Anti-lock Brake System
Foreword

The ABS system is installed in modern vehicle to prevent wheel lock up during braking. This ensures the vehicle steering control is maintained during hard braking. In this training manual, we will study the operation of the ABS and EBD systems.

Suzuki Technician curriculum

This training manual is part of the Non Suzuki Technician to Suzuki Technician curriculum. The curriculum consists of the following modules:

1. GE01 Suzuki Introduction
2. GE02 Electrical / Electronics
3. GE03 Diagnostics
4. EN02 Engine Mechanical part I
5. EN03 Engine Mechanical part II
6. EN04 Engine Mechanical part III
7. EN05 Engine Auxiliary systems
8. DS01 Driveshaft/Axle
9. DS02 Driveshaft/Axle transfer case
10. BR02 Brake control systems
11. Manual transmission / transaxle
12. CS02 Control system / body electrical
13. CS03 Communication / bus systems

You are currently studying BR02 Brake control systems. This module consists of the following courses:

- Anti-lock Braking System
- ABS Practical Activities

This document is intended solely for training purposes only. All vehicle repairs and adjustments must be carried out according to the procedures stipulated in current service manuals and technical bulletins.
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Lesson 1

Anti-lock Braking System

Learning outcomes

The contents of this chapter will enable learners to:

• Describe the purpose of ABS.
• List the components of the ABS.
• Describe the functions of each of the components of the ABS.
• Explain the working principles of the ABS.
• Describe the load changes in the vehicle due to braking force.
• Describe the displacement of load of the vehicle during braking force.
• Define slip ratio
• Explain the different ABS control module functions.
1.1 Wheel lock

When you drive a vehicle on a wet paved road or on a road covered with snow, you may lose control of the vehicle if you step on the brake pedal strongly.

If the driver steps on the brake pedal deeply while driving on such a slippery road, the driver may not be able to control the vehicle by steering wheel. In such a case, the driver cannot turn the vehicle and the vehicle will run out of the road. There is also a probability of hitting some obstacles even though the driver drives on a straight road. ABS (Anti-lock Braking System) is a system which was developed to prevent such dangerous situations.

ABS was developed as an active safety system to be added to the conventional brake system which consists of master cylinder, disc brake, drum brake, proportioning valve and so on.

The ABS has become a more familiar system to automobile these years, although ABS itself had already been adopted to aircrafts and trains earlier than automobile.

When a driver strongly steps on the brake pedal of a vehicle without ABS, the wheels may be decelerated and finally stopped. In spite of this, the vehicle may keep on running. We say in this situation that a big slip occurred between the wheel and the road or that the wheels were locked. Under this condition, the vehicle loses skid friction (skid means slip or slide in the direction perpendicular to the vehicles forward traveling direction), resulting in the following symptoms:

- Reduction of steering stability: steering wheel out of control, fishtailing, spin or jackknife (jackknifing means to bend suddenly at the connecting part of a truck and its trailer and go out of control, see figure 1).
- Reduction of cornering force: the vehicle cannot turn even if the driver turns the steering wheel.
- Expansion of braking distance: in general, braking distance becomes longer.

Figure 1: Jackknifed truck
1.2 Description of ABS

The ABS controls the fluid pressure applied to the caliper or the wheel cylinder of each brake from the master cylinder so that each wheel is not locked even when hard brake is applied. ABS controls the wheels in the narrow slip range where a skid can be prevented.

Under this control, the front wheels guarantee the steering stability, while the rear wheels guarantee the straight line stability. Moreover, the selected slip range is the range where the maximum braking force is created to guarantee the optimum braking distance.

The performance of ABS, therefore, can be evaluated by these three elements;

• Steering stability,
• Straight line stability and
• Braking distance.

In order to evaluate adequately the ABS, the performance should be tested also on a curve and on an asymmetrical road (split friction surface) where friction coefficients on the right and left sides are different. ABS also should respond effectively to turbulences like engine drag torque and unexpected change in road surface. The performance of ABS varies with system configuration.

Previously ABS used to be called in different ways depending on the system suppliers as follows:

• ASB : Anti Skid Brake
• ALB : Anti Lock Brake
• ESC : Electronic Skid Control
• 4WAS : 4-Wheel Anti Skid
• ABS : Anti-lock Braking System

Nevertheless, ABS was uniformly used in North America and Europe. Although Mercedes Benz had obtained the right to use the term “ABS” as its registered trade mark, the use of this trade mark was opened to the public in 1990 and Japanese car manufacturers started using ABS in 1991. For your reference, ABS comes from German term “Antiblokiersystem”
1.3 ABS principles

1.3.1 Vehicle movement during braking

1.3.1.1 Force generated due to braking

When an optimum braking force is applied to a running vehicle, the vehicle may stop smoothly. This is because a friction is generated between tires and road in the opposite direction to the vehicle’s traveling direction. This situation is shown below where only the wheels are drawn. In the figure 2, the friction is shown by the arrow which originates from the wheel center. This friction is called braking force.

The friction coefficient related to this braking force is called braking friction coefficient. The bigger the braking friction coefficient, the bigger the braking force. The vehicle, therefore, can be stopped within a short period of time.

The force (which is equal to the total braking force applied to 4 wheels) applied to the vehicle’s center of gravity in the opposite direction to the braking force is called inertia. When the braking force is applied symmetrically to right and left wheels, the vehicle stops in the vehicle traveling direction. If the braking force is applied asymmetrically to right and left wheels, a moment to turn the vehicle around vehicle’s center of gravity is generated. This moment is called yaw moment. According to the cases, the vehicle turns regardless of steering wheel angle.

![Figure 2: Braking forces on different road conditions](image)

[A] Braking force evenly applied
[B] Braking force unevenly applied
[FWD] Forward
[1] Inertia
[2] Vehicle’s centre of gravity
[3] Braking force
1.3.1.2 Skid friction

On the other hand, a different friction is applied to tires sideways between tires and road. This friction is called skid friction. This is also called cornering force or side force. This force works to maintain the vehicle traveling direction against inconvenient force (disturbance), like crosswind, which is applied perpendicularly to the vehicle traveling direction.

In cornering (cornering means to change the vehicle’s traveling direction), a slip angle * is applied by turning the steering wheel to generate a skid friction so that the vehicle can maintain a turning movement against the centrifugal force. This situation is shown by figure 3.

The coefficient related to this skid friction is called skid friction coefficient. Slip angle stands for angle between tire traveling direction and tire rotation surface. In case of normal curved movement, a measured value of slip angle is smaller than 4 or 5 degrees in most cases and the permissible angle is up to 7 or 8 degrees.

To facilitate the understanding of this phenomenon, hereafter we call skid friction ‘cornering force’ for front wheels and ‘side force’ for rear wheels respectively. The cornering force created for front wheels has an effect to change the vehicle driving direction according to the driver’s steering control. The side force created for rear wheels maintains the vehicle traveling direction against side slip.

