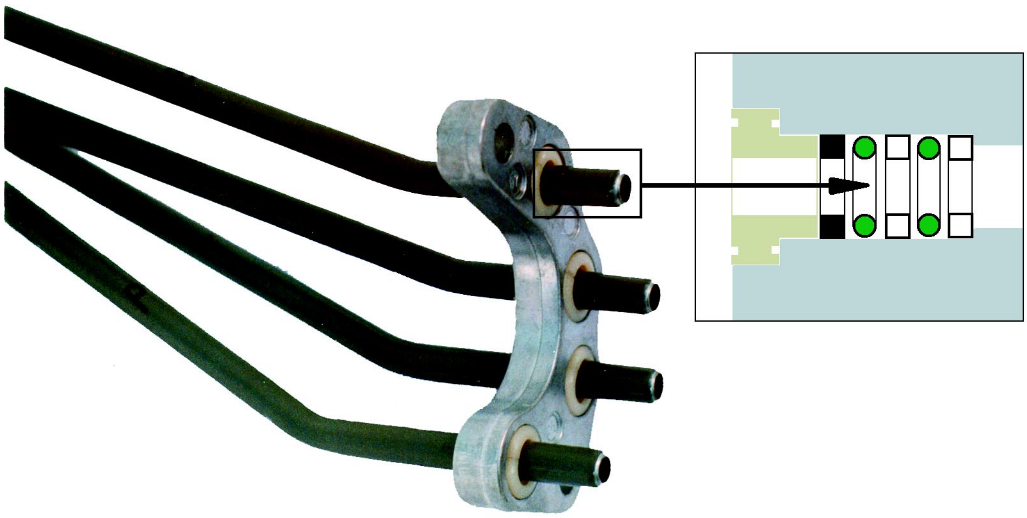
Reservoir

The ACE system reservoir is combined with the power steering fluid reservoir but can be thought of as a separate reservoir, as it has its own filling neck and there is no provision for the fluids to mix. A characteristic of a radial piston pump and the ACE system is that, in the case of fluid loss, no discernible noise will be heard from the system, so the driver will have no audible indication that there may be a problem. The ACE ECU has an onboard diagnostics capability to determine if the system is low on fluid. If the ECU does detect this, it will alert the driver by flashing the warning lamp red and sounding an audible warning.

It is important that the oil level is maintained correctly and that any leak in the system be investigated immediately. The ACE system requires clean uncontaminated oil. The oil used to top-up the reservoir must be taken from a new container of oil or, if the oil is held in bulk, it must be filtered before it is dispensed into the reservoir. The oil used in the ACE system can be obtained through Unipart. It is a green semi synthetic oil (Texaco 14315), which provides consistent performance throughout the temperature range that will be experienced by vehicles in all world markets. The oil capacity of the ACE system is 1.62 litres.

Valve block

The valve block is located on the chassis, under the right hand seat. It is fixed to the chassis by three bolts that pass through bushes in the valve block. These bushes have been designed to isolate the chassis frame from the vibration frequencies of the valve block whilst firmly locating the valve block to the chassis rail. The valve block has six pipes connected to it. As previously described, these pipes must not deviate from the designed route and must not be altered in size or shape. The valve block pipe fittings each have a double ‘O’ ring system that has support rings and a plastic retainer (see figure 6). If the seals need to be replaced, the retainer rings are removed by using a new clean 10mm bolt. A smooth plastic hook should then be used to remove the ‘O’ rings and support rings (this could be a crochet hook). A plastic sleeve supplied with the new seal set is used to refit the new seals and supporting rings into their correct position. If any of the ‘O’ rings or support rings are removed, then all the parts must be replaced. The diagram in figure 6 illustrates the seal position and the clamping system used to locate the pipe in the correct position. The pipes are retained in the valve block seal packs by a cast aluminium connector plate and plastic collet arrangement.



To assemble the pipe retainer assembly, the pipe is passed through the aluminium connector plate, and then a plastic ‘split’ collet is clipped around the flare of the pipe. The pipe/collet assembly can then be pulled back into the connector plate where it again clips in position ready for assembly into the valve block. When a pipe is removed and you are preparing to refit it, make sure that there are no score marks in the direction of the long axis of the pipe. This is especially important around the area sealed by the ‘O’ rings. The cleanliness of all units before removal, whilst the system is open and during reassembly cannot be overstated. The valve block has small orifices and the valves are machined to exacting tolerances. If foreign material is allowed to enter the system, it can adversely affect the operation of the valve block.

The valve block incorporates an ultra fine filter. This should be replaced in accordance with the maintenance schedule. It should also be replaced if the fluid has any foreign material in it, or if any hydraulic components are replaced in the system. When the filter is replaced, the cleanliness of the working area, new filter and any tools used is paramount. It is important that any pipe disconnected from any part of the system is suitably protected from the ingress of dirt particles. Use suitable cleaned ‘pipe-plugs’ in both the removed pipe end and the opened port. Care must be taken not to damage any internal surface when fitting or removing the pipe plugs.

There are three solenoid valves incorporated into the valve block. The first is a proportional pressure control valve. This valve is fitted in the back face of the valve block assembly and has a blue coil fitted. This valve is ‘normally open’, such that, with the engine running and the vehicle stationary, the oil is free to flow from the pump, through the valve and back to the reservoir with the minimum amount of resistance.

