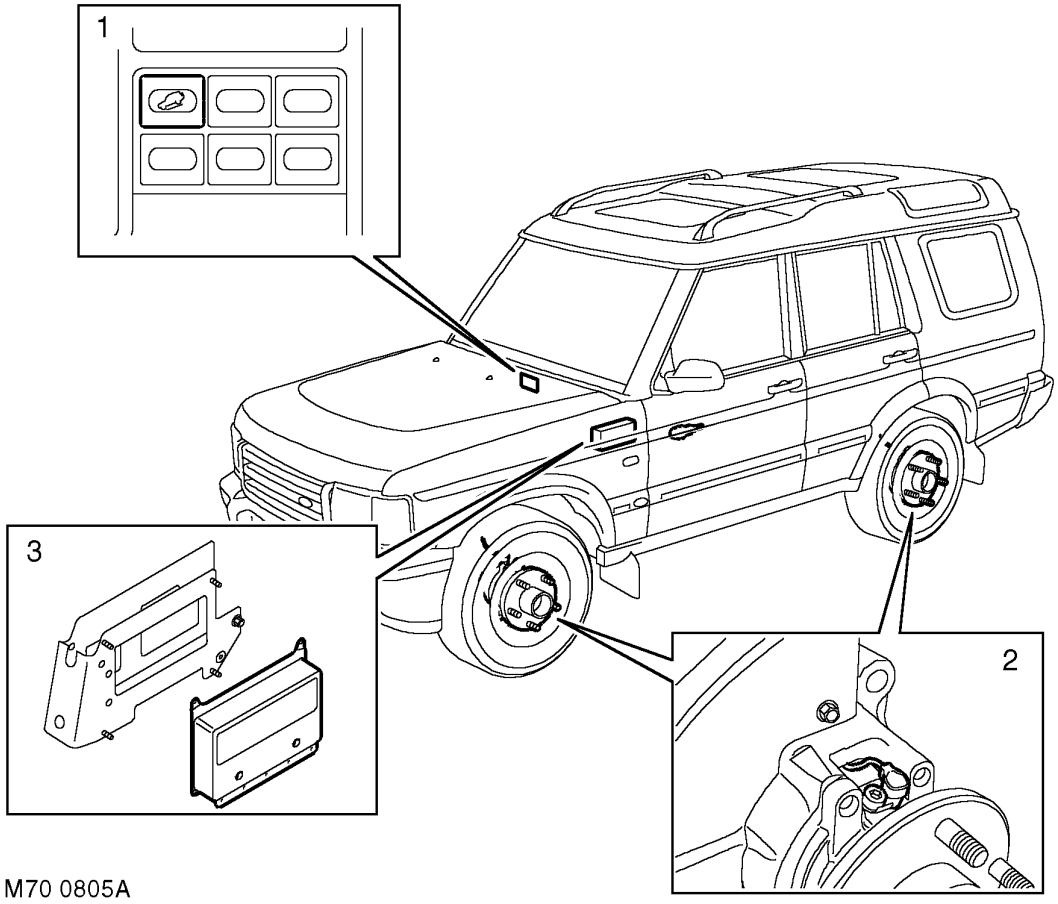
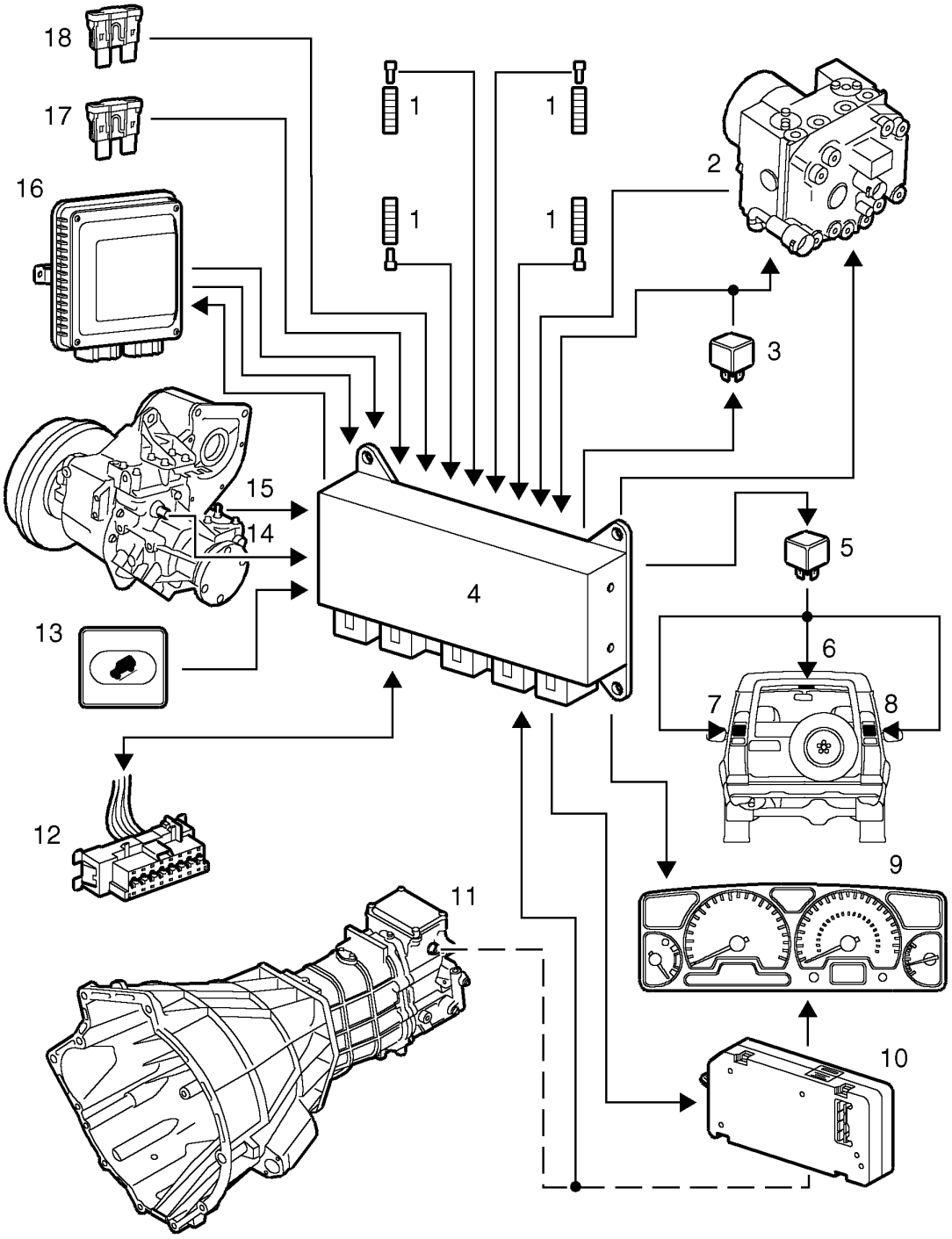
Brake system control component layout