Exactly speaking, the side force means a force applied to the tire perpendicularly to tire rotation surface and the cornering force means a force applied to the tire perpendicularly to tire traveling direction. But the difference between side and cornering forces is negligible if the slip angle is small. In other words, the vehicle’s straight line stability increases as the side force becomes bigger and the steering stability increases as the cornering force becomes bigger.

On the other hand, when these forces decreases, the vehicle cannot be controlled in spite of driver’s demand. A fishtailing and a spin on a frozen or a snowy road while braking are examples of reduction of side force or cornering force. Another example is a similar phenomenon caused by strong braking while driving at a high speed or on a wet road. These examples may result in serious traffic accidents.
1.3.1.3 Vehicle’s movement in case of wheel lock

(i) In case of straight travel
The vehicle’s movement described above is shown by figure 4 below. Assume that an excessive braking force is applied and all wheels are locked while the vehicle is traveling straight forward. In this case, as the skid friction becomes almost zero, the side force to maintain vehicle’s direction also becomes almost zero.
This is an unstable condition and causes an unexpected turning if only a small yaw moment is applied to the vehicle whose right and left tires are rotating on different surfaces and right and left braking forces are not equal. This phenomenon can be caused if the rear wheels are locked on an icy road and a strong crosswind blows on the vehicle.
When the brake is released during the unexpected turning, the vehicle may suddenly start moving in the direction of the tires, which may result in a serious danger.

(ii) In case of cornering
Assume that an excessive braking force is applied and wheels are locked while the vehicle is traveling on a curve.

In case of front wheel lock
If the front wheels are locked, as the cornering force becomes almost zero, the force to maintain the vehicle’s movement controlled by driver’s steering demand becomes smaller and the vehicle may slip in an unexpected direction regardless of the driver’s demand. In this case, the direction of the slip is that of tangent line of the curve.

Figure 4: [1] disturbance [2] wheel lock [3] brake released

Figure 5: Front wheels locked during cornering
In case of rear wheel lock
If the rear wheels are locked, as the side force of rear wheels becomes almost zero, the force to maintain the vehicle’s movement controlled by driver’s steering demand becomes smaller. Due to a centrifugal force applied to the vehicle and front wheel cornering force, the vehicle may run out of the curved course, spinning as shown in the figure 6 below (spin out).

In case of four-wheel lock
If all wheels are locked, as both the side and cornering forces become almost zero, both straight line and steering stabilities are lost and the vehicle may show combined movement of the two phenomena shown above figure 5 and 6. In other words, the vehicle may turn in an unexpected direction, slipping in the direction of the tangent line of the curve.

Conclusion
As shown above, although the vehicle may stop safely if an appropriate braking force is applied, an excessive braking force may lock the wheels, resulting in a cause of dangerous movement of the vehicle. We, therefore, must apply adequate braking force so as not to lock the wheels according to the condition of road (icy, snowy, gravel, wet, dry, straight or curve), vehicle speed and steering.
1.3.2 Displacement of load

The vehicle weight is supported by 4 wheels. A vertical force, therefore, is applied to the mating surface between each tire and road as shown in the figure below. This vertical force, that is, the load applied to the tire varies with braking force and inertia applied to the vehicle’s center of gravity.

![Figure 8: Displacement of load](image)

1.3.2.1 Load change due to braking force (figure 8A)

The braking force is expressed by the product of load applied to tire and braking friction coefficient. Although the vehicle decelerates proportionally to the total braking force, an inertia is applied to the vehicle in the opposite direction to the braking force. The absolute value of inertia is the same as that of the total braking force.

As a result, a rotational moment is applied to the vehicle and the driver feels a force which tends to tumble the vehicle forward. The load applied to front tire is increased by \(dW_b\) and load to rear tire is decreased by \(dW_b\).
1.3.2.2 Load change due to centrifugal force (figure 8B)

Inertia is generated by centrifugal force when the vehicle is turning. The value of inertia is the product of vehicle mass and acceleration (or deceleration). The centrifugal force is applied to the vehicle's center of gravity. As shown in the figure 8[b] a rotational moment is generated. Load applied to the outer wheel on a curve is increased by dWc and load applied to the inner wheel is decreased by dWc.

This kind of change in load applied to the tire is called ‘load displacement’ and its absolute value is proportional to acceleration or deceleration. Due to this load displacement, the braking force is maximum at outer front wheel and minimum at inner rear wheel if brake force is applied in cornering.

1.3.2.3 Slip ratio

As described earlier, vehicle speed is decreased due to friction (braking force) created between tires and road. This is because braking force reduces the wheel speed and difference is created between vehicle speed and wheel speed as shown in the figure below. Slip means a phenomenon which is caused by the difference between vehicle speed and wheel speed. The grade of slip is expressed by slip ratio. Slip ratio is defined as follows:

\[ \text{Slip ratio (\%)} = \left( \frac{\text{vehicle speed} - \text{wheel speed}}{\text{vehicle speed}} \right) \times 100 \]

As shown by this formula, the slip ratio is 0% if the vehicle speed is equal to wheel speed. It becomes bigger as the difference between vehicle and wheel speeds becomes bigger. If the wheel is locked before the vehicle stops, the slip ratio becomes 100% because only the wheel speed becomes zero. As described later, until the slip ratio reaches a certain value after starting to apply brake, as the slip ratio increases, the braking friction coefficient increases, generating friction, that is, braking force.
1.4 ABS control technology

1.4.1 General description
ABS judges whether the wheels are turning in the stable range or the wheel rotation is about to enter the unstable range, by detecting whether the slip ratio or wheel deceleration reaches the specified level or not. If the wheel rotation is about to enter the unstable range, ABS holds or reduces the brake fluid pressure. In this situation, the two factors, that is, (friction coefficient) - (slip ratio) characteristic and the moment of inertia affect the ABS control technology to a considerable extent.

In order to realize an ideal control, we have to choose one between slip ratio and wheel deceleration as the main parameter according to the type of road [(friction coefficient) - (slip ratio) characteristic] and gear position (moment of inertia). Then we have to adjust the preset value of the main parameter that corresponds to the wheel stability limit.

Nevertheless, it is almost impossible to predict (friction coefficient) - (slip ratio λ) characteristic of the actual road and the moment of inertia at each gear depends on the vehicle model. Therefore, we use one of the following technologies:

1) Prediction control
In this technology, we adjust in advance the preset value of parameters mentioned above.
2) Learning control
In this technology, ABS control module memorizes the value of each parameter in present control cycle* and determines the control conditions for the next control cycle according to the stored data.

Note* Control cycle : one control cycle is a process starting from ‘brake fluid pressure reduction’ and end by ‘brake fluid pressure increase’
As the goal of ABS is to keep the slip ratio closest to optimum while braking, the simplified control situation is shown in the figure below.