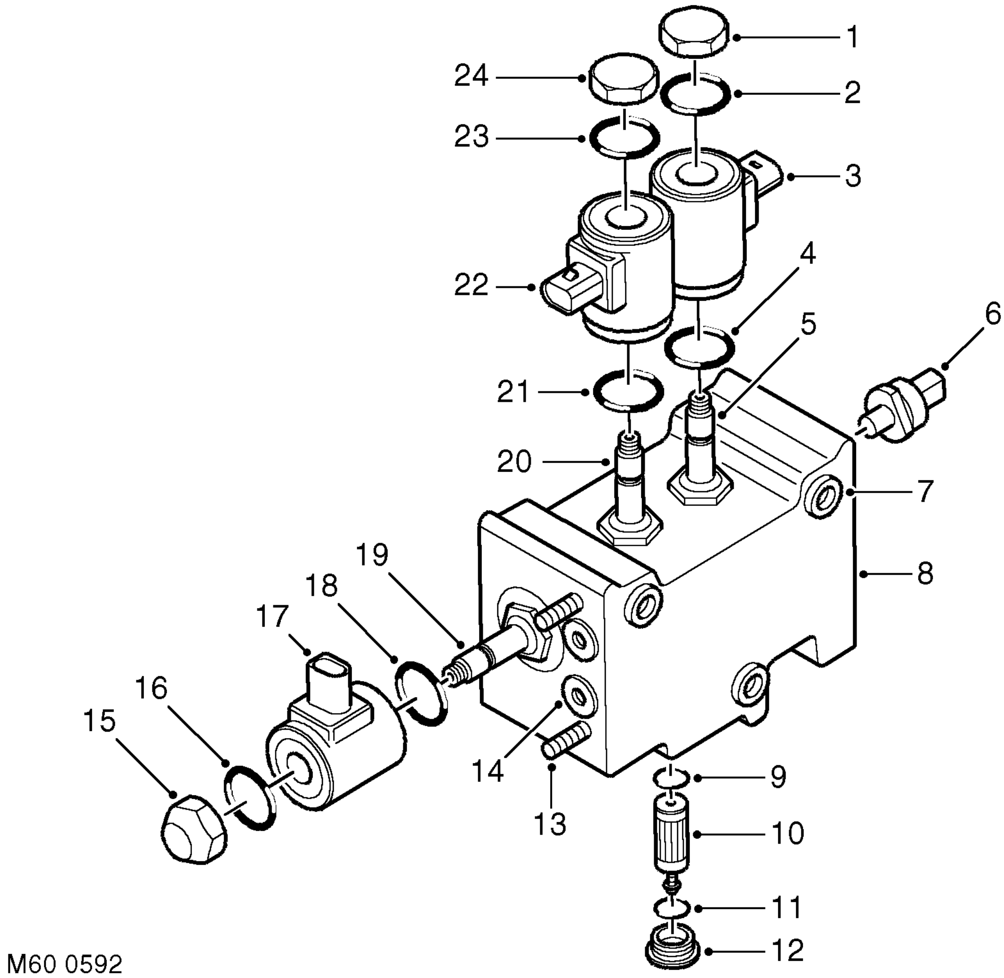
In this case, the system is operating at ‘residual pressure’. Residual pressure occurs as a result of pipe lengths and diameters, as well as the ‘porting’ in the valve block and a very light spring in the proportional pressure control valve. When the vehicle is cornering, the ACE ECU controls the current in the valve with a 200Hz pulse width modulated (PWM) signal to regulate the pressure drop across the valve to the required level. This pressure can be infinitely varied over the operating pressure range to ensure refined operation of the system. It is important to remember that this valve does not stop the fluid flowing through the valve block but internally balances forces to create a ‘back pressure’.

The other two solenoid valves are directional spool valves located on the top of the valve block assembly. These solenoids are black in colour, these are both ‘normally closed’ so that they will open only when the ACE ECU determines that the vehicle is cornering and assistance is required. Only one of the valves is operated to ensure that the correct side of the front and rear actuators are exposed to the controlling pressure, whilst the opposite side is opened to the reservoir. For control of the system, only one of these valves will be opened at once.

The valve coils are serviceable, though the valves themselves are not. Care must be taken when refitting the electrical coils that there is no dirt or other contamination between the hydraulic valve and the inner surface of the electrical coil. The coil, retaining nut, ‘O’ ring seals and the valve must be clean prior to being fitted. The retaining nut ‘O’ ring should be checked to ensure that it is in good condition. The retaining nuts on the solenoids form part of the magnetic field and, therefore, it is important that only the correct nuts are used to hold the electrical coils on to the valves.

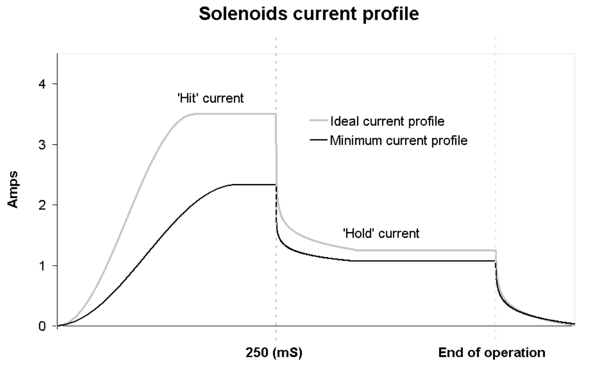
All fixings, retaining bolts and pipes must be tightened to the specified torque. If items are over torqued or under torqued, system operation can be adversely effected.

The diagram in figure 7 shows the positions of the three solenoids.



1.Cap
2.'O' ring
3.Coil
4.'O' ring
5.Directional control valve 1 (extend)
6.Pressure transducer
7.Mounting bush 3 off
8.Valve block
9.'O'ring
10.High pressure filter
11.'O' ring
12.Cap
13.Stud 4 off
14.Pipe connections
15.Cap
16.'O' ring
17.Coil
18.'O' ring
19.Pressure control valve
20.Directional control valve 2 (retract)
21.'O' ring
22.Coil
23.'O'ring
24.Cap

The ACE ECU powers the two directional spool valves with a 200Hz PWM 'hit' and 'hold' current control feed. This feed is similar to the feed sent to the proportional pressure control valve, except that this feed is not continuously variable. The ECU controls the pulse width to one of two levels, either the 'hit' current or the 'hold' current. The current supplied to all solenoids is independent of battery voltage. The 'hit' current is a minimum of 3.75 amps for 250mS at which point the current is dropped to a 'hold' current of 1.65 amps $\pm$ 0.3 amps. Figure 8 demonstrates the current/time characteristics of the directional spool valves.