RH drive shown, LH drive similar

1 Hill descent switch
2 ABS sensor
3 SLABS ECU

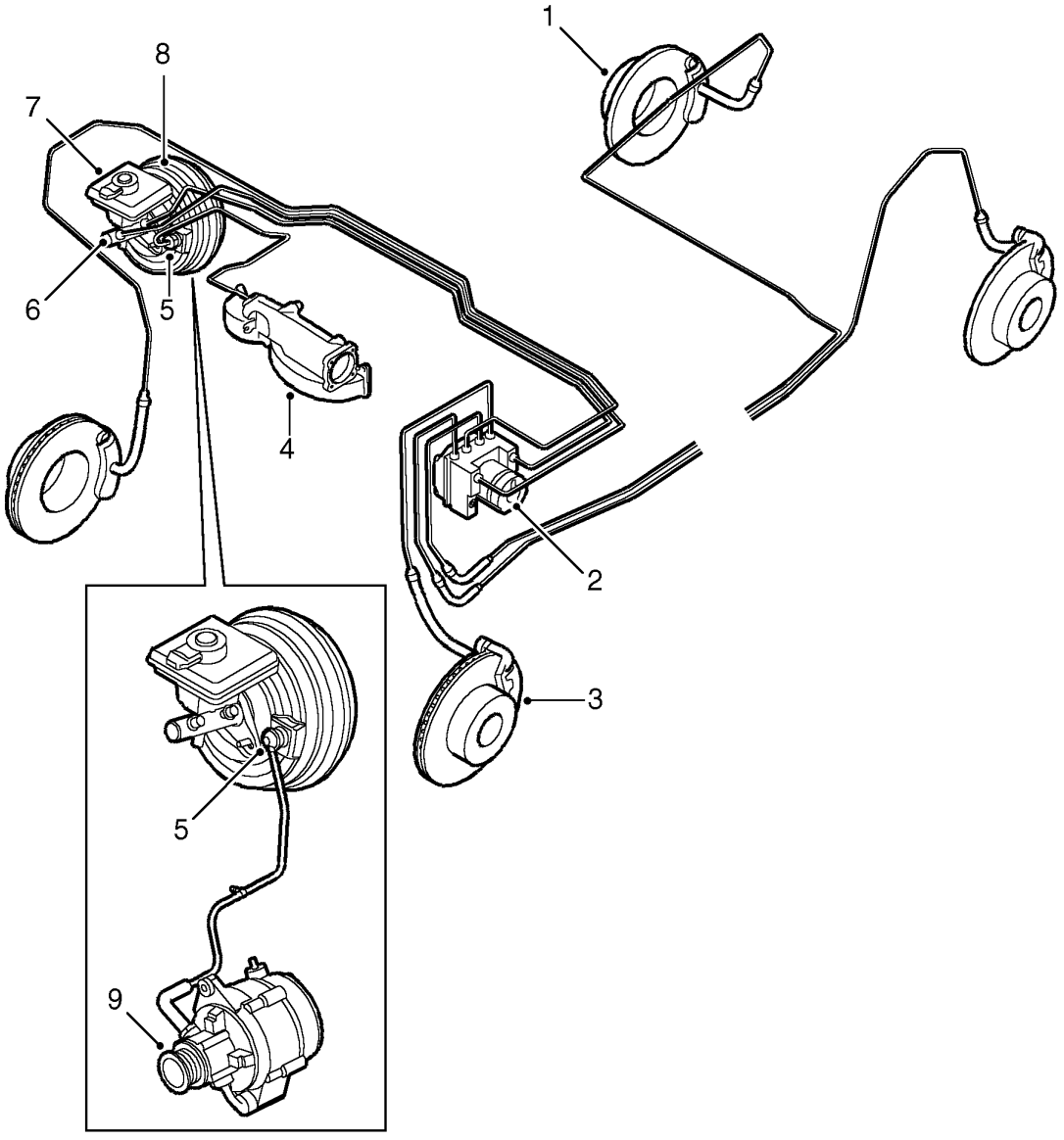
Brake system control diagram



M70 0845

1 ABS sensor
2 ABS modulator
3 Return pump relay
4 SLABS ECU
5 Brake lamp relay
6 Centre high mounted stop lamp
7 LH brake lamp
8 RH brake lamp
9 Instrument pack
10 Body control unit
11 Reverse lamp switch (manual gearbox)
12 Diagnostic socket
13 HDC switch
14 Transmission high/low switch
15 Centre differential lock switch
16 Engine control module
17 Battery power supply
18 Ignition power supply

Brake system hydraulic component layout



M70 0804

RH drive shown, LH drive similar

1 Rear brake
2 ABS modulator
3 Front brake
4 Inlet manifold plenum (V8 models)
5 Non return valve
6 Master cylinder assembly
7 Brake fluid reservoir
8 Brake servo assembly
9 Vacuum pump (diesel models)

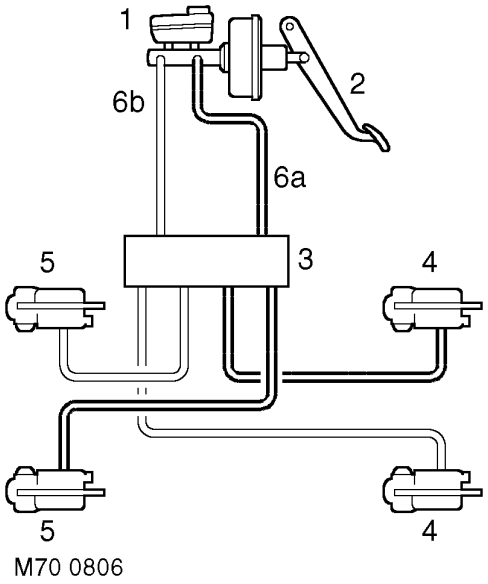
Description

General

The brakes consist of front and rear disc brakes operated by a diagonally split, dual circuit hydraulic system with vacuum servo power assistance. The system incorporates the following control functions as standard on all models:

- Anti-lock Brakes (ABS), to prevent road wheels locking during brake application.
- Electronic Brake Distribution (EBD), to control distribution of hydraulic pressure between front and rear axles. Replaces mechanical pressure limiting valve of previous systems.
- Electronic Traction Control (ETC), to maintain even torque distribution to the road wheels.
- Hill Descent Control (HDC), to provide controlled descent ability in off road conditions.

Hydraulic system schematic



M70 0806

1 Master cylinder/brake servo assembly
2 Brake pedal
3 ABS modulator
4 Rear brake
5 Front brake
6 Hydraulic circuit
a Primary
b Secondary

For normal brake operation, brake pedal movement is assisted by the brake servo assembly and transmitted to the master cylinder assembly. The master cylinder assembly converts brake pedal movement to hydraulic pressure. Primary and secondary brake pipe circuits supply the hydraulic pressure to the brakes via the ABS modulator: the primary circuit supplies the front left and rear right brakes; the secondary circuit supplies the front right and rear left brakes. Vacuum for the brake servo assembly is obtained from the engine inlet manifold (V8 models) or a vacuum pump (diesel models), through a vacuum line and non return valve. To reduce operating noise, sleeving is installed on some of the brake pipes in the engine compartment and the pipes are located in sprung pipe clips.

For all control functions, the ABS modulator regulates the hydraulic pressure to the brakes to control the speed of all four wheels, either individually or in axle pairs. Operation of the ABS modulator is controlled by the Self Levelling and Anti-lock Braking Systems (SLABS) ECU. The SLABS ECU also operates warning indications in the instrument pack to provide the driver with status information on each function.

Brake servo assembly

The brake servo assembly provides power assistance to reduce the pedal load when braking. If the brake servo assembly fails, the hydraulic system still functions but will require greater brake pedal effort due to the lack of vacuum assistance.

Two integral tie bolts attach the brake servo assembly to the pedal and bracket assembly on the engine bulkhead. The master cylinder assembly is attached to the forward ends of the tie bolts.

The brake servo assembly consists of a circular housing which contains two diaphragms, a central plate, a control valve assembly, input and output push rods and a filter. The input push rod is connected to the brake pedal. The output push rod locates in the primary piston of the master cylinder. A protective gaiter is installed on the control valve assembly where it extends from the rear of the housing. A non return valve, installed in a port in the front face of the housing, is connected to a vacuum line from the engine.

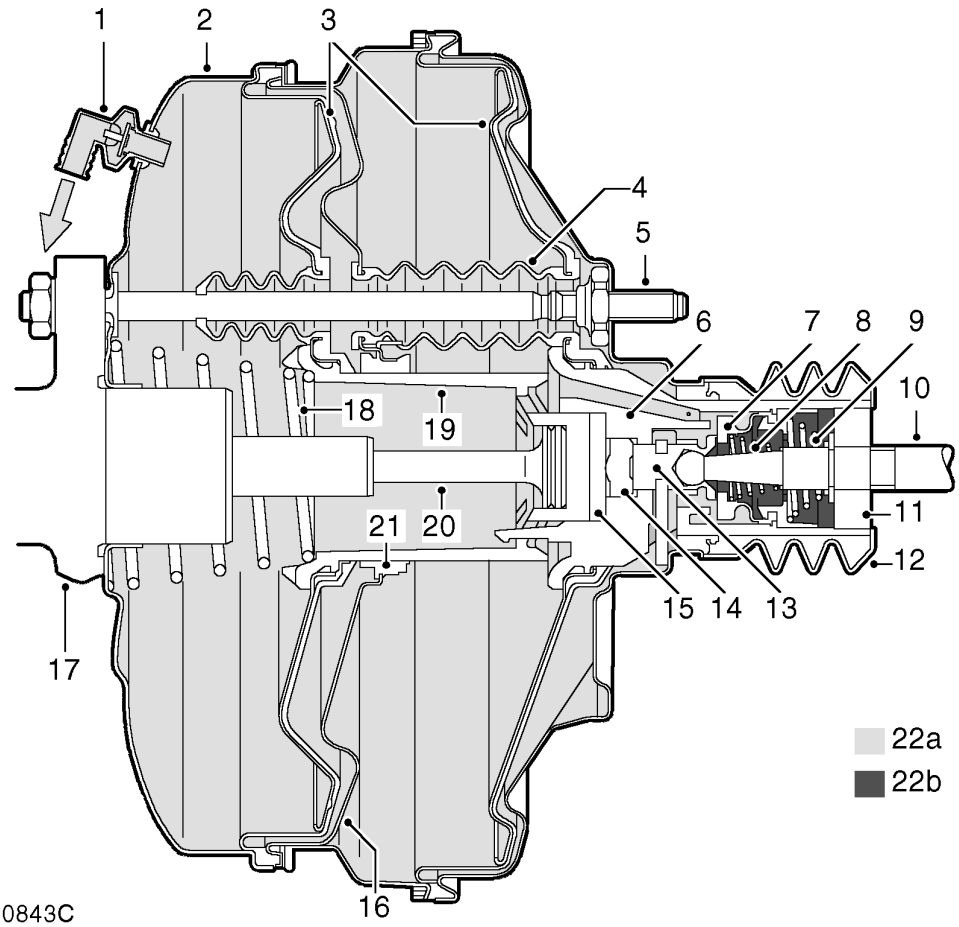
The control valve assembly consists of a valve body containing a valve, a piston, a valve spring and an input rod spring. The valve controls a vacuum port in the valve body. The piston controls an air inlet port between the valve and the piston. A reaction disc and a ratio disc separate the piston from the output push rod. A guide tube on the front of the valve body is attached to the front diaphragm and supported in a bush in the central plate. A return spring locates in the open end of the guide tube.

The two diaphragms and the central plate separate the interior of the housing into four sealed chambers. The chambers at the front of the diaphragms are connected together through fixed passages in the valve assembly. The chambers at the rear of the diaphragms are connected together through the interior of minor diaphragms on the tie bolts.