Figure 10: Brake control
1.4.2 Calculation of vehicle speed

When the brakes are applied to a vehicle running at a certain speed,
• brake fluid pressure is increased
• vehicle speed and wheel speed start decreasing at almost the same rate.
But soon after that, slip occurs and the wheel speed starts decreasing suddenly. When the slip ratio exceeds the optimum level, and the wheel rotation enters the unstable range (the situation in which wheels are about to be locked), ABS holds (hold mode) or reduces (reduced mode) the brake fluid pressure.

If the wheel speed recovers from dropping and becomes close to the vehicle speed, ABS increases (increase mode) the brake fluid pressure. By repeating this step, the vehicle will be stopped. The slip ratio, however, is calculated by difference between vehicle speed and wheel speed. Refer to figure 11 and assume that Vf is vehicle speed and that Vr is wheel speed. Vr can be easily detected by wheel speed sensor, while there is no adequate method to measure vehicle speed while braking.

The vehicle speed can be calculated by vehicle speed sensor. But vehicle speed sensor detects the rotational speed of transmission output shaft or transfer output shaft. To facilitate the understanding, imagine that all tires are locked due to hard braking while driving the vehicle at 100km/h. As the tires are locked, output shaft of transmission or transfer is also locked. This means that there is no signal generated by vehicle speed sensor and speedometer will stand 0km/h, even though the vehicle may be still moving. This is why actually there is no appropriate way of measuring vehicle speed during braking.
We, therefore, estimate $V_f$ according to $V_r$. Without braking, $V_f$ is changing together with $V_r$. When brake is applied and the wheel deceleration reaches the preset value, the value $V_r$ at this moment is taken as the initial value of estimated vehicle speed. We call this estimated value ‘reference speed’ and indicate it by $V_{ref}$. After this moment, $V_{ref}$ is decreased with the constant ratio (constant gradient as shown below). The ABS calculates the slip ratio according to $V_r$ and $V_{ref}$.

In reality, wheel acceleration or deceleration and slip ratio are used as main parameters. When each parameter reaches the specified value, the hydraulic control is performed.

1.5 ABS system structure

In general, ABS mainly consists of the three elements, that is, wheel speed sensor, electronic control unit and hydraulic unit.

(i) Wheel speed sensor: the wheel speed sensor detects the presence and absence of teeth of the gear which is rotating together with wheel or driving axis. Thus this sensor generates a signal proportional to wheel speed.

(ii) Electronic control unit: This unit performs the following functions:

- **Operational function**: ECU calculates the wheel speed according to the signal from wheel speed sensor. ECU then calculates slip ratio and wheel acceleration or deceleration.

- **Control function**: ECU logically combines the signals processed by operational part and sends command to hydraulic unit in order to adjust brake fluid pressure.

- **Monitoring function**: ECU checks and monitors each component and the whole system. ECU then warns the driver of malfunction with warning light and suspends the ABS control in order to maintain the conventional brake system function.

1.5.1 System configuration

ABS system configuration can be expressed by number of sensors and control channels as shown in the next table.
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<th>Hydraulic control</th>
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<td></td>
<td>Front</td>
<td>Rear</td>
</tr>
<tr>
<td>4-sensor 4-channel Type 1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4-sensor 4-channel Type 2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4-sensor 4-channel Type 3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4-sensor 3-channel</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3-sensor 3-channel</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4-sensor 2-channel Type 1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4-sensor 2-channel Type 2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2-sensor 2-channel</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1-sensor 1-channel</td>
<td>0</td>
<td>0</td>
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Figure 12: Alto/Celerio AMF 310 4 sensor, 4 channel system

Suzuki Jimny ABS configuration

Figure 13: Jimny 4 sensor, 3 channel system

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<td>7. Wheel speed sensor (Left-rear)</td>
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<td>2. Stop lamp switch</td>
<td>8. “ABS” warning lamp</td>
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<td>3. ABS control module</td>
<td>9. ABS pump motor relay (transistor)</td>
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<td>4. Wheel speed sensor (Right-rear)</td>
<td>10. ABS solenoid valve relay (transistor)</td>
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<td>5. Monitor connector</td>
<td>11. Proportioning valve</td>
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<tr>
<td>6. Lamp driver module</td>
<td>12. Wheel speed sensor (Left-front)</td>
</tr>
</tbody>
</table>

[A]: M13 engine model only
Grand Vitara JB424 ABS configuration

Figure 14: GV 4 sensor, 4 channel system

Swift AZH414 ABS configuration

Figure 15: Swift 4 sensor, 4 channel system
Figure 16: Swift 4 sensor, 4 channel system

1. ABS control module
2. Hydraulic unit
3. ECM
4. BCM
5. Combination meter
6. Brake light switch
7. Wheel speed sensor
8. DLC
9. Electronic signal
10. CAN signal
11. Hydraulic circuit

Figure 17: Swift 4 sensor, 4 channel system

1. ESP® hydraulic unit / control module assembly
2. Hydraulic unit
3. ECM
4. BCM
5. Combination meter
6. Steering angle sensor
7. Brake light switch
8. 4WD control module
9. Brake master cylinder pressure sensor
10. Wheel speed sensor
11. ESP® OFF switch
12. Electronic signal
13. CAN signal
14. Hydraulic circuit
15. 4WS control module
1.6 ABS system components

ABS component locations

1.6.1 Wheel speed sensor

The wheel speed sensor detects the wheel speed and sends it to the ABS control module. It is located close to the rotor which rotates together with the wheel or driving axis. The wheel speed sensor operates according to the inductive or hall principle for rotational speed measurements discussed in course GE02 Electrical/Electronics.
As a method of detecting the slipperiness, a G sensor is used in some ABS systems. The G sensor detects the deceleration of the vehicle and the system detects a slippery surface if the deceleration exceeds a predetermined value. In such a case, the system switches the control logic from the high friction road mode to the low friction road mode to increase the precision of control. Thus, wheel lock can be prevented.

### 1.6.2.1 Types of G sensor

Suzuki has employed the following types of G sensors:

1) Variable capacitance type
2) Distortion gauge type
3) 2-switch type
4) 1 switch type

#### 1) Variable capacitance type

This is a silicon capacitive type consisting of a sensing element, detector and an amplifier circuit. The sensing element contains cantilever type movable electrode and a pair of fixed electrodes. The capacitance between the movable and fixed electrodes varies according to the air gap between them.

As the vehicle speed changes, capacitance value varies and thus this difference shows the acceleration or deceleration level. The signal coming from this difference is amplified by amplifier circuit to attain final output electrical signal. This type of G sensor is used in the SN series Jimny.
This resistance is converted into voltage in the bridge circuit and in this way, deceleration speed of the vehicle body is detected.

2) Distortion gauge type

This is a distortion gauge type semi-conductor sensor consisting of a detector and an amplifier circuit. When an acceleration or deceleration is applied to the weight (5) figure 22, the silicon base (6) is distorted. Due to this distortion, the resistance of the distortion gauge varies according to that distortion level.
3) 2-switch type

This type contains two steel balls. Steel ball moves according to the vehicle speed change. As shown below, each ball turn on its switch in different pattern according to the acceleration or deceleration. The EBCM detects the acceleration or deceleration level, using the combination of G sensor output voltages V1 and V2.