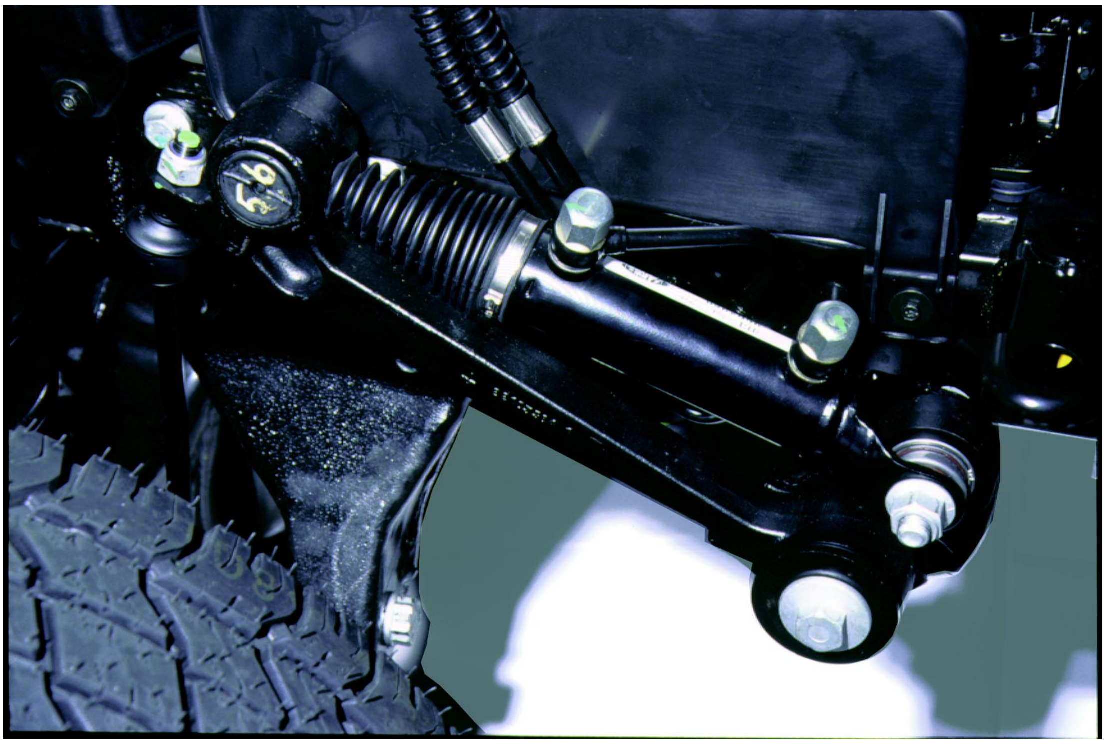


The ACE ECU senses the pressure in the valve block with a pressure transducer, to enable closed loop control of the system. The ECU uses this signal to tune the operation of the proportional pressure control valve. The ECU maps the amount of current needed to produce the required pressure in the system and then fine tunes the proportional pressure control valve to deliver the appropriate pressure. The pressure transducer unit screws into the valve block assembly and measures the fluid pressure directly after the high-pressure filter. The transducer alters a voltage in proportion to the pressure acting on it and sends this information to the ACE ECU via a dedicated wire.

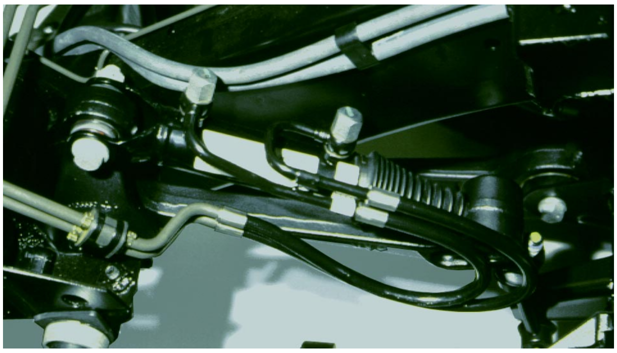
Actuators

There are two actuators in the ACE system. Their position is indicated in figures 9 and 10 below.

Front actuator



Rear Actuator



The actuator is the unit in the ACE system which transfers hydraulic pressure supplied by the valve block into a force and, hence into mechanical movement. The actuator is constructed in a similar manner to a standard hydraulic cylinder, with a 40mm diameter piston connected to the end of a 14mm rod. As the force applied by the actuator is determined by the pressure multiplied by the effective area (force = pressure x area). In order to apply a similar force to the roll control module, it is necessary for the system to apply a higher pressure to the rod side of the cylinder (area of piston – area of rod) than the piston side (area of piston only). Due to the installation of the hydraulic actuators within the roll control modules, a higher pressure is used in the system when cornering to the right. The configuration of the valve block assembly and the pipework ensures that both the front and rear actuators are always supplied with the same pressure on the same side of the cylinder. When one side of the actuators is being pressurised the other is vented to the reservoir.

It should be remembered that it is the force applied by the actuator that resists the vehicle body movement and not the actuator displacement i.e. the ACE system is pressure controlled, not displacement controlled.

The actuator has no replaceable seals within it and if a leak is evident the actuator must be replaced. The `jump' hoses are sealed by `Dowty' self centring banjo sealing washers. It is important that only self-centring washers are used, as standard `Dowty' seals will result in serious system leaks. Such leaks may happen when the pipes are first fitted, but are more likely to occur during the service life of the vehicle. To avoid confusion, it is strongly recommended that the washers are obtained by ordering the correct Land Rover part number as a replacement. The washers should be replaced every time the connection is loosened.