Brakes off

With the brake pedal released, the piston in the control valve assembly positions the valve so that the vacuum port is open and the two pairs of chambers are connected together. When the engine is running air is evacuated through the vacuum line and non return valve, creating a partial vacuum in all four chambers. When the engine stops, the non return valve closes to maintain the partial vacuum and, on V8 models, prevent fuel vapour entering the brake servo.

Section through brake servo assembly - brakes off



M70 0843C

1 Non return valve
2 Housing
3 Diaphragms
4 Minor diaphragm
5 Tie bolt
6 Valve body
7 Valve
8 Valve spring
9 Input rod spring
10 Input push rod
11 Filter
12 Gaiter
13 Piston
14 Ratio disc
15 Reaction disc
16 Central plate
17 Master cylinder
18 Return spring
19 Guide tube
20 Output push rod
21 Bush
22 Air pressures
a Partial vacuum
b Ambient

Brakes on

When the brake pedal is pressed, the input push rod and the piston initially move forward in the valve body. The valve body and output rod then move with the input rod, against resistance from the return spring, to transmit the brake pedal force to the master cylinder assembly.

During the initial movement of the piston, the valve, assisted by the valve spring, moves with the piston and closes the vacuum port to isolate the chambers at the rear of the diaphragms from the vacuum source. Further movement of the input push rod causes the piston to move away from the valve and open the air inlet port. This allows a restricted flow of filtered ambient air through the air inlet port, which creates a servo pressure in the chambers at the rear of the diaphragms. Force from the resultant pressure differential across the diaphragms is transmitted through the valve body to the output push rod, augmenting the pressure being applied by the brake pedal. The force produced by the diaphragms, in proportion to the input force, i.e. the boost ratio, is 5.6 : 1. The boost ratio remains constant, as the input force from the brake pedal increases, until the limit of assistance is reached when servo pressure is equal to ambient pressure.

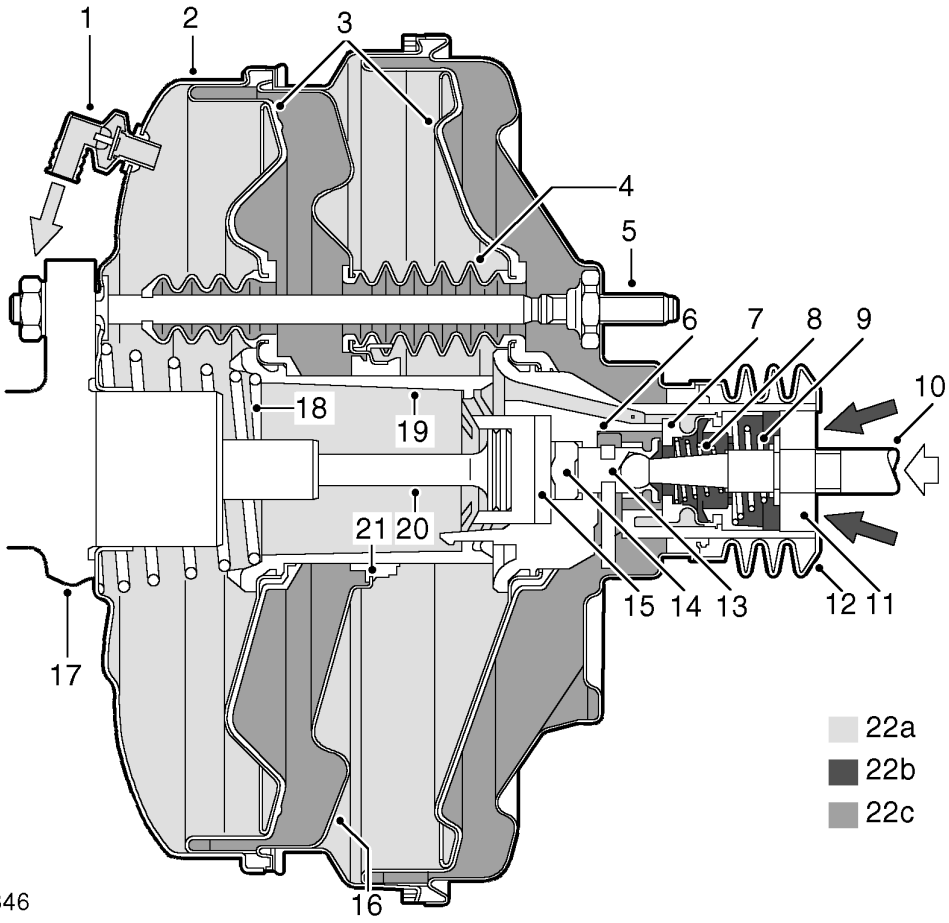
Brakes held on

When the brake pedal effort is constant, opposing pressures cause the reaction disc to extrude onto the ratio disc, which moves the piston against the valve to close the air inlet port. This prevents any further increase in servo pressure and maintains a constant output force to the master cylinder assembly.

Brakes released

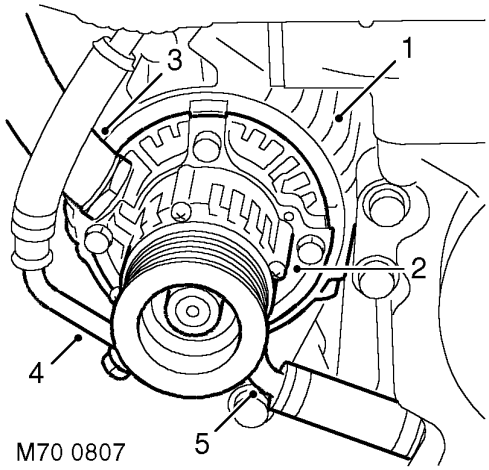
When the brake pedal is released, the input rod spring moves the input rod and piston rearwards within the valve body to close the air inlet port and open the vacuum port. The air from the chambers at the rear of the diaphragms is then evacuated, through the vacuum port and the chambers at the front of the diaphragms, to restore a partial vacuum in all four chambers. Simultaneously, the return spring moves the valve body, diaphragms, output rod and input rod rearwards to return them to their brakes off position.

Section through brake servo assembly - brakes on



1 Non return valve
2 Housing
3 Diaphragms
4 Minor diaphragm
5 Tie bolt
6 Valve body
7 Valve
8 Valve spring
9 Input rod spring
10 Input push rod
11 Filter
12 Gaiter
13 Piston
14 Ratio disc
15 Reaction disc
16 Central plate
17 Master cylinder
18 Return spring
19 Guide tube
20 Output push rod
21 Bush
22 Air pressures
- **a** Partial vacuum
- **b** Ambient
- **c** Servo

Vacuum pump (diesel models only)



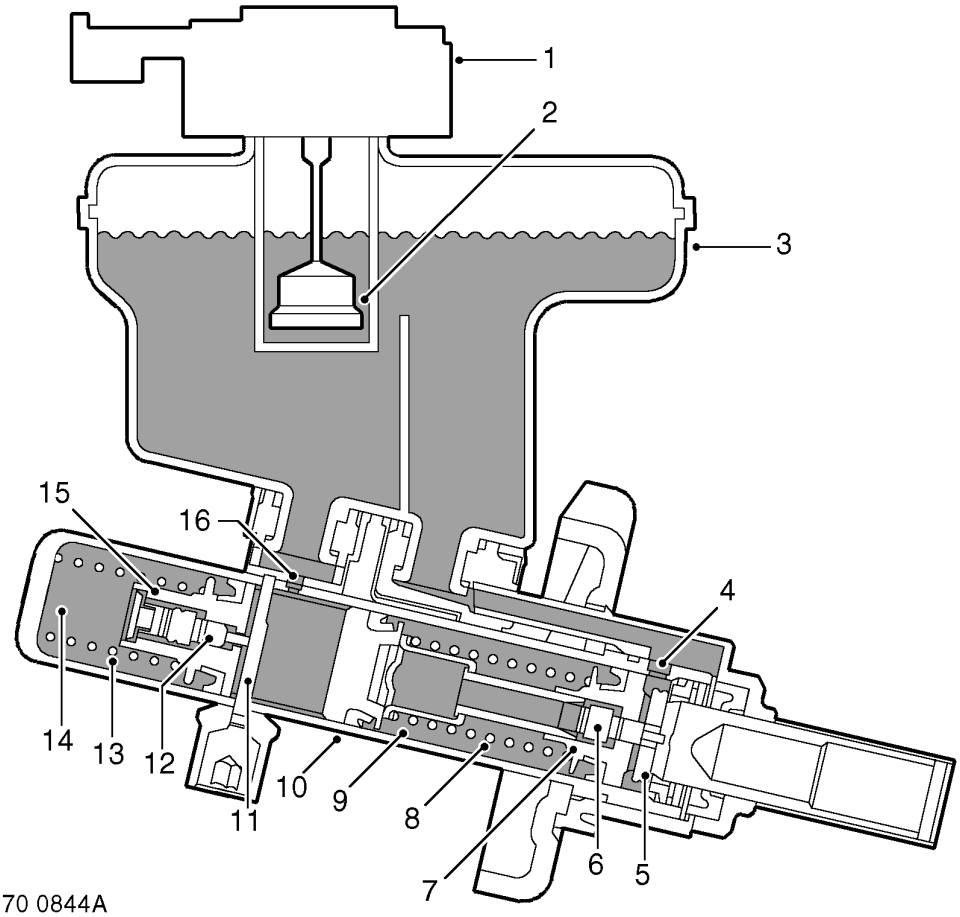
1 Alternator
2 Vacuum pump
3 Brake servo assembly vacuum connection
4 Oil feed pipe
5 Oil drain pipe

As the diesel engine air inlet system does not produce sufficient depression to operate the brake servo assembly, an engine driven vacuum pump is installed.