<table>
<thead>
<tr>
<th>a (deg)</th>
<th>V1 (V)</th>
<th>V2 (V)</th>
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<tbody>
<tr>
<td>0</td>
<td>1.79~2.38</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3.66~4.22</td>
<td></td>
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4) 1-Switch type

This consists of an accelerator switch and resistor. When vehicle speed changes by the value exceeding a certain specified value, the accelerator switch in the G sensor turns ON. Then, the output voltage from the G sensor varies and thus EBCM can detect that a speed change exceeding a certain specified value has occurred.

Figure 23: Distortion gauge type G sensor

Figure 24: Distortion gauge type G sensor

1.6.3 Brake light switch

The brake light switch is installed on the brake pedal and detects the status of the brake pedal (released or depressed). When the brake pedal is depressed, the brake light switch circuit closes and sends a signal to the ABS or ECM control module. The ABS control module uses this signal for ABS hydraulic operation check.

1.6.4 Hydraulic Unit

The hydraulic unit controls the brake pressure to each wheel by using solenoid valves and a hydraulic pump. It is composed of inlet solenoid valves, outlet solenoid valves, pumps, pump motor, reservoirs and check valves. It activates the inlet and outlet solenoid valves by the signals from ABS control module and controls the brake fluid pressure applied on each wheel brake.

Hydraulic unit operation

The hydraulic pressure control is performed in 3 modes of pressure increase, pressure hold and pressure reduction.

(i) When ABS is not operating (increase pressure mode)

When brake pedal is depressed, the brake fluid from master cylinder passes inlet solenoid valve and sent directly to wheel cylinder. When the force to the brake pedal is reduced, the brake fluid passes inlet solenoid valve and check valve, then returns to the master cylinder.

Figure 26: Brake pressure increase mode

(ii) When ABS is operating (hold pressure mode)

When electrical signal is sent to the inlet solenoid valve from the ABS control module, the valve is actuated and shuts the fluid passage between master cylinder and wheel cylinder. Then the pressure in the wheel cylinder is held constant.

(iii) When ABS is operating (Brake pressure reduction mode)

When an electrical signal is sent to the outlet and inlet solenoid valves from EBCM, the valves are actuated. The brake fluid in the wheel cylinder is sent to the low pressure accumulator and the pressure in the wheel cylinder goes down, so does the braking force. The pump, pumps out the brake fluid in the low pressure accumulator and sends high pressure brake fluid to the master cylinder side.
1.6.5 ABS pump and motor

Pump plungers are driven by the cam of pump motor shaft. The pump sends fluid stored in the reservoir to master cylinder. **CAUTION:** When battery voltage is applied to motor connector, motor operating sound can be heard. Although Suzuki service manuals do not mention any prohibition concerning duration of this test, applying power to the motor for more than 1 minute is not recommended as the motor may be overheated.

![ABS pump and motor diagram](image)

1.6.6 ABS control module

The ABS control module mainly consists of the following circuits:
1) Amplification circuit of input sent from wheel speed sensor
2) Operation circuit
3) Solenoid valve control circuit
4) Power stabilizer
5) Power monitoring circuit
6) Fail memory circuit
7) Relay & lamp driving circuit

![ABS control module circuit diagram](image)
1.6.6.1 Amplification circuit of input for wheel speed sensor

Wheel speed sensor sends alternating voltage (inductive type) signal to the ABS ECU, its frequency is proportional to wheel speed. The amplification circuit in ECU rectifies and amplifies the alternating waveform to rectangular wave. The ECU then sends it to the operational circuit.

The number of amplification circuit corresponds to the number of wheel speed sensors. When the system employs 4 sensors, ECU contains 4 amplification circuits.

When the system employs 3 sensors one of which is fitted to the rear differential gear, ECU contains 3 amplification circuits. But the operational circuit recognizes the rear differential gear speed signal as two signals, that is, rear right and left wheel speed signals.

1.6.6.2 Operational circuit

Operational circuit performs the following roles:

• Calculation of wheel speed according to wheel speed sensor analogical signal
• Calculation of reference speed
• Calculation of slip ratio
• Calculation of deceleration and acceleration
• Driving and monitoring process of solenoid valve

A momentary wheel speed is calculated according to the signal generated by wheel speed sensor which detects the rotation of sensor rotor (32, 48 or 98 teeth, etc.) attached to the wheel. Reference speed is calculated by integrating momentary wheel speed. Reducing pressure, holding pressure or increasing pressure signal is sent to solenoid control circuit, according to slip ratio and deceleration.

1.6.6.3 Solenoid valve control circuit

This circuit controls current applied to solenoid valve according to reducing, holding or increasing signal sent from operational circuit.

1.6.6.4 Power stabilizer

Power stabilizer regulates the battery voltage to a constant voltage of 5 V for the use inside the ECU.
1.6.6.5 Power monitoring circuit
This circuit monitors whether the power voltage of 12V and 5V are within the specified range at all times.

1.6.6.6 Fail memory circuit
This circuit monitors the fail signal sent from amplification circuit, operational circuit and solenoid valve driving circuit.

1.6.6.7 Relay & lamp driving circuit
This circuit drives valve relay and motor relay. In case of system failure, this circuit cuts off current from valve relay in order to suspend ABS control. In this case, brake system works as a conventional one without ABS control. At the same time, this circuit turns on the ABS warning light located on the combination meter in order to warn the driver of the system failure.

1.6.6.8 Safety circuit
ECU performs the self inspection:
- When the power is supplied (when the ignition key is turned to the position ON)
- When the vehicle speed reaches the specified value

ECU also monitors the system while vehicle is traveling. This section describes the ECU's safety function which is realized by microprocessor. In case of system failure, ABS function is suspended. The brake system keeps its function as a conventional system without ABS control. At the same time, ABS warning light on the combination meter is lit.

1.6.6.9 Initial check at power on
When the ignition switch is turned to the position ON and the power is supplied to the ECU, the following inspection is performed:
- Function check of micro processor
- Operation check of valve relay
- Function check of fail memory

1.6.6.10 Check at vehicle's take off
When the vehicle takes off, the surrounding important circuits as follows are checked. After completing this check, system is released.
- Function check of solenoid valve
- Operation check of pump motor
- Confirmation of signals sent from wheel speed sensor and amplification circuit.

The failure condition can be shown by flashing pattern of ABS warning light or by use of SDT. The display function of system failure is suspended when the ignition key is turned to the position OFF. If there is no failure when the ignition key is turned to the position ON again, the system performs the ABS control normally. The ECU memorizes the contents of failure and can show diagnostic trouble codes. The scan tool also has the function of clearing diagnostic trouble codes.
1.6.6.11 Continuous check during travelling

While the vehicle is traveling, continuous check shown below is performed by the microprocessor and surrounding circuits themselves. If some troubles are detected, the microprocessor performs the final confirmation. The diagnosis trouble code is memorized in the non-volatile memory inside the ECU.