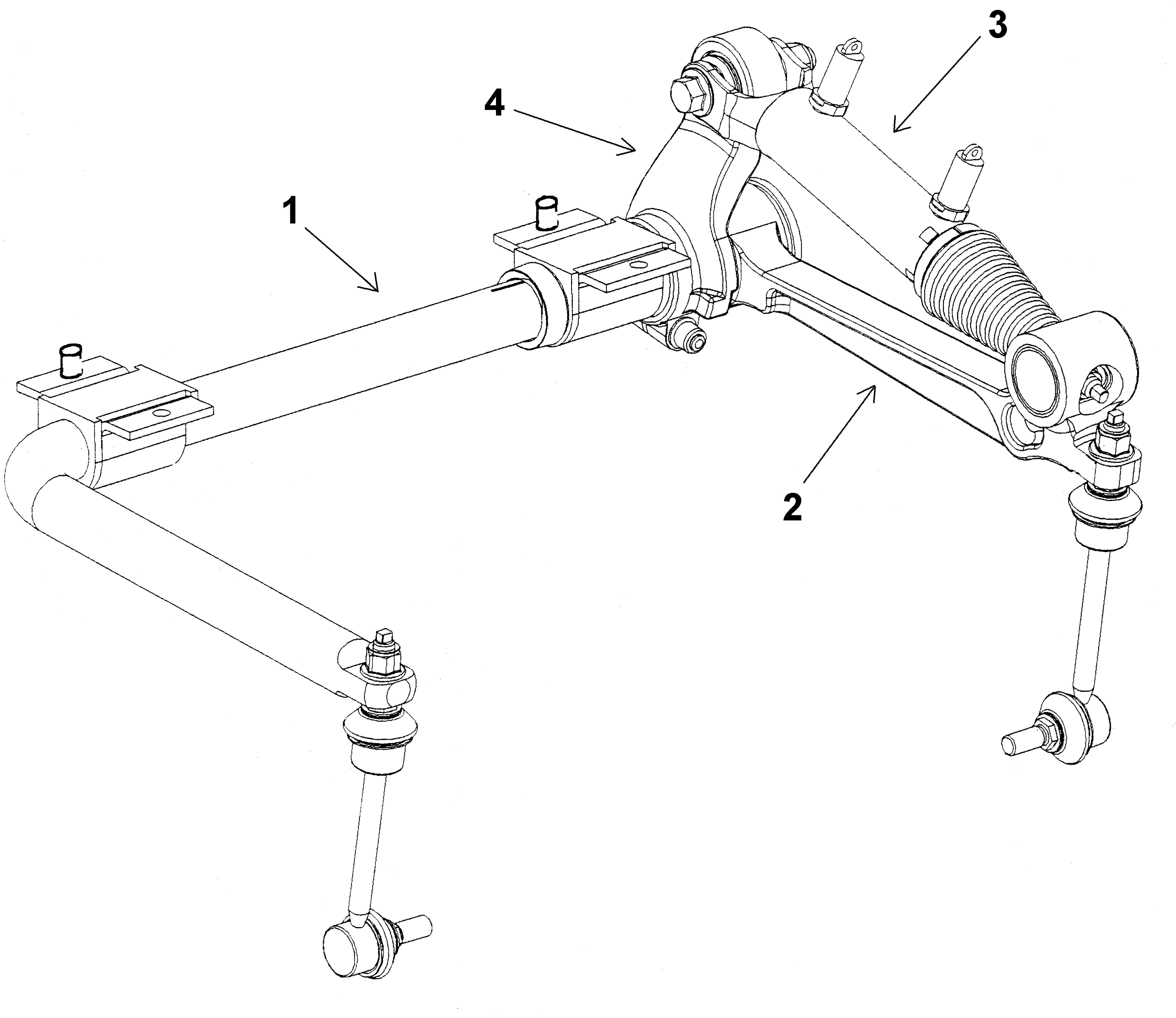
There is no fluid path through the actuator, so the system cannot self-bleed. The bleeding procedure will be explained later in this section.

Anti-roll bar

Conventional anti-roll bars are, effectively, torsion bar springs which resist the relative movement of one wheel on an axle with respect to the other wheel on the same axle. Hence they resist the vehicle body rolling relative to the axle.

The greater (stiffer) the spring rate of the anti-roll bar, the greater the resistance to body movement from the axle line. A road vehicle or a heavy goods vehicle can have comparatively stiff anti-roll bars because there is a reduced need to supply the vehicle with a large wheel articulation. An off-road vehicle requires large wheel articulation to overcome obstacles that effect only one wheel. This gives the suspension designers of off road utility vehicles a problem: achieving the correct balance between the capability of the body to remain composed whilst allowing axle articulation for overcoming an obstacle. This need is offset with the need to keep the body from rolling excessively from the line of the axle when the vehicle is cornering at speed.

The roll control module is quite different in construction to a conventional anti-roll bar. Referring to figure 11, it is constructed from one piece of very high rate spring steel torsion bar (1), a long arm (2) which locates one end of the actuator (3) and pivots on a bush located on the torsion bar. Also, a short arm (4) which locates the other end of the actuator, is clamped rigidly to the torsion bar. All of the components are made from substantially stiffer/thicker steel than in a conventional anti-roll bar to minimise deflections/compliance in the system.



1.Cross bar
2.Long arm
3.Acuator
4.Short arm

The response time of the ACE system is very important as, during avoidance type manoeuvres, the lateral acceleration of the vehicle can build up at a rate of up to 2.0g/s. The ACE system has the ability to build up a system pressure equivalent to 1.0g within the primary circuit (both direction valves closed) in less than 130mS. When cornering, the system has to take up compliance due to bar twist, bush deflections, 'jump' hose dilation, chassis frame deflections etc. This results in a system that is matched to the vehicle response. The system response time is determined by the following key items:

- ECU control algorithm
- Valve response times
- Pump flow
- Hydraulic bleed condition
- Suspension component condition (bushes, links, dampers etc)

If the actuator is removed, there will be no resistance to body roll as the long arm would rotate freely on the torsion bar. Conversely, if the actuator always remained in the same position, the anti-roll bars characteristics would simulate a very stiff conventional anti-roll bar. There are also stabilising links which can pivot on the end of the anti-roll bar and on the axle. These are needed to allow for correct operation over a large axle travel range.