The vacuum pump is integrated with the engine alternator and driven by the auxiliary drive belt. The pump is a rotary vane type, lubricated and cooled by engine oil supplied through a pipe connected to the engine block and returned through a pipe connected to the engine oil sump. Air extracted from the brake servo assembly is vented into the oil sump with returning lubricating oil.

Master cylinder assembly

Section through master cylinder assembly



1 Reservoir filler cap
2 Switch float
3 Brake fluid reservoir
4 Primary feed hole
5 Valve pin
6 Primary centre valve
7 Primary piston
8 Primary spring
9 Pressure chamber
10 Cylinder
11 Valve pin
12 Secondary centre valve
13 Secondary spring
14 Pressure chamber
15 Secondary piston
16 Secondary feed hole

The master cylinder assembly produces hydraulic pressure to operate the brakes when the brake pedal is pressed.

The assembly is attached to the front of the brake servo assembly, and comprises a cylinder containing two pistons in tandem. The rear piston produces pressure for the primary circuit and the front piston produces pressure for the secondary circuit. A brake fluid reservoir is installed on top of the cylinder. The reservoir is internally divided to provide an independent supply of fluid to each brake circuit, and so prevent a single fluid leak from disabling both primary and secondary brake circuits. Should a failure occur in one circuit, the remaining circuit will still operate effectively, although brake pedal travel and vehicle braking distances will increase. If the fluid level in the reservoir is too low, a float operated switch in the reservoir filler cap connects an earth to the instrument pack, which illuminates the brake warning lamp.

Brakes applied

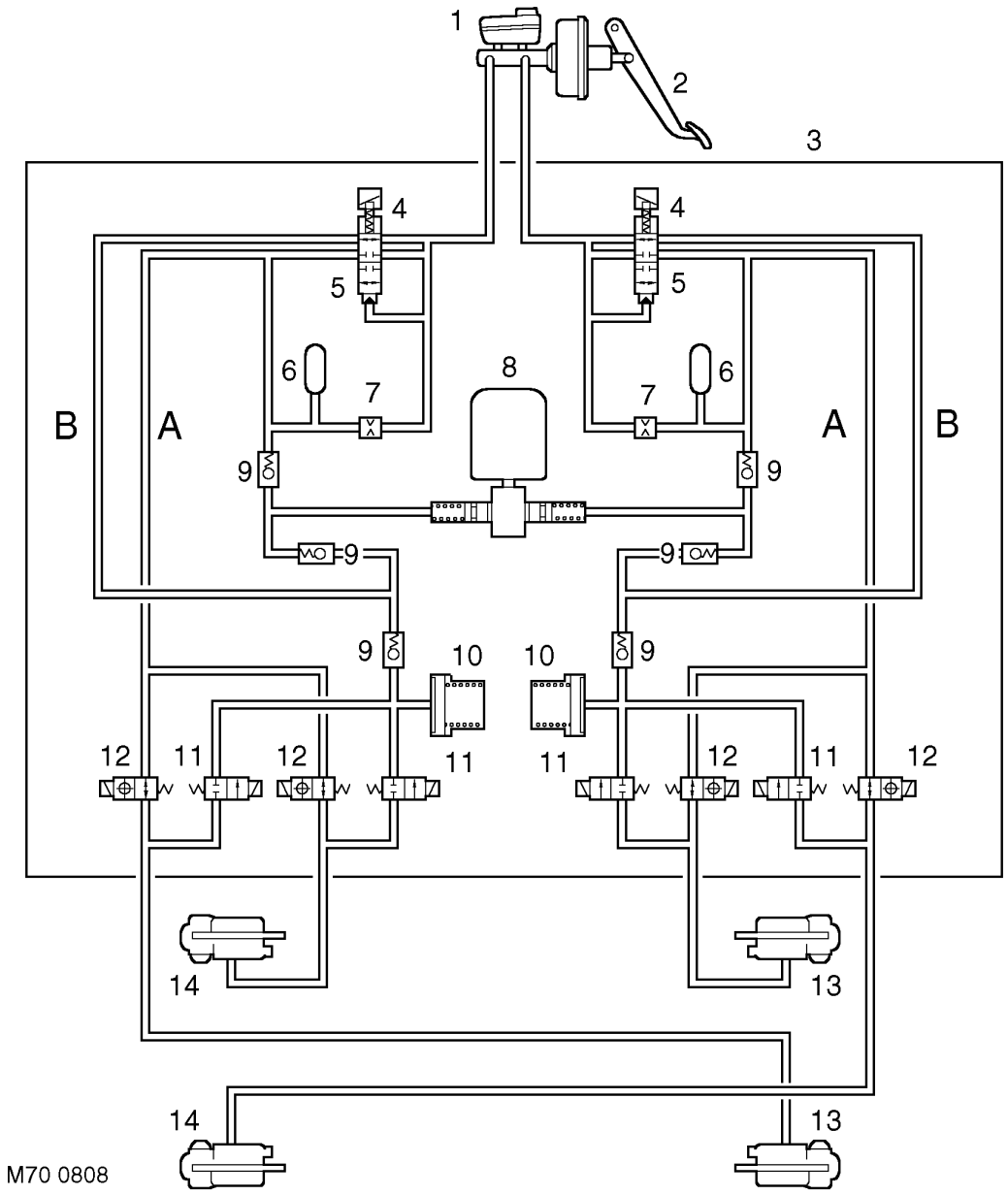
When the brake pedal is pressed, the output rod in the brake servo assembly pushes the primary piston along the cylinder bore. This produces pressure in the primary pressure chamber which, in conjunction with the primary spring, overcomes the secondary spring and simultaneously moves the secondary piston along the cylinder bore. The initial movement of the pistons, away from the piston stops, closes the primary and secondary centre valves. Further movement of the pistons then pressurizes the fluid in the primary and secondary pressure chambers, and thus the brake circuits. The fluid in the chambers behind the pistons is unaffected by movement of the pistons and can flow unrestricted through the feed holes between the chambers and the reservoir.

Brakes released

When the brake pedal is released, the primary and secondary springs push the pistons back down the bore of the cylinder. The rapid movement of the pistons cause partial vacuums to form in the pressure chambers, which opens the centre valves and allows fluid to circulate unrestricted between the two hydraulic circuits and the reservoir. When the pistons reach the brakes off position, the centre valves are held open by the piston stops.

ABS modulator

ABS modulator schematic



1 Master cylinder/brake servo assembly
2 Brake pedal
3 ABS modulator
4 Shuttle valve switch
5 Shuttle valve
6 Damper chamber
7 Restrictor
8 Return pump
9 Non return valve
10 Expansion chamber
11 Outlet solenoid valve
12 Inlet solenoid valve
13 Rear brake
14 Front brake

The ABS modulator is a 4 channel unit that controls the supply of hydraulic pressure to the brakes in response to inputs from the SLABS ECU. The modulator is attached by three mounting bushes to a bracket on the LH inner front wing, and connected to the primary and secondary hydraulic circuits downstream of the master cylinder assembly. Three electrical connectors link the ABS modulator to the vehicle wiring.

Passages within the ABS modulator, separated into primary and secondary circuits, connect to the various internal components that control the supply of hydraulic pressure to the brakes:

- Shuttle valves and non return valves control the flow through the internal circuits.
- Shuttle valve switches, connected in series to the SLABS ECU, provide a brakes on/off signal.
- A damper chamber and restrictor are included in each circuit to refine system operation.
- Inlet and outlet solenoid valves control the flow to the individual brakes.
- An expansion chamber is connected to each circuit to absorb pressure.
- A return pump is connected to both circuits to provide a pressure source.

The ABS modulator has three operating modes: Normal braking, ABS braking and active braking.

Normal braking mode

When the brake pedal is pressed, pressurised fluid from the master cylinder assembly moves the shuttle valves to open lines 'A' and close the shuttle valve switches. Pressurised fluid then flows through the open inlet solenoid valves to operate the brakes. The closed shuttle valve switches supply a brakes on signal to the SLABS ECU. If the SLABS ECU determines that EBD is necessary, it energises the inlet solenoid valves for the brakes of one axle. The inlet solenoid valves close to isolate the brakes from any further increase in hydraulic pressure.