- Monitoring the voltage of 12V and 5V
- Monitoring the operation of valve relay
- Check of operation result in operation circuit
- Micro processor runaway. Check
- Monitoring the clock signal
- Confirmation of ROM (Read Only Memory) data

1.6.6.12 Diagnosis display

If an abnormality is detected by the safety circuit, the brake system works as a conventional brake system without ABS control. The ABS control module switches to the fail mode. In the fail mode, it displays the diagnostic trouble code by ABS warning light or Scan Tool.
1.6.6.13 ABS control module input/output diagrams
Suzuki Alto/Celerio AMF310
Summary

- ABS is an abbreviation for Anti-lock Braking System
- The coefficient of friction between the vehicle’s tyres and the road surface determines how well the vehicle will adhere to the road surface.
- Road surfaces like wet asphalt or roads covered with ice have poor coefficient of friction and road surfaces like dry asphalt and concrete have good coefficient of friction.
- The ABS controls the amount of braking pressure applied to each wheel in order to ensure that the wheels do not lock-up. 
- In case of front wheel lock-up, the ability to steer the vehicle becomes zero.
- In case of rear wheel lock-up, the force to maintain the vehicle’s movement by driver’s steering demand becomes almost zero.
- “Slip” is a phenomenon which is caused by the difference between vehicle speed and wheel speed. The slip ratio is 0% when the vehicle speed is equal to wheel speeds and becomes higher when the difference between the vehicle speed and the wheel speed increases.
- The ABS control module uses signals from the wheel speed sensors to determine if wheels are turning in the stable range or about to enter unstable range.
- The ABS control module controls brake pressure to each wheel via solenoids in the hydraulic unit.
- In AWD and 4X4 vehicles, a G sensor is used to detect slipperiness.
- In modern ABS systems, the ABS control module and hydraulic unit are one unit.
- The ABS control module also contains on board diagnosis and monitoring of the system and its components.
- The ABS control module controls the pressure to each wheel in three modes.
- During normal braking, the pressure to the wheels is increased.
- If the wheel speed enters the unstable range (speed becomes too low) the control module closes the intake solenoid so the pressure to that wheel will no longer be increased. This is the pressure hold phase.
- Just before the wheel speed becomes zero, the control module opens the outlet valve solenoid, which reduces the brake pressure in that wheel.
- Malfunctions of the ABS are indicated to the driver via the ABS warning light in the combination meter.
- ABS DTC’s can be read out using the SDT. In some vehicles, the flash pattern of the warning lamp can be used to read out the fault codes.
Lesson 2

Electronic Brake-force Distribution

Learning outcomes

After studying this training manual, you will be able to:

• Describe the purpose of EBD.
• Describe the function of the proportioning valve
• Describe the function of the LSPV.
• Explain how EBD functions/operates.
• List the possible causes of EBD warning light illumination.
2.1 Introduction

While brake is applied not so hard as to activate ABS control, brake force is proportionally distributed between the front and rear brakes to prevent rear wheels from being locked too early for better stability of the vehicle. So, the objective of EBD is to control rear brake forces to prevent rear wheels from being locked and to obtain minimum braking distance according to the weight loaded on the vehicle.

2.1.1 Proportioning valve

Some Suzuki earlier models equipped with ABS had the proportioning valve (P valve) installed. The P valve reduces rear brake force according to hydraulic pressure produced in the master cylinder.

As hydraulic pressure applied to the rear wheel cylinder does not depend on the weight loaded on the vehicle, rear brake force becomes less effective when the vehicle is heavily loaded. The hydraulic control in the past models, therefore, is far from ideal.
2.1.2 LSPV

LSPV enables brake system to obtain an adequate rear brake force according to the weight loaded on the vehicle. As shown on the graph, the split point varies with the load sensed by LSPV spring located on the rear axle. But as LSPV controls hydraulic pressure mechanically, the gradient of the characteristic curve is constant, which makes it impossible for actual curve to match the ideal curve.

![LSPV Characteristics Curve](image)

Figure 3: LSPV characteristics curve

2.1.3 EBD

EBD distributes brake force to front and rear wheels according to driving conditions. EBD enables rear force to be effectively utilized according to load state and load change due to deceleration. Rear brake force is increased especially while weight is loaded so that brake effect can be maintained.

![EBD Characteristics Curve](image)

Figure 4: EBD characteristics curve

- [Ff] Front brake force
- [Fr] Rear brake force
- [a] With light load
- [b] With heavy load
- [a1] Ideal curve with light load
- [a2] Actual curve with light load
- [b1] Ideal curve with heavy load
- [b2] Actual curve with heavy load
- [dFr] Front brake load increase with load
- [1] EBD active area
2.2 EBD operation

ABS and EBD system share common hardware. Front and rear wheel speeds are detected by front and rear wheel speed sensors respectively. EBCM calculates difference between front and rear wheel speeds. Then reduction needed in rear hydraulic pressure is estimated. Finally optimum pressure is distributed to rear wheel cylinders.

2.2.1 Solenoid valve operation

When the vehicle speed drops by more than a specified level, if rear wheel speed becomes smaller than front wheel speed, the hydraulic unit closes rear inlet valve to hold rear hydraulic pressure. If rear wheel speed decreases further, the hydraulic unit opens rear outlet valve for a short time to reduce rear hydraulic pressure. EBCM sends high frequency duty signal to solenoid to control valve position precisely.
2.2.2 EBD and ABS

The biggest difference between EBD and ABS is the threshold values. When the difference between vehicle speed and wheel speed is larger than EBD control threshold, EBD control is implemented. In this control, rear outlet valve is opened only for a short moment, as described on the previous page, and rear wheel speed increases a little bit.

As the weight loaded on the vehicle becomes heavier, the rear wheel deceleration becomes smaller. This means that a bigger brake force is needed to exceed EBD control threshold. In other words, a bigger brake force can be applied to rear wheel when a heavier weight is loaded. If the difference between vehicle speed and wheel speed becomes larger than ABS control threshold, ABS control is implemented. In this control, rear outlet valve is opened for a longer period than EBD control and wheel speed increases fast.

2.2.3 Front and rear brake forces in EBD and ABS

[Period 1 : EBD control]
Rear brake force is electronically regulated to prevent wheel lock. The EBD control is performed to obtain a rear brake force close to the ideal curve.

[Period 2 : ABS control]
Rear brake force is suddenly reduced due to a hard braking.

![Figure 7: ABS and EBD control](image)
2.2.4 EBD warning light

EBD warning light works also as EBD warning light.
EBD warning light comes on in the following cases:
• Two or more wheel speed sensors are faulty
• Faulty rear inlet or outlet solenoid valves
• Faulty ABS control module
• Low battery (lower than 7.5 volts)

EBD warning light does not come on in the following cases:
• Only one wheel speed sensor is faulty
• Faulty front inlet or outlet solenoid valve
• ABS pump motor faulty

Note that front inlet and outlet solenoid valves are not involved in EBD system because EBD system controls rear brake force only. Also note that ABS pump motor is not involved in EBD control.