The long arm is constructed from forged steel and, as previously mentioned, is free to rotate around the torsion bar on a `slipper' bush. This bush is a two piece design, with locations preventing relative movement of the outer housing to the long arm. The second bush in the long arm locates the rod of the actuator. The location of this bush in the long arm is extremely important and changes between the front and rear roll control modules.

The roll control modules are different from front to rear; the relative lengths and widths of the component parts have been designed to give the required front/rear suspension balance. This is similar to the way a conventional passive suspension balances the forces using different spring rated material. The ACE system is a force balance system, as opposed to a roll stiffness balance for a passive suspension system.

Accelerometers

There are two accelerometers used in the ACE system. These are electronic devices which measure acceleration along one axis (the `Y' axis). This is achieved by changes within the internal capacitance. The accelerometers have a 5 volt supply; the output from the sensor will fall into a range between 0.25 - 4.75 volts, depending on the lateral acceleration currently being experienced. The accelerometers are located on the body of the vehicle, one behind the headlining above the front interior lamp, the second by the bottom of the `A' post, under the vehicle near the body-to-chassis fixing point on the right hand inner sill. The orientation of these devices is very important for correct operation. They are attached to the vehicle by brackets and must only be removed from the brackets using a special tool LRT-76-002.

Care must be taken when relocating each sensor in its bracket to ensure that it has slotted into the correct position. The bracket must be in a good condition, (not bent or loose) as this will result in the system becoming unrefined and, possibly, inoperable. Mislocating a sensor will either disable the system completely or at the very least greatly reduce its performance. Figure 15 illustrates the position of the accelerometer within its bracket.

The position of the brackets on the vehicle is also very important. As you can see, both the sensors are positioned so that they fall on the same 90° plane, taken from a line drawn from the front of the vehicle to the rear. The sensors are positioned in this manner so that during cornering they each see the same accelerations. If the sensors are moved, the calibration in the system will be lost and, again, the system will function with a reduced finesse, or may be disabled.

Both accelerometer assemblies are mechanically and electrically identical, but the system uses the information each one supplies in a different manner. The system can operate on the lower accelerometer if the upper accelerometer fails, but will not operate if this condition is reversed. If the upper accelerometer does fail, the system will function with a reduced level of finesse and the driver will be alerted by means of a warning light, details of which will be covered later in this section.

Accelerometers are very sensitive electronic devices. Do not drop or ‘shock’ them in any way. If the device does experience a shock it will need to be replaced. The device has no serviceable parts and must not be tampered with in any way. There is no way to check that the accelerometer is in a serviceable condition apart from when it is fitted to the vehicle and assessed for correct operation using TestBook. If a new accelerometer is fitted or if an accelerometer is removed and refitted, TestBook must be used to recalibrate the system. This procedure must also be followed if a new ECU is fitted.

The accelerometers, as previously mentioned, supply a voltage signal to the ACE ECU when they are subjected to an acceleration force in the correct direction. It must be understood that these sensors do not measure the amount of body roll that the vehicle is experiencing, but the vehicle’s lateral acceleration due to cornering. This statement might be seem to be ‘splitting hairs’, but there is a fundamental difference. If the accelerometers did measure the amount of vehicle body roll, the system would act only as a consequence of movement, so the driver would experience body roll before any action took place to correct it. By having accelerometers that return a signal when the vehicle is experiencing cornering forces, the system can act before the vehicles body starts to roll. This makes the system an active system, rather than a reactive or adaptive system.

Two accelerometers are used so that the ECU can detect the level of road roughness and modify the system control appropriately. The accelerometer locations have been selected carefully so that, by monitoring the upper and lower acceleration signals, the ECU can detect the level of body roll and rock due to the road condition. Both accelerometers are subjected to the lateral acceleration generated when the vehicle corners, but only the upper accelerometer will see inputs as the body rocks. The difference in signal can be used for road roughness detection by the ACE ECU. On detection of a ‘rough road’, the ECU will modify the level of assistance the system provides, as long as the vehicle speed is below 40 Km/h (25 mph). Above 40 Km/h (25 mph), the system gives full assistance, regardless of the ‘roughness’ of the road surface. If the assistance currently being provided to the vehicle is reduced by the ACE ECU sensing a ‘rough road’ and the vehicle speed increases to above 40 Km/h (25 mph), full assistance will quickly return.

Below 40 Km/h (25 mph), the accelerometer signals are used to detect if the vehicle is on a side slope. A side slope with a lateral acceleration of greater than +/-0.2g will result in both direction valves being closed and no ACE assistance is given (locked bars). This enables the vehicle to maintain a consistent attitude, which is parallel to the ground.

ACE ECU

The ACE ECU is situated behind the passenger glove box on a metal bracket. To gain access to it, lift the two sprung glove box stays and release the glove box to hang towards the vehicle floor. There are three ECU’s on the bracket, the ACE ECU, the body control unit (BCU) and the self levelling anti-lock brake ECU (SLABS). The ACE ECU can be identified because it is the only ECU with a single 36-way connector. On a vehicle with left hand drive (LHD), the position of the ECU’s on the bracket is still behind the passenger-side glove box and remains in the same order, (looking from left to right: SLABS, BCU, ACE). The system is supplied current via a fuse in the engine compartment fusebox. This fuse feeds the ACE relay, which is also located inside the engine compartment fusebox. The ACE ECU supplies the ACE relay with an earth signal, thus energising the relay. This, in turn, supplies the ACE ECU with its main power feed. An ignition on signal is supplied to the ACE ECU by a fuse located in the intelligent drivers module.

