ANTI LOCK BRAKING

Braking – one of the most repetitious tasks we perform every day when driving our motor vehicles.

Something that drivers do so often that they could just about do it with their eyes closed – a conditioned reflex the experts call it, and certainly when it rains, or when driving on a gravel road, they have to be more careful, leave more space between them and the vehicle in front, but by and large most drivers feel reasonably confident when it comes to stopping their vehicles safely.

But what happens in an emergency situation – especially on a wet or slippery surface – most drivers just press down on the brake pedal as hard as they can, and continue to do so until the vehicle comes to rest.

This usually causes the wheels to lock, resulting in a loss of vehicle stability and steearing control.

Racing car drivers learn to immediately release and then re-apply the brakes as soon as a wheel locks. It too is a conditioned reflex, but takes time to learn, and then must be practised regularly to remain proficient.
And it's because we are not all racing car drivers, that anti-lock braking systems were developed.

With an anti-lock brake system fitted to the vehicle, the driver can not only press on the brake pedal as hard as possible, no matter what the road conditions, but can also maintain a high level of vehicle control.

It's just like having an invisible racing driver in the car, applying and releasing the brakes for you every time the wheel starts to lock – except that this one can apply and release the brakes between four and ten times every second.

But to better understand where the advantages lie with ABS, we first need to understand what happens between the tyre and the road surface when a vehicle is accelerating, braking, changing direction, or doing the combination of any two at the same time.

In order for a vehicle to accelerate, change direction or stop, a tyre must develop friction between itself and the road surface. We call the friction developed grip, and different types of tyres develop different amounts of it, on different surfaces.

If the vehicle is accelerating, then all the available grip can be used to push the vehicle down the road.

If however, the vehicle is cornering, then the total amount of grip has to be shared. Some of it is used to continue to propel the vehicle forward, whilst the rest of it is used to make the vehicle change direction.

When it comes to slowing or stopping the vehicle, we once again rely on the grip being generated by the tyres on the road surface.

And just as when we were negotiating a corner under power, the grip has to be shared when we apply the brakes whilst turning.

The surprising thing about the generation of grip is, that there has to be a certain percentage of slip between the tyre and the road surface for it to occur. Looking at this graph we can see that for

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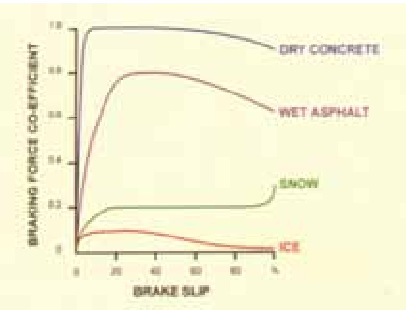
virtually any road surface condition, the maximum amount of grip generated by the tyre occurs when there is approximately 10 to 30 percent slip between the tyre and the road surface. The only exceptions being loose gravel or snow, where the ploughing effect of a locked wheel builds a wedge to material in front of it, helping to slow the vehicle.



What this slip means is that the maximum stopping rate is reached when the wheels are rotating at somewhere between 10 and 30 percent slower than the vehicle is travelling, no matter what the condition of the road surface may be.

An anti-lock brake system achieves this by constantly monitoring wheel speeds, and computing vehicle speed, before and during braking, and then modulating the brake pressures to maintain this 10 to 30 percent slip during a maximum deceleration stop.

With most systems, when the anti-lock starts working, the driver feels the pedal kicking back, indicating that ABS operation has been initiated, a notable exception to this being the Bendix LC5 system fitted to EB and ED Falcon, which has internal valving in the moducator to prevent kick-back.

It is important to understand though, that the system is only effective while the driver is pressing on the brake pedal, and even then, only when the system detects that a wheel, or wheels, are about to lock. A gentle driver, that never encounters an emergency situation, might never brake heavily enough to make the ABS work for the life of the vehicle.

In this next section we are going to look at the components that make up a typical anti-lock brake system, and their functions. Whilst there are several different systems available on the market, and which on some specialist vehicles may have additional sensors installed to further refine ABS operation, the system discussed here is representative of what is fitted to the high volume vehicles on the market today.

However, before looking at the ABS components it must be stressed that the vehicle still has all the components of a conventional brake system, which function in just the same way as they always have.

In the majority of cases, the ABS components are additions to the standard system, not replacements.