Summary

• EBD is a function of ABS that controls the rear brake force to prevent rear wheel lock up and obtain minimum braking distance according to the weight and load on the vehicle.
• The EBD system is used instead of the proportioning valve and the LSP valve.
• The EBD system uses the same hardware components used for ABS.
• The EBD system only control the solenoids for the rear wheels.
• The EBD system is implemented if the EBD control threshold is exceeded and the ABS system is implemented when the ABS control threshold is exceeded.
• The 'brake warning light' also functions as the EBD warming light and illuminates in cases of faults in the EBD system.
Learning outcomes

The contents of this chapter will enable learners to:
• Describe the purpose of using the Customer Complaint Analysis form
• Explain the steps involved in ABS malfunction analysis.
• Describe the possible causes of different ABS malfunction conditions.
• Describe the procedure for ABS hydraulic unit operation check.

Lesson 3

ABS and EBD diagnosis
2.1 ABS check

Step 1: Malfunction analysis

Customer complaint analysis
The first step in the diagnosis of ABS complaints is to record details of the problem (failure, complaint) and how it occurred as described by the customer.

For this purpose, use of such a questionnaire form as shown below will facilitate collecting information to the point required for proper analysis and diagnosis.

<table>
<thead>
<tr>
<th>Customer’s name:</th>
<th>Model:</th>
<th>VIN:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of issue:</td>
<td>Date of Reg:</td>
<td>Date of problem:</td>
</tr>
</tbody>
</table>

Problem Symptoms
- ABS warning light abnormal: fails to turn on/fails to go off/flashes
- Abnormal noise while vehicle is running: from motor, from valve, other
- Wheel is locked at braking:
- Pump motor does not stop (running):
- Brake does not work:
- Other:

Frequency of occurrence
- Continuous/Intermittent (times a day, a month)/other

Conditions for Occurrence of Problem
- Vehicle at stop & ignition switch ON:
- When starting: at initial start only/at every start/Other
- Vehicle speed: while accelerating/while decelerating/at stop/
  while turning/while running at constant speed/other
- Road surface condition: Paved road/rough road/snow-covered road/other
- Chain equipment:

Environmental Condition
- Weather: clear/cloudy/rain/snow/other
- Temperature: °F (°C)

Diagnostic Trouble Code
- First check: Normal code/malfunction code
- Second check after test drive: Normal code/malfunction code

Problem symptom confirmation
Check if what the customer claimed in “Customer Questionnaire” is actually found in the vehicle and if that symptom is found, whether it is identified as a failure. (This step should be shared with the customer if possible.) Check warning lights related to brake system referring to “EBD Warning Light (Brake Warning Light) Check” and “ABS Warning Light Check” under Warning Light Check.

DTC check, record and clearance
Perform a DTC check using the SDT. Record and clear DTC’s. When DTC which is recorded at DTC check procedure is detected again after performing DTC clearance, perform ABS Check.

When DTC which is recorded at DTC check procedure is not indicated anymore after performing DTC clearance, ABS control module does not perform the system diagnosis, or temporary abnormality may occur, perform a driving test.

Step 2: Visual inspection
As a preliminary step, be sure to perform visual check of the items that support proper function of the ABS. Check the following parts visually:
- Battery (Electrolyte level, leakage)
- Connectors of electric wire harness
- Fuses
- Brake fluid level
- ABS warning light
- EBD warning light (Brake warning light)
Step 3: Driving test

If the malfunction DTC is confirmed again at ignition switch ON, driving test as described is not necessary. Test drive the vehicle at 40 km/h for more than a minute and check if any trouble symptom (such as abnormal lighting of ABS warning light) exists.

Step 4: Recheck DTC after test drive

Step 5: ABS system diagnosis

Proceed with ABS diagnosis according to ABS Check for the DTC confirmation, locate the cause of the trouble, namely in a sensor, switch, wire harness, connector, actuator assembly or other part and repair or replace faulty parts.

Check the parts or system suspected as a possible cause referring to Brakes Symptom Diagnosis and based on symptoms appearing on the vehicle (symptom obtained through Steps 1 to 3 and repair or replace faulty parts, if any).

Step 6: Check for Intermittent Problem

Check parts where an intermittent trouble is easy to occur (e.g., wire harness, connector, etc.), referring to Intermittent and Poor Connection Inspection and related circuit of trouble code recorded.

Step 7: Final Confirmation Test

Confirm that the problem symptom has gone and the ABS is free from any abnormal conditions. If what has been repaired is related to the malfunction DTC, clear the DTC once referring to DTC Clearance and perform test driving and confirm that no DTC is indicated.
## 2.2 ABS symptom diagnosis

<table>
<thead>
<tr>
<th>Condition</th>
<th>Possible Cause</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS warning light turns ON after ignition switch has turned ON for 2 sec.</td>
<td>Malfunctioning ABS function</td>
<td>Perform ABS check.</td>
</tr>
<tr>
<td></td>
<td>ABS control module power supply and ground circuit faulty</td>
<td>Check ABS control module power supply and ground circuit.</td>
</tr>
<tr>
<td></td>
<td>Malfunctioning CAN communication system function</td>
<td>Check CAN communication system</td>
</tr>
<tr>
<td></td>
<td>Combination meter faulty</td>
<td>Replace combination meter.</td>
</tr>
<tr>
<td></td>
<td>ABS hydraulic unit / control module assembly faulty</td>
<td>Replace ABS hydraulic unit / control module assembly.</td>
</tr>
<tr>
<td>ABS warning light does not turns ON for 2 sec. after ignition switch has turned ON</td>
<td>Combination meter power supply and ground circuit faulty</td>
<td>Check combination meter and its circuit.</td>
</tr>
<tr>
<td></td>
<td>Combination meter faulty</td>
<td>Replace combination meter.</td>
</tr>
<tr>
<td></td>
<td>ABS hydraulic unit / control module assembly faulty</td>
<td>Replace ABS hydraulic unit / control module assembly.</td>
</tr>
<tr>
<td>ABS warning light flashes</td>
<td>New ABS hydraulic unit / control module assembly installed</td>
<td>Perform ABS Hydraulic Unit Operation Check.</td>
</tr>
<tr>
<td></td>
<td>Combination meter faulty</td>
<td>Replace combination meter.</td>
</tr>
<tr>
<td></td>
<td>ABS hydraulic unit / control module assembly faulty</td>
<td>Replace ABS hydraulic unit / control module assembly.</td>
</tr>
<tr>
<td>EBD warning light (Brake warning light) lights after ignition switch has turned ON for 2 sec.</td>
<td>Parking brake applied</td>
<td>Release parking brake and check that EBD warning light (brake warning light) turns OFF.</td>
</tr>
<tr>
<td></td>
<td>Insufficient amount of brake fluid</td>
<td>Check brake fluid level.</td>
</tr>
<tr>
<td></td>
<td>Parking brake switch circuit and/or brake fluid level switch circuit faulty</td>
<td>Check BCM and its circuit.</td>
</tr>
</tbody>
</table>
| | Parking brake switch and/or brake fluid level switch faulty | Check parking brake switch and/or brake fluid level switch. Parking brake switch:
2.3 ABS warning light check

To check the ABS warning light, turn the ignition switch to ON position. Check that ABS warning light comes ON for about 2 seconds and then goes OFF. If ABS warning light never light up, go to ABS Warning Light Does Not Come ON at Ignition Switch ON. If ABS warning light remains ON and no DTC is stored in ABS control module, go to ABS Warning Light Comes ON Steady.
2.4 EBD warning light check

It is important to ensure the following are in order before proceeding with EBD diagnosis.
- Check brake fluid level.
- Check parking brake position.