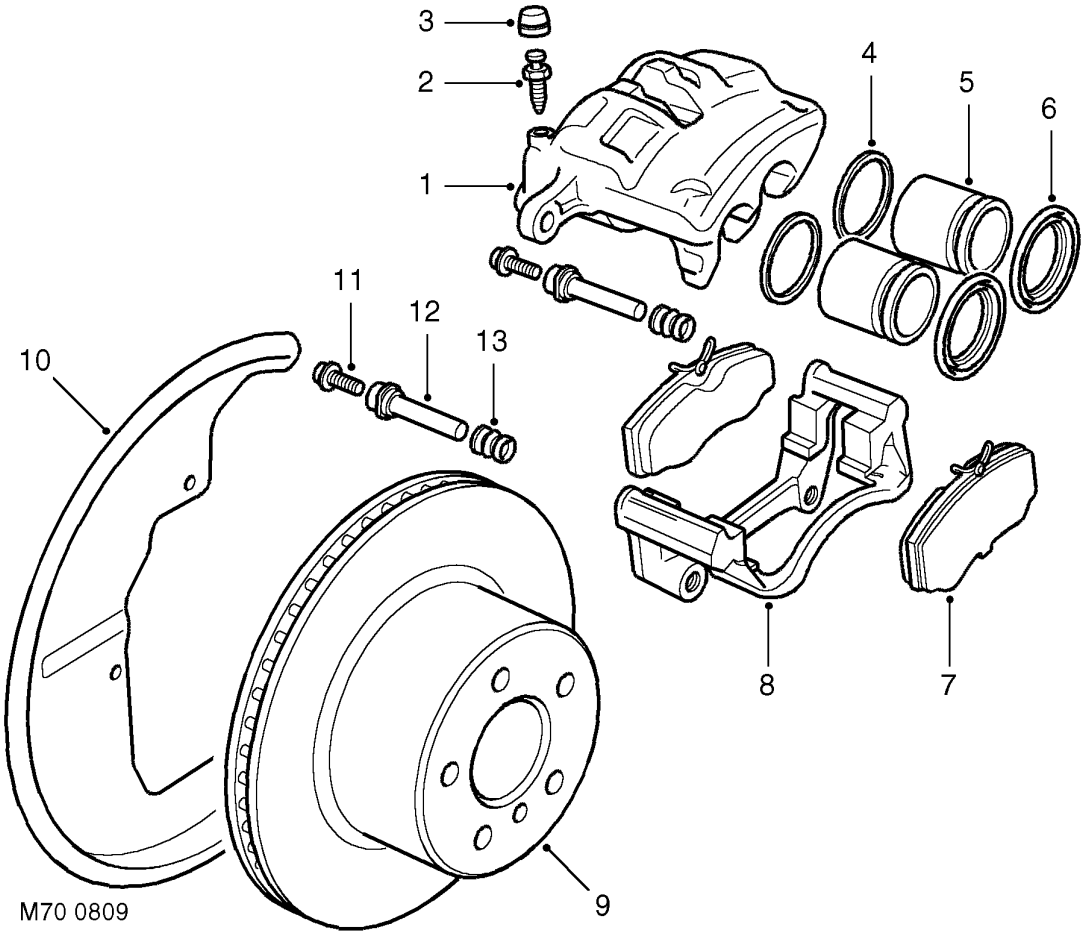
ABS braking mode

When in the normal braking mode, if the SLABS ECU determines that ABS braking is necessary, it energises the inlet and outlet solenoid valves of the related brake and starts the return pump. The inlet solenoid valve closes to isolate the brake from pressurised fluid; the outlet solenoid valve opens to release pressure from the brake into the expansion chamber and the return pump circuit. The brake releases and the wheel begins to accelerate. The SLABS ECU then operates the inlet and outlet solenoid valves to control the supply of hydraulic pressure to the brake and apply the maximum braking effort (for the available traction) without locking the wheel.

Active braking mode

When ETC or HDC are enabled, and the SLABS ECU determines that active braking is necessary, it starts the return pump. Hydraulic fluid, drawn from the reservoirs through the master cylinder, shuttle valves and lines 'B', is pressurised by the return pump and supplied to lines 'A'. The SLABS ECU then operates the inlet and outlet solenoid valves to control the supply of hydraulic pressure to the individual brakes and slow the wheel(s).

Front brakes

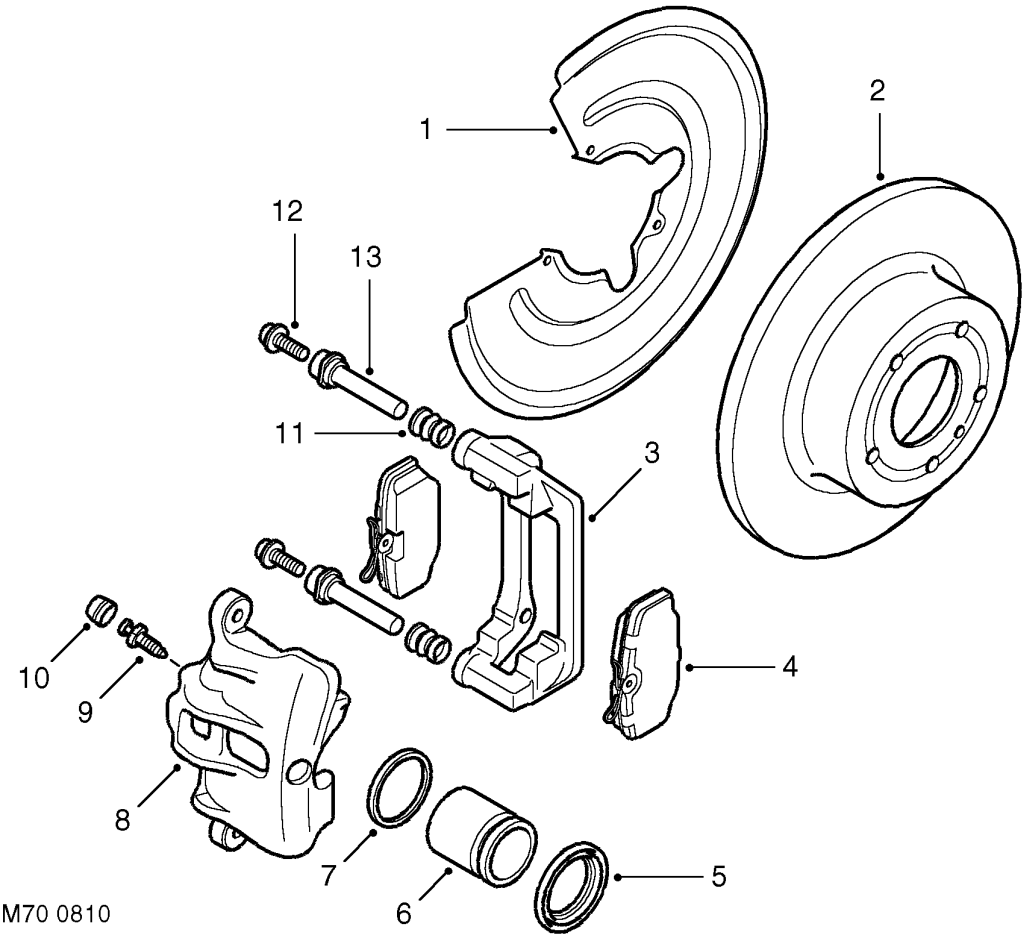


1 Caliper body
2 Bleed screw
3 Bleed screw cap
4 Piston seal
5 Piston
6 Piston dust cover
7 Brake pad
8 Caliper carrier
9 Brake disc
10 Mudshield
11 Guide pin bolt
12 Guide pin
13 Guide pin dust cover

The front brakes each comprise of a hub mounted, twin piston caliper assembly and a ventilated disc. The inboard side of the disc is protected by a mudshield.

When hydraulic pressure is supplied to the caliper, the pistons extend and force the inner pad against the disc. The caliper body reacts and slides on the guide pins to bring the outer pad into contact with the disc.

Rear brakes



1 Mudshield
2 Brake disc
3 Caliper carrier
4 Brake pad
5 Piston dust cover
6 Piston
7 Piston seal
8 Caliper body
9 Bleed screw
10 Bleed screw cap
11 Guide pin dust cover
12 Guide pin bolt
13 Guide pin

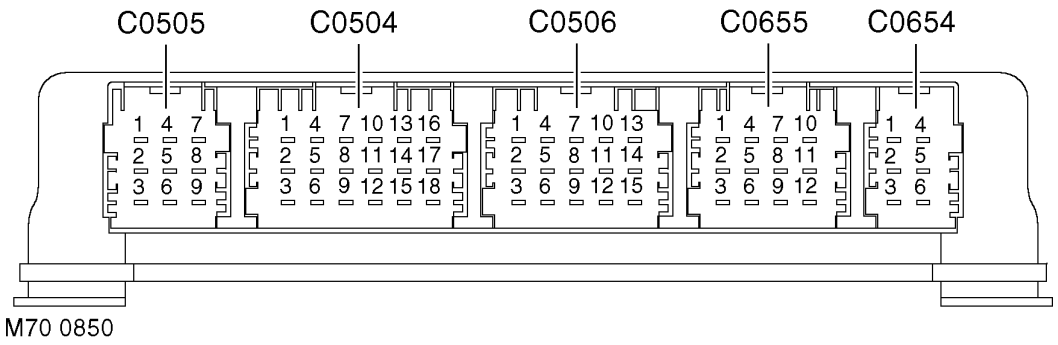
The rear brakes each comprise of a hub mounted, single piston caliper assembly and a solid disc. The inboard side of the disc is protected by a mudshield.

When hydraulic pressure is supplied to the caliper, the piston extends and forces the inner pad against the disc. The caliper body reacts and slides on the guide pins to bring the outer pad into contact with the disc.

SLABS ECU

The SLABS ECU is attached to a bracket behind the front passenger glovebox. Brake related inputs are processed by the SLABS ECU, which then outputs control signals to the ABS modulator. Five electrical connectors interface the SLABS ECU with the vehicle wiring.