Warning indicators

There is one ACE system warning light, located in the instrument pack. The warning lamp can display either a red or amber light. Both colours inform the driver of the status of the system. In certain fault conditions, the red lamp will flash and the vehicle’s internal sounder will be activated, indicating to the driver that the vehicle must be stopped to prevent serious damage to the ACE system and, potentially, the auxiliary drive belt.

In the event of a new ECU being fitted to a vehicle, the amber warning light will be illuminated continuously and the system will be in a ‘locked bars’ condition. The ACE ECU needs to be programmed using TestBook and the accelerometer calibration entered into the ECU before the lamp will extinguish.

Under most circumstances, when the ECU detects a system fault the amber light will be illuminated and the system will default to a ‘locked bars’ condition. The primary hydraulic circuit is allowed to run at a residual pressure i.e. only the restriction of the pipes dimension and internal valve block components. This condition minimises body roll, by allowing the roll control modules to act like very stiff passive anti-roll bars whilst cornering. However with a front to rear interconnection, axle articulation and vehicle ride are not impaired significantly.

If the system detects a loss of fluid in the primary circuit (which would result in the pump running dry and subsequently causing serious damage to itself and other system components) the red lamp will flash and the audible warning will sound. This combination warning will last for approximately 30 seconds, at which point the red light remains on permanently. The red lamp indicates to the driver that s/he must stop to prevent serious damage. The system will close both direction valves, causing a 'locked bars' condition. If the system has detected a fault of this nature, it is likely that a significant amount of oil will have been lost from the secondary circuit. This loss of oil will result in the driver experiencing greater body roll. Safe handling characteristics are always maintained in all fault conditions.

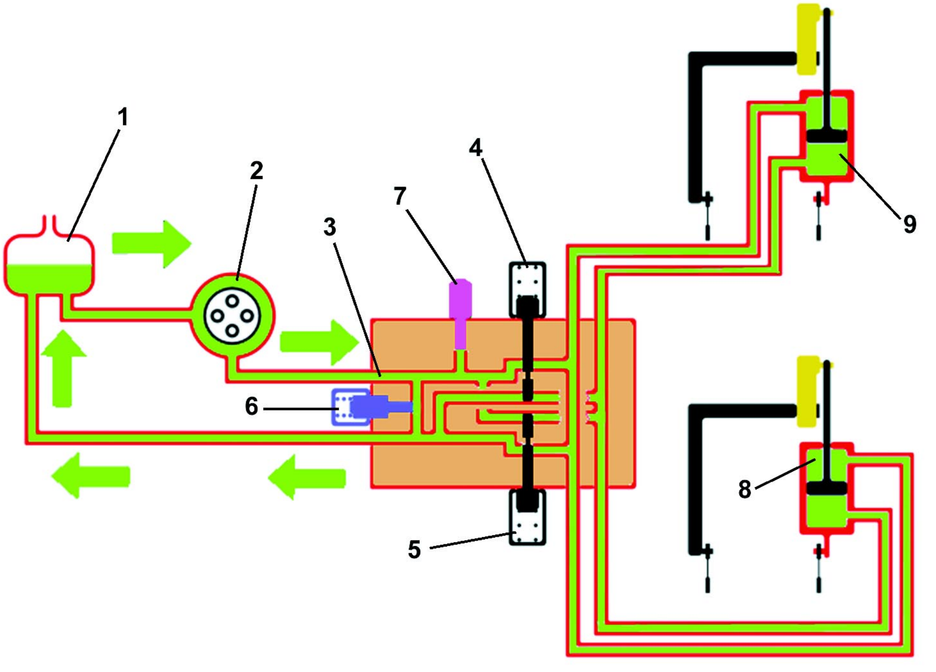
System operation

Hydraulic operation

Within the section describing the system components, a brief description of the hydraulic fluid flow through each components was introduced. This section will describe the flow of fluid in more detail and how different pressures within the system allow the Active Cornering Enhancement system to operate.

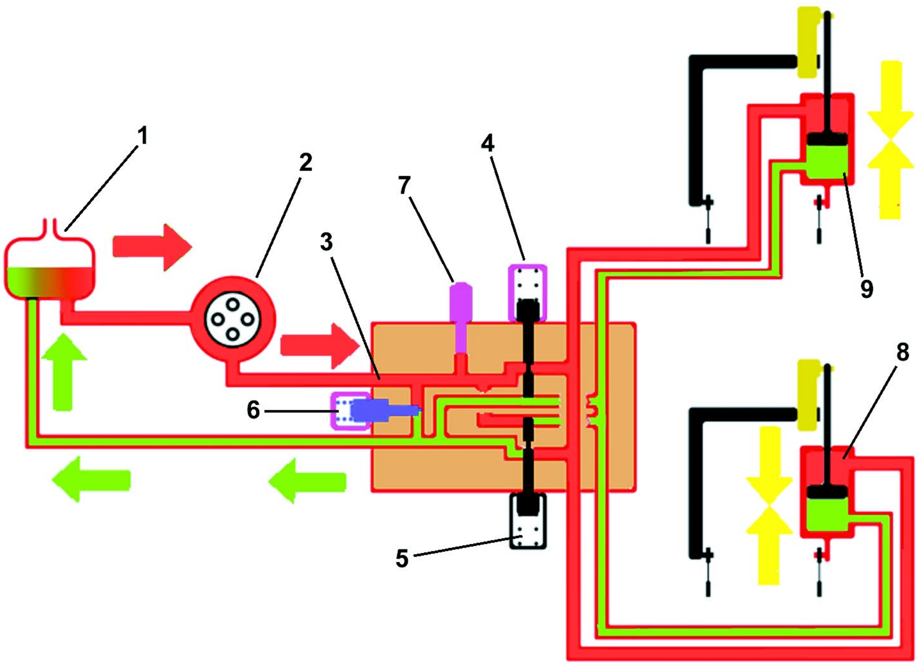
Figure 14 shows an ACE system that is currently not detecting the need to operate.