To proceed with EBD warning light check, turn the ignition switch to ON position. Check that EBD warning light (brake warning light) comes ON for about 2 seconds and then goes OFF. If EBD warning light (brake warning light) never light up, go to EBD Warning Light (Brake Warning Light) Does Not Come ON at Ignition Switch ON. If EBD warning light (brake warning light) remains ON and no DTC is stored in ABS control module, go to EBD Warning Light (Brake Warning Light) Comes ON Steady.

2.5 ABS hydraulic unit operation check

To check the operation of the hydraulic unit, the following steps can be followed. Before proceeding with the operational check, ensure to check the following:
- No air is trapped in the brake system
- Battery voltage is 11 V or more
- Brakes do not drag
- ABS control module has detected no DTC’s

Step 1: Turn ignition switch to OFF position
Step 2: Connect SDT
Step 3: Hoist vehicle until wheels can be rotated.
Step 4: Hoist vehicle until tire can be rotated.
Step 5: Set transmission to neutral and release parking brake.
Step 6: Turn each wheel gradually by hand to check if brake dragging occurs. If it does, correct.
Step 7: Turn ignition switch to ON position and select menu to “Depressurization check” of “Hydraulic control test” under “Utility” mode of Suzuki SDT.
Step 8: Perform the following checks with help of another person.
Brake pedal (1) should be depressed and then select testing wheel by Suzuki SDT and the wheel (2) should be turned by another person’s hand. At this time, check that:
- Operation sound of solenoid is heard and the wheel turns only about 0.5 sec. (Brake force is depressurized).
- Operation sound of pump motor is heard and pulsation is felt at brake pedal.
Step 9: Perform step 8 for all 4 wheels, if any faulty condition is found, replace ABS hydraulic unit/control module assembly.

Figure 1: [1] Brake pedal   [2] Wheel
## 2.6 ABS DTC table

**4 channel system with 2-position solenoid valve**

<table>
<thead>
<tr>
<th>DTC (displayed on SUZUKI scan tool)</th>
<th>Diagnostic items</th>
<th>Detecting condition (DTC will be set when detecting)</th>
<th>ABS warning light</th>
<th>EBD warning light</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1021</td>
<td>Right-front wheel speed sensor circuit voltage</td>
<td>Wheel speed sensor circuit is opened, shorted to power, ground and/or each other circuit.</td>
<td>0</td>
<td>*1</td>
</tr>
</tbody>
</table>
| C1022                               | Right-front wheel speed sensor signal performance | • Wheel speed is different from other wheel speed (vehicle speed) for more than specified time.  
• Abnormal wheel speed sensor signal is detected for more than specified time. | 0                 | *1                |
| C1025                               | Left-front wheel speed sensor circuit voltage | Wheel speed sensor circuit is opened, shorted to power, ground and/or each other circuit. | 0                 | *1                |
| C1026                               | Left-front wheel speed sensor signal performance | • Wheel speed is different from other wheel speed (vehicle speed) for more than specified time.  
• Abnormal wheel speed sensor signal is detected for more than specified time. | 0                 | *1                |
| C1031                               | Right-rear wheel speed sensor circuit voltage | Wheel speed sensor circuit is opened, shorted to power, ground and/or each other circuit. | 0                 | *1                |
| C1032                               | Right-rear wheel speed sensor signal performance | • Wheel speed is different from other wheel speed (vehicle speed) for more than specified time.  
• Abnormal wheel speed sensor signal is detected for more than specified time. | 0                 | *1                |
| C1035                               | Left-rear wheel speed sensor circuit voltage | Wheel speed sensor circuit is opened, shorted to power, ground and/or each other circuit. | 0                 | *1                |
| C1036                               | Left-rear wheel speed sensor signal performance | • Wheel speed is different from other wheel speed (vehicle speed) for more than specified time.  
• Abnormal wheel speed sensor signal is detected for more than specified time. | 0                 | *1                |
<p>| C1041                               | Right-front inlet solenoid valve circuit correlation | | 0                 | 0                 |
| C1042                               | Right-front outlet solenoid valve circuit correlation | | 0                 | 0                 |
| C1045                               | Left-front inlet solenoid valve circuit correlation | | 0                 | 0                 |
| C1046                               | Left-front outlet solenoid valve circuit correlation | • Solenoid valve circuit is opened, shorted to power, ground and/or each valve in ABS hydraulic unit / control module assembly. | 0                 | 0                 |
| C1051                               | Right-rear inlet solenoid valve circuit correlation | • Mismatching solenoid output and solenoid monitor is detected. | 0                 | 0                 |</p>
<table>
<thead>
<tr>
<th>DTC (displayed on SUZUKI scan tool)</th>
<th>Diagnostic items</th>
<th>Detecting condition (DTC will be set when detecting)</th>
<th>ABS warning light</th>
<th>EBD warning light</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1052</td>
<td>Right-rear outlet solenoid valve circuit correlation</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1055</td>
<td>Left-rear inlet solenoid valve circuit correlation</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1056</td>
<td>Left-rear outlet solenoid valve circuit correlation</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1057</td>
<td>Power supply voltage</td>
<td>ABS control module power supply voltage is too low.</td>
<td>0</td>
<td>*3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABS control module power supply voltage is too high.</td>
<td>0</td>
<td>*4</td>
</tr>
<tr>
<td>C1061</td>
<td>Pump motor circuit performance</td>
<td>• Pump motor is defective and/or motor power supply voltage is too low.</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pump motor circuit in ABS control module is opened, shorted to power or ground circuit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1063</td>
<td>Solenoid valve power supply driver circuit performance</td>
<td>• Solenoid valve power supply driver circuit is opened, shorted to power supply and ground circuit in ABS control module.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solenoid valve power supply voltage is too low.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solenoid valve power supply driver is stuck to ON or OFF position.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Output circuit from control unit is opened or shorted in ABS control module.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mismatching solenoid output and solenoid monitor is detected.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1071</td>
<td>ABS control module internal failure</td>
<td>ABS control module internal defect is detected.</td>
<td>0</td>
<td>*2</td>
</tr>
<tr>
<td>U0073</td>
<td>Control module communication bus off</td>
<td>• Communication is not available with all control modules connected by CAN.</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>U01000</td>
<td>Lost communication with ECM</td>
<td>ECM message data is missing from CAN communication.</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note:**

*1: If two or more wheel speed sensors are defective, EBD warning light (brake warning light) is lit.
*2: It is irregular whether warning lights can be lit by ABS control module.