The ABS system itself consists of wheel speed sensors, of which there are usually four, an electric control unit or ECU, which may be separate to, or combined with the hydraulic modulator and pump assembly.

On some systems there is also a specific master cylinder for ABS, however, all systems include additional hydraulic piping and electrical wiring, as well as a dashboard warning lamp.

We'll start our discussion with the wheel speed sensors. These comprise of a sensor, which is usually fixed to some part of the suspension system, and a toothed sensor wheel, which is attached to a rotating member of the brakes or drive train, such as a brake disc or drive shaft.

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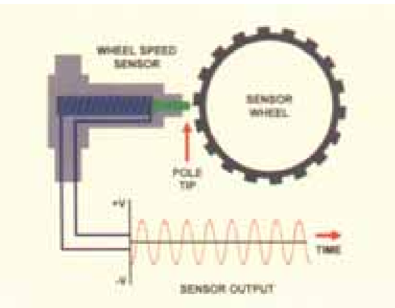
Although the fully sealed, non-serviceable hub design, with built in sensor is steadily gaining in popularity.

A typical sensor consists of a magnetic core surrounded by a wire coil. As the toothed sensor wheel rotates the tip of the magnetic core is alternatively aligned with a tooth or a gap. This causes change in the stength of the manetic field, which in turn generates an alternating, or AC voltage in the wire core. As vehicle, and hence sensor wheel speed increases, so does the voltage and frequency of the AC signal, thus making the signal proportional to vehicle wheel speed.



These AC signals are then sent via electrical cables, to the ABS electronic control unit, which uses them to calculate vehicle and wheel speeds.

The ABS electronic control unit, which constantly processes signals from the wheel speed sensors, calculate the optimum wheel slip for maximum braking, and then control the hydraulic pressure delivered to the brakes by operating the solenoid valve housed in the modulator assembly.

The modulator and pump assembly, is hydraulically connected to the braking system between the master cylinder and wheel brakes. Solenoid valves, housed within the modulator, are operated by the ECU to constantly adjust the brake pressure at the wheels during braking, to maintain the correct slip ratio. The pump also controled by the ECU, is used to return fluid released from the hydraulic cylinders during ABS operation, back to the master cylinder.

The master cylinder itself, is still called upon to create the hydraulic pressure in the brake system for all normal braking situations. In most cases the ABS system merely modifies this pressure when it is brought into operation. However, because many systems return fluid released from the hydraulic cylinders during ABS operation back to the master cylinder, certain internal modifications are made to enhance the master cylinders reliability, thereby making it specific for ABS equipped vehicles.

As has already been mentioned, the hydraulic modulator assembly is connected between the master cylinder and wheel brakes, necesitating additional hydraulic piping.

In similiar fashion, additional wiring is required to send signals and provide power to the ECU and for the ECU to send signals to the hydraulic modulator. Due to the large amounts of electrical and magnetic interference existing in modern vehicles, some of the electrical cables may be specially shielded, and the routing of the ABS wiring loom is carefully chosen to minimise interference. Our final component in the system is the dashboard warning lamp.

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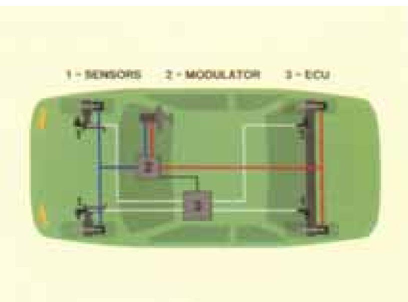
Due to the ABS being a primary safety system in the vehicle, the driver needs to be warned if for any reason, the system has failed. The ABS electronic control unit, constantly tests and checks the various systems components, and itself for defects. Should any major problem be detected, the ECU immediately turns the ABS system off, and turns the warning light on, to alert the driver. The braking system then reverts to a normal system, the same as a vehicle without ABS fitted.

Before we start on a description of how a typical ABS system works, we must first discuss some of the more common configurations when it comes to controlling the brake system. This is commonly known by the number of channels and sensors the system has.

The most comon in rear wheel drive vehicles, is the three channel four sensor variety. This means that each wheel has a sensor, but the modulator only has three channels. This type of system controls the pressure of each front wheel individually, but regulates the pressure to both back wheels at the same time, so that as soon as one rear wheel starts to slow too quickly, pressure is held or reduced in both the rear wheels.