The fluid travels from the reservoir (1) and is drawn into the radial piston hydraulic pump (2). The fluid travels from the pump, through the damping hose and metal pipe to the valve block. Here the fluid is filtered by the high-pressure filter (3) and, because both spool valves (4)(5) are shut, it then flows through the pressure control valve (6) and back through the return pipe to the reservoir. At this point, there is a small pressure difference between the two sides of the pressure control valve due to a spring acting on the spool valves, as described in the earlier section. The pressure transducer (7) monitors the pressure of the fluid in the system and feeds back this information to the ACE ECU.



1.Reservoir
2.Hydraulic pump
3.High pressure filter
4.Spool valve
5.Spool valve
6.Pressure control valve
7.Pressure transducer
8.Actuator (front)
9.Acuator (Rear)

When the ACE ECU detects the need for the system to operate, it energises the required directional spool valve (4) or (5) and the pressure control valve (6). This pressure control valve then starts to restrict the flow through the valve, so building pressure in the system to the required level due to the hydraulic and solenoid forces being balanced within the valve. The fluid will travel into one side of both hydraulic actuators (8) (9) as the pressure builds, the increased forces take up compliance within the mechanical system. As the actuators move against the incoming pressure, so the fluid from the other side of the actuator is displaced back into the valve block. This fluid is returned to the reservoir through a separate gallery in the same opened spool valve, which is currently open to allow the pressurised fluid into the actuators.



1.Reservoir
2.Hydraulic pump
3.High pressure filter
4.Direction spool valve
5.Direction spool valve
6.Pressure control valve
7.Pressure transducer
8.Actuator (front)
9.Actuator (rear)

It is only when the vehicle experiences extreme manoeuvres that all the pump flow is required to take up the compliance within the complete ACE system, at a rate deemed necessary for the particular manoeuvre. Under most circumstances, as the vehicle enters a corner, most of the pump flow will still pass through the proportional pressure control valve and back to the reservoir. If the vehicle then maintains a constant speed and radius (i.e. constant lateral acceleration), the pressure is maintained within the actuators and all the pump flow passes through the proportional pressure control valve. Under most cornering situations, the lateral acceleration will vary and, hence, the ACE ECU will adjust the demanded pressure accordingly. This will result in hydraulic oil flowing in and out of both sides of the actuators to maintain the force equilibrium needed at that particular moment in time.

As the vehicle comes out of the corner the ACE ECU decreases the pressure in the system at the required rate. This then allows fluid to flow back from the pressurised side of the actuators due to the mechanical forces in the suspension pushing the actuator rams back into a neutral position. Only once the vehicle has stopped cornering completely will the ACE ECU turn off the spool valve.

The valve block cannot restrict or direct fluid pressure to just one of the actuators. Inside the valve block there is a drilling through from one side to the other. Even when the valve block has both valves closed, fluid can flow freely from one actuator to another on the same side of each ram; i.e. if the piston of one actuator were forced in it would force the piston out on the other actuator. This feature is used at very low speeds to allow minimal resistance to axle cross articulation when off road, yet give a high resistance to body roll or body rock motions. When the valve block is not operating, or has been locked electronically from operating with both valves closed, the ACE system is said to be in a ‘locked bars’ condition.

The system can act very quickly to assist the vehicle’s suspension in stopping body roll. As an indication, the system can produce enough assistance to contain body roll of a magnitude from 0g to 0.5g within 250mS (0.25 seconds). Because the system operates so quickly, it is impossible to gain any useful readings from usual electrical measuring equipment. The ACE ECU has on board diagnostic capability of capturing implausible sensor signals and storing relevant system faults. It is also capable of communicating with TestBook to relay these faults and to display relevant system information.

Mechanical operation

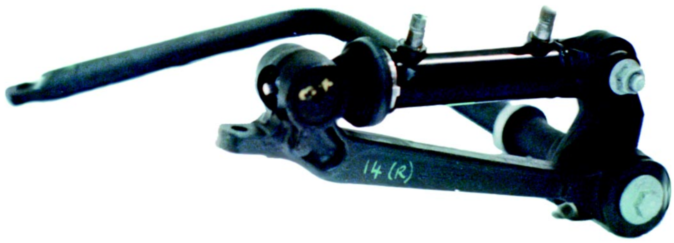
When the ACE ECU demands a system response, the valves in the valve block respond and the actuators have a pressure fed through to one side of the ram as previously described. The pressure of the fluid now changes into mechanical force. Depending upon which side of the ram the pressure is applied, the ram will either move together (reducing its overall length), or apart (increasing its overall length). It should be remembered that both the front and the rear actuators have the same high pressure acting upon them, hence the actuators are applying the same force. These forces that are then applied to the front and rear axles are different due to the roll control modules having different short lever lengths and torsion bar widths. As previously stated, the system requires different pressures to apply the same force for left and right hand corners, due to the effective area of the rod in the actuator.

The forces of the roll control modules are transferred to the chassis by the roll control modules chassis brackets and by the stabiliser links to the vehicle axles.

Anti-roll bar in extended position

During the repair of the suspension system, there is no necessity to release any hydraulic pipe connections or complete a de-energising process, as the system has no reservoir of stored energy like the ABS or air suspension systems on a Range Rover.

Anti-roll bar in compressed position



Electrical operation

The sensors on the vehicle supply information on the vehicle status and the pressure in the system. The pressure signal, as previously discussed, provides a feedback mechanism to the ACE ECU so it can fine tune the control of the pressure control valve in the valve block. The accelerometers supply information about the lateral forces acting on the vehicle. The ACE ECU uses this information, in conjunction with a road speed signal supplied by the SLABS ECU, to calculate the amount of assistance needed. The accelerometer signals go through a conditioning process inside the ACE ECU to modify them according to the learned base value of that particular sensor.