SLABS ECU connector pin details



Connector/Pin No.	Description	Input/Output
C0504		
1	Battery supply	Input
2	Ignition supply	Input
3	Road speed	Output
4	Rough road (V8 models only)	Output
5	K line (diagnostics)	Input/Output
7	Reverse gear	Input
8	Return pump monitor	Input
9	Brake warning lamp	Output
10	Engine data (throttle position, torque, engine type, gearbox type)	Input
11	Transfer box range	Input
12	Earth	-
13	ETC warning lamp	Output
14	HDC switch	Input
15	Neutral selected (automatic gearbox only)	Input
16	HDC fault warning lamp	Output
17	HDC information warning lamp	Output
18	ABS warning lamp	Output
C0505		
1	Front left wheel speed	Input
2	Front left wheel speed	Input
3	Rear right wheel speed	Input
4	Front right wheel speed	Input
5	Front right wheel speed	Input
6	Rear right wheel speed	Input
7	Rear left wheel speed	Input
8	Rear left wheel speed	Input
C0506		
1	Front left outlet solenoid valve	Output
2	Front left inlet solenoid valve	Output
3	Earth	-
4	Front right outlet solenoid valve	Output

Connector/Pin No.	Description	Input/Output
5	Front right inlet solenoid valve	Output
6	Shuttle valve switches	Input
7	Rear left outlet solenoid valve	Output
8	Rear left inlet solenoid valve	Output
9	Centre differential lock switch	Input
10	Rear right outlet solenoid valve	Output
11	Rear right inlet solenoid valve	Output
12	Brake lamp relay	Output
15	Return pump relay	Output
C0655		
7	Audible warning	Output
10	Engine speed	Input
Connector and pins not listed are either not used or used by the self levelling suspension system. ☞ **REAR SUSPENSION, DESCRIPTION AND OPERATION, Description.**		

The SLABS ECU continually calculates vehicle speed using the wheel speed inputs from all four ABS sensors. The calculated vehicle speed is then used as a reference against which individual wheel speeds are monitored for unacceptable acceleration or deceleration. The ABS sensor inputs are also used by the SLABS ECU to detect vehicle deceleration rate, vehicle cornering rate and rough terrain.

The engaged forward gear and (on manual gearbox models) the clutch status are computed from the engine data input, the engine speed input and vehicle speed. Reverse gear status is provided by an input from the reverse lamp switch (manual gearbox models) or the BCU (automatic gearbox models). On automatic models, the BCU also provides the neutral selected input.

In addition to controlling the brake related functions, the SLABS ECU:

- Controls the operation of the self levelling suspension (SLS) system (where fitted).
  ☞ **REAR SUSPENSION, DESCRIPTION AND OPERATION, Description.**
- On V8 models, outputs a rough road signal to the ECM when traversing rough terrain.
- Outputs a vehicle speed signal.

The vehicle speed signal is output to the following systems (where fitted):

- Active Cornering Enhancement.
  ☞ **FRONT SUSPENSION, DESCRIPTION AND OPERATION, Description - ACE.**
- Air conditioning.
  ☞ **AIR CONDITIONING, DESCRIPTION AND OPERATION, Description.**
- Cruise control.
  ☞ **ENGINE MANAGEMENT SYSTEM - Td5, DESCRIPTION AND OPERATION, Description.**
  ☞ **ENGINE MANAGEMENT SYSTEM - V8, DESCRIPTION AND OPERATION, Description - engine management.**
- Engine management.
  ☞ **ENGINE MANAGEMENT SYSTEM - Td5, DESCRIPTION AND OPERATION, Description.**
  ☞ **ENGINE MANAGEMENT SYSTEM - V8, DESCRIPTION AND OPERATION, Description - engine management.**
- In-car entertainment.
  ☞ **IN CAR ENTERTAINMENT, DESCRIPTION AND OPERATION, Description.**
- Instrument pack.
  ☞ **INSTRUMENTS, DESCRIPTION AND OPERATION, Description.**

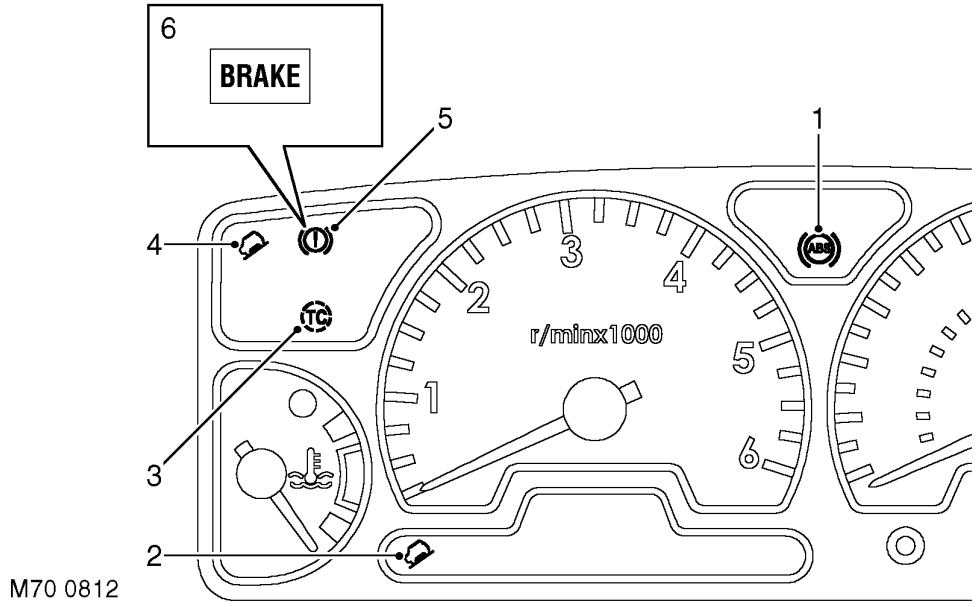
ABS sensors
The ABS sensors supply the SLABS ECU with a sinusoidal speed signal from each wheel. An inductive sensor, installed in the hub bearing of each wheel, senses off a 60 tooth exciter ring integrated into the inner race of the hub bearing. Each ABS sensor has a fly-lead connecting it to the vehicle wiring.

HDC switch
The HDC switch is a latching push switch installed on the fascia, in the switchpack inboard of the steering wheel. When pushed in, the switch connects an ignition supply to the SLABS ECU to initiate HDC.

Warning indications
The SLABS ECU operates audible and visual warnings to convey brake system status.

Audible warning
A repetitive chime, at a frequency of 2 Hz, draws attention to warning lamp indications. The chime is produced on the speaker in the instrument pack.

Warning lamps



1 ABS warning lamp
2 HDC fault warning lamp
3 ETC warning lamp
4 HDC information warning lamp
5 Brake warning lamp (all except NAS)
6 Brake warning lamp (NAS only)

The following brake system warning lamps can be found in the instrument pack:
- A red brake graphic (all except NAS vehicles) or red BRAKE legend (NAS vehicles), to warn of low brake fluid level, handbrake on and brake control system failure affecting EBD.
- An amber ABS graphic, to warn of brake control system failure affecting the ABS function.
- An amber TC graphic, to warn of brake control system failure affecting the ETC function.
- Two inclined vehicle graphics, one amber (fault) and one green (information), to indicate operating status of HDC and to warn of brake control system failure affecting the HDC function.

Each warning lamp is illuminated by a separate LED. The ABS, brake and ETC warning lamps are continuously on while illuminated; the two HDC warning lamps are either continuously on or flash at a frequency of 2 Hz while illuminated.

Operation

Refer to illustration.

☞ **BRAKES, DESCRIPTION AND OPERATION, Brake system control diagram.**

When the ignition is switched on, the SLABS ECU performs a check of the brake related warning lamps as part of the power up procedure. The warning lamps are illuminated for approximately 3 seconds and then extinguished. If a fault warning lamp remains illuminated after the lamp check, a fault has been detected and repair action is required.

ABS

The ABS function prevents the road wheels locking during brake application, thus maintaining vehicle stability even under emergency conditions.

WARNING: ABS is an aid to retaining steering control and stability while braking:

- ***ABS cannot defy the natural laws of physics acting on the vehicle.***
- ***ABS will not prevent accidents resulting from excessive cornering speeds, following another vehicle too closely, aquaplaning, etc.***
- ***The additional control provided by ABS must never be exploited in a dangerous or reckless manner which could jeopardise the safety of driver or other road users.***
- ***The fitting of ABS does not imply that the vehicle will always stop in a shorter distance.***

NOTE: During normal braking the feel of the brake pedal on vehicles equipped with ABS will be the same as that on non ABS vehicles. During anti-lock braking operation the driver will experience feedback in the form of a pulsating brake pedal and solenoid/pump motor noise from the ABS modulator.

The anti-lock braking function is automatically enabled whenever the ABS modulator is in the normal braking mode. While the anti-lock braking function is enabled, if the SLABS ECU detects a wheel decelerating faster than the average and at the calibrated wheel slip limit for ABS operation, it operates the ABS modulator in the ABS braking mode for the affected wheel.

EBD

The EBD function optimises the distribution of hydraulic pressure between the front and rear axles, under all vehicle load configurations and road conditions, to maintain vehicle stability during braking. EBD operates in forward and reverse and is automatically enabled whenever the ABS modulator is in the normal braking mode at vehicle deceleration rates of 0.3 g and above (i.e. medium to high brake pedal loads). EBD operation is similar to that of ABS, but is calibrated to intervene at lower wheel slip limits and operates the brakes in axle pairs instead of individually.

During braking, if the SLABS ECU detects the wheels of one axle going slower than those of the other axle, i.e. a potential wheel slip situation, it signals the ABS modulator to close the inlet solenoid valve for the brakes of the slower wheels. This prevents any further increase in hydraulic pressure to those brakes, while allowing the hydraulic pressure to the brakes on the other axle to increase and so maximise the overall braking effort. If the wheel speeds of the axle being subjected to EBD control return within the calibrated wheel slip limits, the SLABS ECU signals a stepped opening of the inlet solenoid valves, which allows a progressive increase of hydraulic pressure to the related brakes.