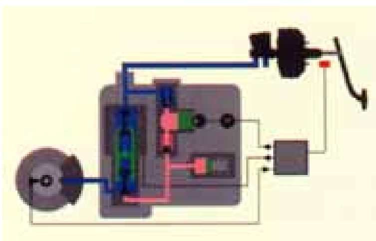


Front wheel drive, high performance and luxury vehicles, including four wheel drive vehicles, may have four channel, four sensor systems fitted. As the name implies, these systems control all four wheels individually, and may include additional sensing devices to further adjust hydraulic pressure to compensate for high lateral loads during cornering.

At the low end of the market we may encounter the one and two channel systems which only control pairs of wheels, either fronts, rears, or diagonal pairs, and may come with up to four sensors.

For the purposes of clarity, we shall only discuss what happens to one front wheel on a typical three channel system during ABS operation, using this graphical representation.

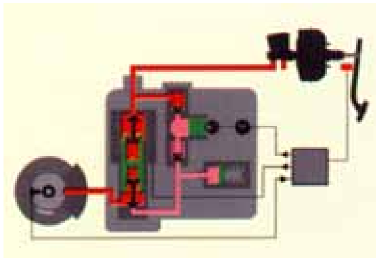
The diagram shows a wheel speed sensor and brake caliper, which is connected to one channel of the hydraulic modulator.



Inside the modulator we have the solenoid valve, pump assembly and accumulator.

Hydraulically connected to the modulator is the master cylinder – whilst electrically, we find the electronic control unit, with stop light switch and wheel speed sensor connected to it, controlling modulator operation.

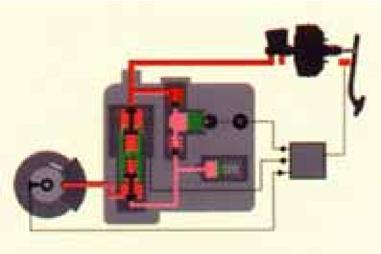
During normal braking the modulator remains passive, with brake fluid from the master cylinder simply running through the solenoid valve and to the brake caliper.



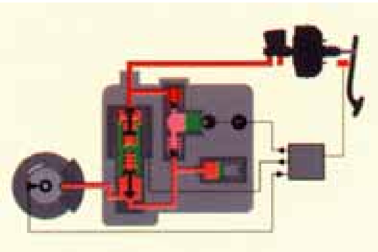
The ECU, as we have already stated constantly monitors wheel speed, but will not activate the modulator until it receives an input signal from one or more of the wheel sensors, telling it that a wheel, or wheels, are close to lock-up.

Some systems, such as the Bendix LC5 fitted to EB and ED Falcon also require a signal from the stop light switch for ABS operation to commence.

Upon receiving these signals the ECU then allows current to flow to the solenoid, moving the valve assembly half it's total stroke, effectively isolating the master cylinder from the caliper.



Should the ECU continue to receive signals from the wheel speed sensor telling it that the wheel is still slowing down at too fast a rate, it will then further increase current flow to the solenoid. This then moves the valve assembly the second half of it's stroke and connects the caliper to the accumulator circuit.



At this time the pump motor is also turned on by the ECU and brake fluid released from the caliper is returned to the master cylinder, causing the brake pedal to "kick back".

Once the wheel speed has exceeded a predetermined value, the ECU switches the current off, allowing the valve assembly to return to the rest position, and fluid from the master cylinder back into the brake caliper.

Whilst the driver continues to apply high pressure to the brake pedal, and the wheels are in danger of locking, the ECU will cycle the system four to ten times every second. This rapid cycling of the system is made possible by the sophisticated electronics in the ECU, and the valve assemblies total stroke being only 0.25mm.

The operating cycle we have just described is typical of several of the more common ABS systems available on the market today. Other systems, such as that fitted to EB and ED Falcon, operate slightly differently.

These systems, whilst haivng only a presure reducing and pressure increasing mode, use the pump motor, instead of the master cylinder, to increase hydraulic pressure during ABS operation.

Still other systems may use an hydraulic accumulator to store pressure for use during anti-lock operation, however, no matter what differences exist in modulator operation, they all still maintain wheel speed in the ten to thirty percent slip range during ABS operation.

Anti-lock brake systems are themselves virtually maintenance free, however, there are normal servicing operations carried out on brake systems that required additional precautions to be taken with an ABS equipped vehicle.