Vehicle communications

The ACE takes and gives information to other systems in the vehicle. The type of interface is listed below:

Communication	System	Signal	Used for
From ACE	Instrument pack	Digital	Illumination of the warning indicators and sounder
From ACE	Diagnostic socket	Digital	Used diagostics in conjunction with TestBook
From ACE	Under bonnet fusebox	On/OFF	Turning the ACE ECU power line 'On'
To ACE	Reverse signal switch/	On/Off	To inhibiting operation when in reverse
To ACE	SLABS road speed	Digital	Operational calculations for determining the required assistance
To ACE	ECM engine speed	Digital	Engine running reference
To ACE	In-car fusebox 29	On/Off	Ignition status information
To ACE	Under bonnet fuse box	On/Off	Supplying power to the ACE ECU

Fault code strategy

The ACE ECU diagnostic system follows a strategy when handling fault diagnostics. Like many of today's vehicle systems, the ECU performs a self-check when it powers-up, along with a complete system check. Assuming the system check reports no faults on power-up, the driver warning indicators will be extinguished and the system will be fully functional. This will happen even if, on a previous journey, there was a recorded fault.

A journey is defined as the vehicle travelling at over 32 Km/h (20 mph) for a minimum continuous period of 5 minutes.

If the ACE ECU detects a fault on power-up or when it is in operation, it will give the driver an indication of the fault. It does this in one of two ways:

1. It will turn on the 'amber' LED in the instrument pack. The system will default to a 'locked bars' condition. No hydraulic functions will take place and the pump will circulate the fluid round the primary circuit with all flow going through the pressure control valve
2. It will flash the 'red' LED and will activate the audible warning system for a period of 30 seconds and then leave the 'red' LED on. The system will default to a 'locked bars' condition

The ACE system will keep only the recorded faults encountered within the last 50 journeys. After this period, it will not be possible to read or analyse the fault with TestBook.

TestBook diagnostics

TestBook can supply live information of various system parameters, including pressure demands and actual readings, solenoid demands and operation and sensor inputs. The live data also incorporates signals from other vehicle systems that the ACE ECU uses to modify its operation.

Real time monitoring

Data is supplied via the ACE ECU to TestBook. This can be displayed in one screen, showing all the system inputs and outputs, or in individual screens that detail the sensors individually. The advantage of looking at the individual sensors is that TestBook details the plausible reading for that particular sensor and states the value or tolerance which applies to that particular sensor.

The ACE system has three routines which it uses to ensure that the mechanical system is operating correctly and giving optimum performance. It is possible to view them whilst in real time monitoring.

On engine start up, the ACE ECU controls the system pressure to approximately 20 bar. This pressure is set at a level which the ACE ECU knows will not be exceeded due to temperature and viscosity variations. With both the direction valves closed, the system reads the valve block pressure and quickly reduces the PCV current to the minimum controllable residual pressure in the system. In the case of both direction valves being opened at the same time, this PCV current is still maintained. During vehicle running, the residual pressure will change slightly due to fluid temperature and system operating conditions.

The second routine that the ACE ECU completes is to instruct the system to increase the pressure in the primary circuit by applying 0.5 amps to the pressure conscious valve for 200mS. It does this every 10 seconds whilst the system is not actively controlling the vehicles body roll. The information returned by the pressure transducer provides the ACE ECU with a ‘virtual’ system temperature measurement. The measurement is based on coil resistance and is used to compensate for temperature drift in the pressure transducer, as well as to detect if the system is overheating.

The third routine is a self-diagnostic routine, which the ACE ECU performs to check for stuck directional spool valves. It does this by opening both direction valves simultaneously and monitoring the effect on residual pressure. If both direction valves open there will be a small drop in residual pressure. The ECU performs this test only if the vehicle speed exceeds 25 Km/h (15 mph), and the vehicle has not tried actively to control the vehicles body movement for more than 5 seconds.

System response checks

TestBook has the facility to enable a system test within the ACE ECU. This test operates the hydraulic system and measures the response time of the hydraulics/mechanics to achieve the demanded pressure in both primary and secondary circuits. Care should be taken when undertaking this test as the engine will need to be running at a minimum of 1200rev/min, and the vehicle body will move quickly. This has implications if rigid equipment is attached to the vehicle.

Diagnostic procedures

As explained, the ACE ECU completes a power-up self test and then continues to monitor the system whilst operational. Fault codes can be retrieved from the ECU and their meanings displayed on TestBook. An indication is then given to the possible causes and any necessary checks and measurements that need to be made. Also incorporated within TestBook is a mechanical diagnostics help, for instances where there is a problem that does not result in a fault being recorded by the ECU, such as mechanical noise or mechanical knocks etc.

Hydraulic bleeding procedures

The hydraulic system does not have a constant flow of fluid through the secondary circuit (actuator lines). Although moved by pressure changes in the hydraulic fluid the actuators do not normally allow fluid or air to flow through them. Because of this, there is a procedure that must be followed when an actuator pipe, valve block or an actuator is replaced. This procedure removes air from the secondary hydraulic circuit. If this procedure is not used to remove all the air from the circuit, it is possible that the vehicle behaves normally to start with, or normally when the system is not working at 100% capacity, but, in conditions of maximum demand, the system may store a fault code because the air in the system reduces the response time. It is, therefore, imperative that, if any one of the above components is changed, the system is bled using the procedure detailed in TestBook. If the pump or ACE high pressure oil filter are changed, bleeding the secondary system is not required. If the hydraulic pump is changed, it is necessary to prime the pump to prevent damage; refer to the relevant section within the workshop manual for the exact procedure.