Operation of EBD is detectable from a stiffening of brake pedal movement as the inlet solenoid valves close and a slight pulsing of the brake pedal as the inlet solenoid valves open. EBD operation ceases immediately the brake pedal is released.

The wheel slip limit for EBD operation varies with vehicle speed. During normal operation, the inlet solenoid valves always operate in axle pairs, with only one axle pair closed at any one time. Since the most lightly loaded wheel during a braking manoeuvre will usually be the first to reach the slip limit, under most vehicle load configurations and road conditions EBD control occurs on the trailing axle. However, EBD control can occur on the leading axle or switch between axles during the braking manoeuvre.

ETC

The ETC function uses brake intervention to prevent wheel spin and maintain even torque distribution to the wheels. ETC is automatically enabled while the brakes are off at speeds up to 62.5 mph (100 km/h), and operates the brakes either individually or in axle pairs:

- At speeds up to 31.3 mph (50 km/h), ETC uses individual brake intervention to maintain even torque distribution between wheels on the same axle.
- **Vehicles up to 03 model year** – At speeds between 0 and 62.5 mph (0 and 100 km/h), ETC also uses brake intervention in axle pairs to maintain even torque distribution between the front and rear axles. In effect, this mode of operation replaces the centre differential lock of the transfer box which, although still incorporated, is non operational under normal driving conditions.
  ☞ **TRANSFER BOX - LT230SE, DESCRIPTION AND OPERATION, Description.** If the centre differential lock is in the locked condition, the SLABS ECU illuminates the ABS and ETC warning lamps and inhibits the ETC function (the ABS, EBD and HDC functions are retained, but at degraded performance levels).
- **Vehicles from 03 model year (with differential lock fitted)** – At speeds between 0 and 62.5 mph (0 and 100 km/h), ETC uses brake intervention in axle pairs to maintain even torque distribution between the front and rear axles. If the centre differential lock is in the locked condition, the differential lock warning lamp in the instrument pack is illuminated. The ABS, EBD, ETC and HDC functions are retained, but with revised parameters to suit the locked differential.

While the ETC function is enabled, if the SLABS ECU detects a wheel accelerating faster than the average, indicating loss of traction, it operates the ABS modulator in the active braking mode. Depending on the vehicle speed, active braking is employed for either the brake of the affected wheel or for both brakes on the affected axle, until all four wheels are driven at approximately the same speed again. During active braking the SLABS ECU also illuminates the ETC warning lamp, for a minimum of 2 seconds or for the duration that ETC is active. ETC operation is desensitised during 'hard' cornering.

HDC

HDC uses brake intervention to provide a controlled descent ability in off road conditions when engine braking is insufficient to maintain a comfortable speed. This allows the driver to leave HDC selected and to control the vehicle's descent speed, down to the system's minimum target speed, using only the accelerator pedal. The HDC function is selected on/off by a switch on the fascia. When selected on, HDC is enabled in all forward gears and reverse provided:

- Vehicle speed is below 31.3 mph (50 km/h).
- The transfer box is in low range.
- On manual gearbox vehicles, the clutch is engaged.

When HDC is enabled, the HDC information warning lamp illuminates. If HDC is selected outside the above conditions, the HDC information warning lamp flashes and the audible warning sounds continuously.

When HDC is enabled, the SLABS ECU calculates a target speed from the throttle position element of the engine data input, and compares this with actual speed. If the actual speed is higher than the target speed, the SLABS ECU operates the ABS modulator in the active braking mode to slow the vehicle down to the target speed. While the braking force is being applied, the SLABS ECU also energizes the brake lamp relay to put the brake lamps on. Active braking is discontinued while vehicle speed is below the target speed or if the foot brakes are applied. Applying the foot brakes during active braking may result in a pulse through the brake pedal, which is normal.

During active braking, the brakes are operated predominantly on the wheels of the leading axle, but if that is not sufficient to achieve the required deceleration the brakes of the trailing axle are also applied. The deceleration rate is dependent on the speed differential between initial vehicle speed and the target speed. The deceleration rates are relatively low at higher speed differentials, then progressively increase as vehicle speed approaches the target speed. Anti-lock braking is also enabled during active braking, but at very low speeds some wheel lock can occur.

The target speed increases as the accelerator pedal is pressed, from a programmed minimum with the accelerator pedal released, up to a maximum of 31.3 mph (50 km/h). For any given accelerator pedal position, while travelling uphill or on level ground the target speed is always greater than the corresponding vehicle speed, which allows the vehicle to be driven normally without HDC intervention. However, when travelling downhill, the gravitational effect on the vehicle means that for any given accelerator pedal position the target speed is less than the corresponding vehicle speed, and HDC intervenes to limit vehicle speed to the target speed.

Minimum target speed

The minimum target speed depends on which gear is engaged. Reduced minimum target speeds are employed for some gears if rough terrain or sharp bends are encountered while already travelling at the normal minimum target speed. If loss of traction makes it impossible to maintain the minimum target speed, the SLABS ECU temporarily increases the minimum target speed to maintain stability, then restores the normal minimum target speed when traction improves.

HDC minimum target speeds

Gear	Speed, mph (km/h)			
	Manual gearbox		Automatic gearbox	
	Normal	Reduced	Normal	Reduced
1	4.4 (7.0)	4.4 (7.0)	4.4 (7.0)	4.4 (7.0)
2	5.2 (8.3)	4.4 (7.0)	4.4 (7.0)	4.4 (7.0)
3	6.0 (9.6)	4.4 (7.0)	7.5 (12.0)	6.0 (9.6)
4	7.5 (12.0)	6.0 (9.6)	7.5 (12.0)	6.0 (9.6)
5	8.8 (14.0)	7.0 (11.2)	-	-
Reverse	3.5 (5.6)	3.5 (5.6)	3.5 (5.6)	3.5 (5.6)
Neutral or clutch disengaged	8.8 (14.0)	Last off road speed	4.4 (7.0)	4.4 (7.0)

Fade out

To provide a safe transition from active braking to brakes off, the SLABS ECU invokes a fade out strategy if it detects any of the following during active braking:

- A system fault.
- The conditions for HDC are no longer being met.
- Possible brake overheat.

The fade out strategy increases the target speed at a low constant acceleration rate, independent of actual throttle position. This results in the braking effort being gradually reduced and then discontinued. The SLABS ECU operates warning indications during fade out that are dependent on the cause.

Fade out warning indications

Cause	Warning indication		
	HDC fault warning lamp	HDC information warning lamp	Audible warning
Fault detected	On	Flashes	Continuous
HDC conditions not met	Off	Flashes	Continuous
Brake overheat prevention	Flashes	Off	Continuous

Clutch disengagement/neutral selection

During active braking, if the SLABS ECU detects the clutch is disengaged or neutral is selected, it flashes the HDC information warning lamp and sounds the audible warning continuously to indicate that conditions for HDC are no longer being met. Initially, the SLABS ECU also fixes the target speed to the applicable minimum target speed, but if the condition continues for approximately 60 seconds the SLABS ECU invokes fade out.

Brake overheat prevention

To prevent the brakes overheating, the SLABS ECU monitors the amount of active braking employed and, from this, estimates brake temperature. If the SLABS ECU estimates the brake temperature has exceeded a preset limit, it flashes the HDC fault warning lamp and sounds the audible warning continuously, to indicate that HDC should be deselected to allow the brakes to cool. If active braking continues and the SLABS ECU estimates that brake temperature has increased to an unacceptable level, fade out is employed and HDC is disabled. After fade out, the audible warning is discontinued but the HDC fault warning lamp continues to flash, while HDC is selected, until the SLABS ECU estimates brake temperature to be at an acceptable level. This calculation continues even if the ignition is turned off, so turning the ignition off and back on will not reduce the disabled time. When the SLABS ECU estimates the brake temperature to be acceptable, it extinguishes the HDC fault warning lamp and illuminates the HDC information warning lamp to indicate that HDC is re-enabled. The disabled time is dependent on vehicle speed; typical times at constant vehicle speeds are as follows:

Typical disabled times

Vehicle speed, mph (km/h)	Time, minutes
1.3 (2)	40
12.5 (20)	33
15.6 (25)	17
25.0 (40)	9
31.3 (50)	6

Diagnostics

While the ignition is on, the diagnostics function of the SLABS ECU monitors the system for faults. In addition, the return pump is tested by pulsing it briefly immediately after the engine starts provided vehicle speed exceeded 4.4 mph (7 km/h) during the previous ignition cycle. If a fault exists in a warning lamp circuit, the lamp will not illuminate during the lamp check at ignition on but, provided there are no other faults, the related function will otherwise be fully operational. If a fault is detected during the power up, the SLABS ECU stores a related fault code in memory and illuminates the appropriate fault warning lamps. If a fault is detected later in the drive cycle, the SLABS ECU also sounds the audible warning three times.

Fault codes and diagnostic routines can be accessed by connecting Testbook to the vehicle's diagnostic connector in the driver's footwell.