In addition to these, the standard precautions which must be observed when working on any vehicle fitted with electronic components, applies equally to vehicles fitted with an ABS braking system. These include making sure battery terminals are clean and tight, disconnecting the battery before charging, removing the plug from the ECU before commencing any electric welding on the vehicle, completely removing the ECU before placing the vehicle in a painting oven, and never disconnecting the battery terminals while the engine is running.

Of the mechanical service operations, we shall first look at front disc removal. Because sensor to pulse wheel clearances are usually in the order of 0.3mm to 1.3mm, it is good practice to remove the ABS sensor before loosening the wheel bearing retaining nut, thereby avoiding the risk if damaging the tip of the sensor.

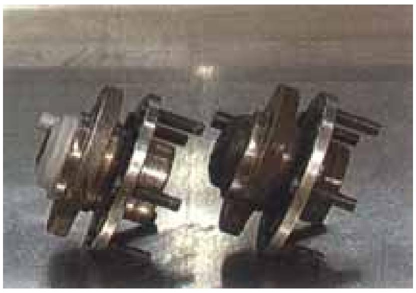
When it comes to on-care machining, the sensor should still be removed, due to filings produced during the machining process, being attracted to the sensor's magnetic head. The filings affect the signals sent to the ECU, which then interprets them as a fault, switching the ABS off, and the dashboard warning light on.

This is equally true for vehicles fitted with external pulse wheels on the rear axles, when they are mounted close to the disc.

If a sensor is removed or a pulse wheel replaced, such as when a new disc is being fitted, sensor clearance will have to be checked and adjusted to manufacturers specifications.

Wheel bearing adjustment is also important, excessively loose bearings could cause the sensor tip to come into contact with the pulse wheel, damaging both.

Also, while we're talking about pulse wheels, if you are replacing one, check that it has the same number of teeth as the one you took off. Commodore for instance, uses pulse wheels with forty eight teeth on independent suspension vehicles, but use only thirty two teeth pulse wheels on models with life rear axles.



And finally on the subject of sensors, some manufacturers recommend that the sensor be cleaned, and a light coating of grease applied before it is replaced, so check the relevant service information before replacement.

Turning our attention to master cylinders now we must emphasise that it performs exactly the same function on the ABS equipped vehicle, as it does on one not equipped with ABS – so replacement procedures are exactly the same.

The main difference lies in it's internal construction, where we find a centre valve has been added to the secondary piston, and the compensating port in the secondary circuit deleted.

All PBR master cylinders use colour coded resevoirs to identify their correct application for the various braking system combinations within a model range. However, manufacturers specifications must always be checked for the correct application prior to fitment.

The final service procedure we shall look at is bleeding. With Bosch systems, such as those fitted to Commodore and EF Falcon, there is no change in the bleeding procedure compared to non ABS equipped vehicles.

So the methods described in the second video in this series "Spongy Pedal Diagnosis" will work equally as well with these systems.

For the Bendix LC5 Pump Back system, fitted to the EB and ED Falcon, and which does not use a specific master cylinder, there are two separate bleeding operations.

The first is for normal, periodic brake fluid changes as specified in the vehicles servicing schedule.

This is once again the same as the bleeding procedure for non ABS equipped vehicles, and therefore covered in "Spongy Pedal Diagnosis".

The second bleeding operation needs to be

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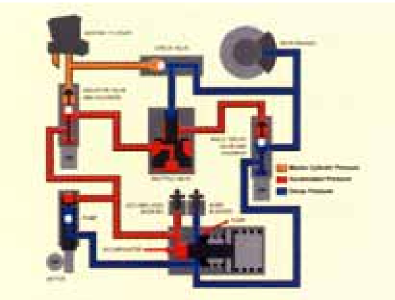
performed when a new modulator is being fitted, or the old one has been removed whilst other repairs are being carried out on the vehicle.

Because this system uses the pump motor, in conjunction with an internal accumulator and sump, to provide all hydraulic pressure during ABS operation, it retains a certain amount of fluid inside the modulator that only enters the hydraulic system during ABS operation.



If the air inside the accumulator and the sump is not removed when a modulator is fitted, air will be transferred into the main hydraulic circuits the fist time the ABS ystem is operated.

The bleeding procedure requires the use of some dedicated equipment and depress the brake pedal, whilst air is bled from the unit through these four bleed nipples.