Warning lamp fault operation

Item	Check	Warning lamp			
		ABS	Brake	ETC	HDC fault
ABS sensors	Resistance (to check status)	On	On	On	On
Brake lamps relay	Open/Short circuit	Off	Off	Off	On
Engine data	Sticking throttle, signal failure, data corruption	Off	Off	On	On
Inlet solenoid valves	Open/Short circuit	On	On	On	On
Outlet solenoid valves	Open/Short circuit	On	On	On	On
Reference earth	Connection to earth	On	On	On	On
Return pump monitor	Correct pump operation	On	On	On	On
Return pump relay	Open/Short circuit	On	On	On	On
Shuttle valve switches	Open/Short circuit	On	On	On	On
SLABS ECU	Internal failure	On	On	On	On
Supply voltages	Range (10 to 16 V)	On	On	On	On

After detecting a fault, the SLABS ECU selects an appropriate default strategy which, where possible, retains some operational capability. A shuttle valve switch fault and throttle position signal fault are classified as permanent faults. If a permanent fault is detected, the related warning lamp illumination and default strategies are automatically employed in subsequent ignition cycles, even if the fault is intermittent, until the fault has been rectified and cleared from memory. If a non permanent fault is detected, the related warning lamp illumination and default strategies will only be employed in subsequent ignition cycles if the fault is still present.

After rectification of an ABS sensor fault, the ABS and ETC functions are disabled, and the ABS warning lamp remains illuminated after the lamp check, until vehicle speed exceeds 9.4 mph (15 km/h) (to allow additional checks to be performed).

Default strategies

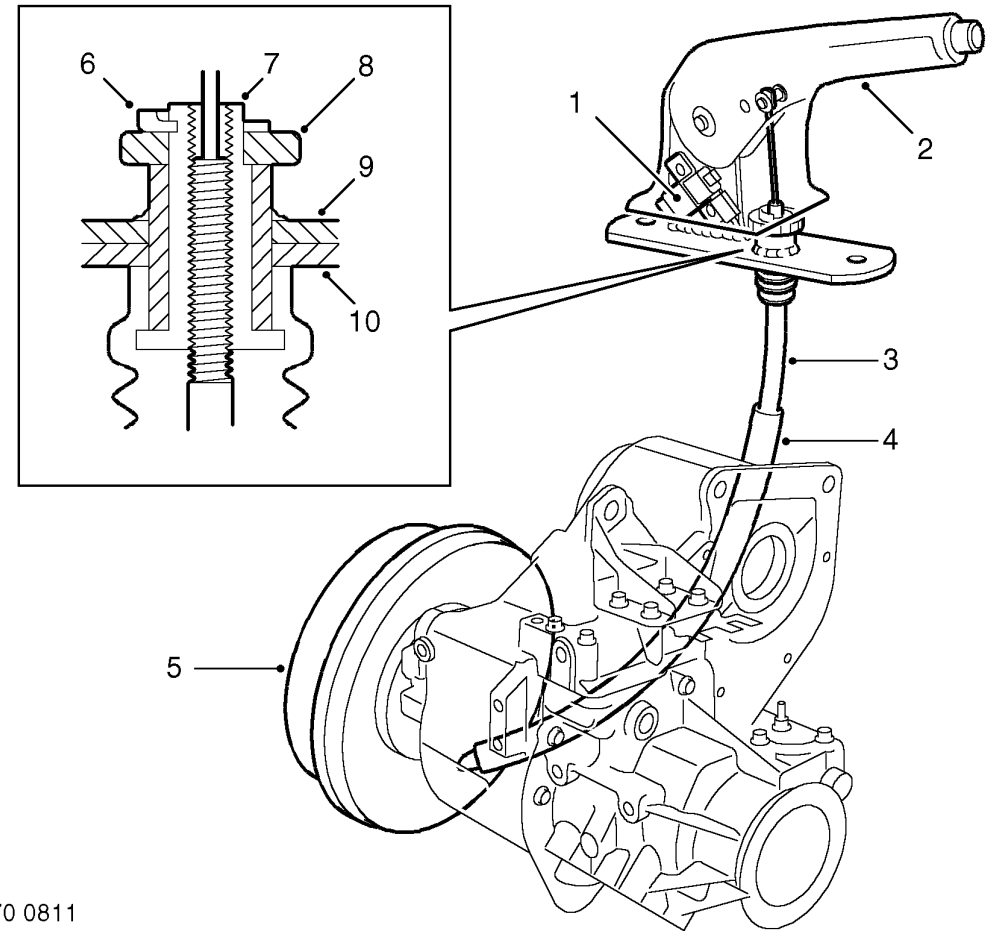
Fault	Default strategy
Brake lamps relay	ABS: Enabled. ETC: Enabled. EBD: Enabled. HDC: Enabled.
Throttle position signal failure	ABS: Enabled. ETC: Disabled. EBD: Enabled. HDC: Immediately disabled if not in active braking mode; faded out then disabled if in active braking mode.
No reference earth	ABS: Disabled. ETC: Disabled. EBD: Partly disabled. HDC: Disabled.
Return pump or relay fault	ABS: Disabled. ETC: Disabled. EBD: Partly disabled. HDC: Disabled.
Shuttle valve switch failure	ABS: Deceleration threshold increased; return pump activated if sum of output valve actuation on one axle exceeds 140 milliseconds. ETC: Disabled. EBD: Inlet valves of rear axle close at vehicle deceleration rates of 0.3 g and above. HDC: Disabled.
SLABS ECU internal failure	ABS: Disabled. ETC: Disabled. EBD: Disabled. HDC: Disabled.
Supply voltage out of limits	ABS: Disabled. ETC: Disabled. EBD: Disabled. HDC: Disabled.

Electrical data

Nominal resistance values for applicable brake control components are as detailed below:

Component	Resistance, ohms
Brake lamp relay coil	117 - 143
Return pump relay coil	82.8 - 101.2
ABS sensor	950 - 1100
Shuttle valve switches, both open (brakes off)	2977 - 3067
Shuttle valve switches, both closed (brakes on)	1007 - 1037
Shuttle valve switches, one open, one closed	1992 - 2052
Inlet solenoid valve	5.9 - 7.3
Outlet solenoid valve	3.0 - 3.6

Handbrake component layout



M70 0811

1 Warning switch
2 Handbrake lever
3 Cable
4 Protective sleeve
5 Drum brake
6 'C' clip
7 Threaded sleeve
8 Adjuster wheel
9 Base plate
10 Transmission tunnel

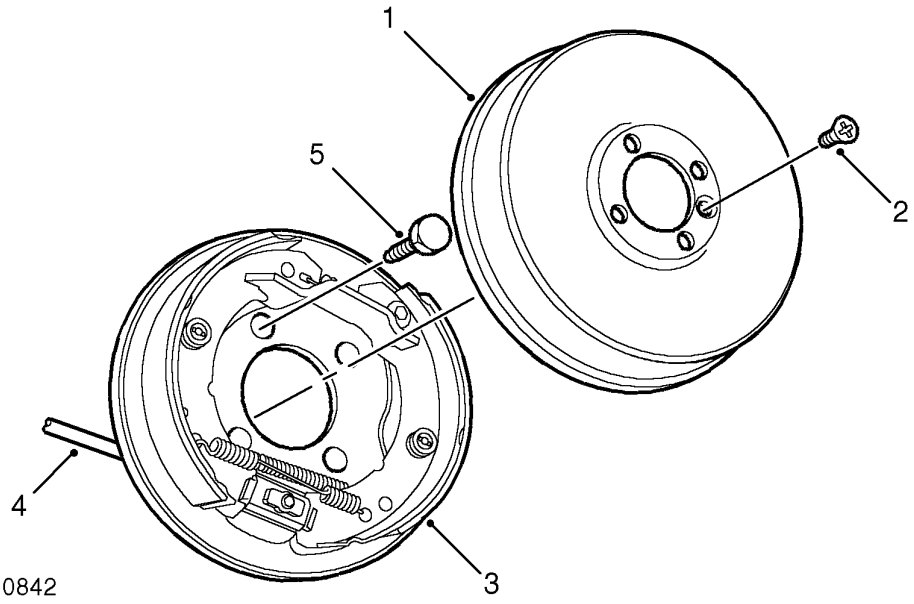
Description

General
The handbrake consists of a drum brake, installed on the rear of the transfer box, operated by a cable connected to a handbrake lever between the front seats.

Handbrake lever
The handbrake lever is mounted on a base plate which attaches to the transmission tunnel. A conventional ratchet and thumb operated release button are incorporated for locking and unlocking the lever. A warning switch on the base of the lever operates the brake warning lamp in the instrument pack. While the handbrake is applied the warning switch connects an earth to the instrument pack which, if the ignition is on, illuminates the brake warning lamp. In some markets, the instrument pack performs a bulb check of the brake warning lamp each time the ignition is switched on.

Cable
The handbrake cable consists of inner and outer cables installed between the handbrake lever and the drum brake. A protective sleeve is installed on the cable to protect the cable from heat from the exhaust system. Handbrake adjustment is provided by a threaded sleeve installed on the outer cable where it locates in the handbrake lever. Turning an adjuster wheel, which is keyed to the threaded sleeve and secured by a 'C' clip, alters the effective length of the outer sleeve and consequently changes the handbrake lever movement needed to apply the drum brake.

Drum brake



1 Drum
2 Drum securing bolt
3 Backplate
4 Cable
5 Backplate securing bolt

The drum brake consists of a backplate attached to the transfer box casing and a drum attached to the transfer box rear output shaft. When the handbrake lever is applied, the movement is transmitted by the inner cable to a lever on one of the brake shoes on the backplate. The lever pivots against the brake adjuster rod, which forces the shoes apart and into contact with the drum. Brake shoe to drum clearance is set by an adjusting bolt on the rear of the backplate.