On systems fitted with external accumulators, such as some Mazda and Honda models, extreme caution should be exercised with any operation involving the modulator. The accumulators maintain fluid pressures in some circuits of the modulator at more than 10,000 KPA, making the indiscriminate disconnection of pipes, or opening of bleeder nipples on the modulator, a dangerous undertaking.

Manufacturers servicing information for each individual system should be consulted before any work is commenced.

Because an ABS system dramatically enhances the safety of a vehicle, and yet operates so infrequently, drivers need to be warned if the system is malfunctioning. To provide this, an ABS warning light is installed in the vehicles dashboard which illuminates when the ignition is first switched on, and then, should no faults be present in the system, extinguishes.

Behind all this is a sophisticated software program in the ECU which, when the vehicle first moves off after being started, runs the pump, cycles the solenoid valves and checks the signal coming from the wheel speed sensors, illuminating the warning light should a fault be detected. After this the ECU constantly checks the system, and should any faults appear, immediately swtiches the system off and illuminates the warning lamp. When this happens the brake system simply reverts back to being the same as a vehicle without ABS fitted.

On some systems this is accompanied by the logging of a fault code in the computers memory. These codes can usually be accessed by earthing a pin in the vehicles diagnostic connector, and counting the flashes of the ABS warning light. Again, manufacturers service information will have to be consulted to establish if the system displays fault codes, and how to access them, along with the specifics on code interpretation.

It must be stressed however, that the fault codes only relate to the electrical devices and circuits in the system.
Faults such as hydraulic leaks from the modulator or brake caliper, or worn brake linings, can only be detected by regular system inspections.

There are however, some basic common sense checks that can be performed on an ABS system without the use of service literature should the warning light come on.

The first is that the vehicles tyres are all the same size and profile, and are the same circumference as those

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stated on the vehicle tyre placard. If one or two tyres have different circumferences, the ECU will receive conflicting wheel speed information occurring without the brakes being applied. This will be interrupted as a fault by the ECU and the system will be switched off.

It's worth mentioning here that if all the tyres are the same size, but have different circumferences to what was originally fitted to the vehicle, no fault code will be logged. However, the ECU, which has been programmed using the original tyre size, will not be able to compute vehicle and wheel speed correctly, thereby adversely affecting ABS operation, and consequently, braking performance.

Our second test is the wheel speed sensors. Because they sit down in the hub or axle areas of the suspension, they are the most suscepible to damage.

As we previously mentioned, the wheel speed sensors produce an AC voltage signal of varying magnitude and frequency which can be easily checked using a digital multimeter.

This is done by first setting the multimeter to AC volts, disconnecting the speed sensor at it's plug, and carefully placing one lead of the multimeter on each connector in the plug.

An assistant can now spin the wheel by hand, and if the sensor is functioning correctly a small AC voltage should be shown on the meter.

Should no voltage be shown, the next step is to change the multimeter to the resistance scale, and check the sensor internally. As an average figure, sensor resistance should be between one thousand and three thousand ohms – a reading of infinity indicating a faulty sensor, with internal breaks in the wiring.

If the resistance reading of the sensor is within the tolerance range, the sensor air gap should then be checked. As a rule sensor air gaps range between 0.3mm and 1.3mm air gap, and on some vehicles are adjusted by the use of shims.

If the gap proves to be within tolerance, then the final check will be the end of the sensor or pulse wheel for clogging by dirt, or possibly filing from disc machining.

Our third and final check is to make sure that all wiring is held in it's correct position in the vehicle, and that none of the electrical plugs in the wiring loom, or into the modulator and ECU, have come loose.

The problem with loose plugs is obvious, but the one of wiring looms being displaced from their original position may not be.

The looms position is important because of the large number of electrical devices fitted to modern vehicles creating strong magnetic fields. If the wiring loom for the ABS system runs too close to these devices, the strong magnetic fields may interfere with the signals being sent to the ECU causing it to log a fault code and switch the system off.

None of the major components in the ABS system are repairable. The modulator, electronic control unit, or ECU, and the wheel speed sensors, all require replacement if proven to be faulty.

In closing, Wingate would like to once again remind you that any time a fault develops in the ABS system, and the warning light indicating that the system has been disabled, the vehicle is perfectly safe to drive. And that even with the light on, problems with the vehicles braking system, such as hydraulic leaks, or worn out lining material, should still be repaired immediately.