*3: If ABS control module power supply voltage is lower about 8 V, EBD warning light (brake warning light) is lit.
*4: If ABS control module power supply voltage is higher than 18 V, EBD warning light (brake warning light) is lit.
2.7 Jimny ABS DTC’s

2.7.1 DTC check without using SDT

In this model, the ABS DTC’s can be checked without using the SDT by following these steps:

Step 1: Perform “ABS” Warning Lamp Check.
Step 2: Turn ignition switch to OFF position and connect diagnosis switch terminal (2) and ground terminal (3) of monitor connector (1) with service wire (4).

Step 3: Turn ignition switch to ON position.
Step 4: Read flashing pattern of “ABS” warning lamp which represents DTC as shown in the following example and write it down. When more than 2 DTCs are stored in memory, flashing for each DTC is repeated three times starting with the smallest DTC number in increasing order.

For details of DTC, refer to DTC Table. Example: When right-front wheel speed sensor circuit opens (DTC 21)

Figure 2: ABS DTC check without SDT

Figure 3: DTC 21 flash pattern
### 2.7.2 Jimny SN series ABS DTC’s

<table>
<thead>
<tr>
<th>DTC indicated by “ABS warning lamp”</th>
<th>DTC indicated by SDT</th>
<th>Diagnostic items</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>-</td>
<td>Normal</td>
</tr>
<tr>
<td>15</td>
<td>C1015</td>
<td>G sensor circuit, 4 wheel drive model only</td>
</tr>
<tr>
<td>16</td>
<td>C1016</td>
<td>Stop lamp switch circuit</td>
</tr>
<tr>
<td>21</td>
<td>C1021</td>
<td>RF wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>25</td>
<td>C1025</td>
<td>LF wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>31</td>
<td>C1031</td>
<td>RR wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>35</td>
<td>C1035</td>
<td>LR wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>22</td>
<td>C1022</td>
<td>RF wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>26</td>
<td>C1026</td>
<td>LF wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>32</td>
<td>C1032</td>
<td>RR wheel speed sensor circuit and/or sensor ring</td>
</tr>
<tr>
<td>36</td>
<td>C1036</td>
<td>LR wheel speed sensor circuit and/or sensor ring</td>
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</table>

### Jimny SN series ABS DTC’s continued

<table>
<thead>
<tr>
<th>DTC indicated by “ABS warning lamp”</th>
<th>DTC indicated by SDT</th>
<th>Diagnostic items</th>
</tr>
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<tbody>
<tr>
<td>41</td>
<td>C1041</td>
<td>RF hold solenoid valve circuit</td>
</tr>
<tr>
<td>42</td>
<td>C1042</td>
<td>RF release solenoid valve circuit</td>
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<tr>
<td>45</td>
<td>C1045</td>
<td>LF hold solenoid valve circuit</td>
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<tr>
<td>46</td>
<td>C1046</td>
<td>LF release solenoid valve circuit</td>
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<tr>
<td>55</td>
<td>C1055</td>
<td>Rear hold solenoid valve circuit</td>
</tr>
<tr>
<td>56</td>
<td>C1056</td>
<td>Rear release solenoid valve circuit</td>
</tr>
<tr>
<td>57</td>
<td>C1057</td>
<td>Power source</td>
</tr>
<tr>
<td>61</td>
<td>C1061</td>
<td>ABS pump motor circuit</td>
</tr>
<tr>
<td>63</td>
<td>C1063</td>
<td>ABS solenoid valve circuit</td>
</tr>
<tr>
<td>71</td>
<td>C1071</td>
<td>ABS control module</td>
</tr>
</tbody>
</table>
The following abbreviations may possibly be used in this training manual

A
A/B Air Bag
ABDC After Bottom Dead Center
ABS Anti-lock Brake System
AC Alternating Current
A/C Air Conditioning
A-ELR Automatic-Emergency Locking Retractor
A/F Air Fuel Ratio
ALR Automatic Locking Retractor
API American Petroleum Institute
APP Accelerator Pedal Position
A/T Automatic Transmission, Automatic Transaxle
ATDC After Top Dead Center
ATF Automatic Transmission Fluid, Automatic Transaxle Fluid
AWD All Wheel Drive

B
BARO Barometric Pressure
BBDC Before Bottom Dead Center
BCM Body electrical Control Module
BTDC Before Top Dead Center
B+ Battery Positive Voltage
BB+ Battery Positive Voltage for Backup

C
CAN Controller Area Network
CKP Crankshaft Position
CMP Camshaft Position
CO Carbon Monoxide
CO2 Carbon Dioxide
CPP Clutch Pedal Position
CPU Central Processing Unit
CVT Continuously Variable Transmission, Continuously Variable Transaxle

D
DC Direct Current
D/C Driving Cycle
DLC Data Link Connector
DOHC Double Over Head Camshaft
DOJ Double Offset Joint
DOT Department of Transportation
DPF® Diesel Particulate Filter
DRL Daytime Running Light
DTC Diagnostic Trouble Code (Diagnostic Code)
D/C Driving Cycle
<table>
<thead>
<tr>
<th>E</th>
<th>EBD</th>
<th>Electronic Brake Force Distribution</th>
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<tbody>
<tr>
<td>EBCM</td>
<td>Electronic Brake Control Module</td>
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</tr>
<tr>
<td>ECM</td>
<td>Engine Control Module</td>
<td></td>
</tr>
<tr>
<td>ECT</td>
<td>Engine Coolant Temperature</td>
<td></td>
</tr>
<tr>
<td>ECU</td>
<td>Electronic Control Unit</td>
<td></td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically Erasable Programmable Read Only Memory</td>
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<tr>
<td>EFE Heater</td>
<td>Early Fuel Evaporation Heater</td>
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</tr>
<tr>
<td>EGR</td>
<td>Exhaust Gas Recirculation</td>
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</tr>
<tr>
<td>EGT</td>
<td>Exhaust Gas Temperature</td>
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<tr>
<td>ELR</td>
<td>Emergency Locking Retractor</td>
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<tr>
<td>ENG A-Stop</td>
<td>Engine Auto Stop Start</td>
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<tr>
<td>EPS</td>
<td>Electronic Power Steering</td>
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<tr>
<td>ESP®</td>
<td>Electronic Stability Program</td>
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</tr>
<tr>
<td>EVAP</td>
<td>Evaporative Emission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>Idle Air Control</td>
</tr>
<tr>
<td>IAC</td>
<td>IAT</td>
<td>Intake Air Temperature</td>
</tr>
<tr>
<td>IAT</td>
<td>IMT</td>
<td>Intake Manifold Tuning</td>
</tr>
<tr>
<td>ISC</td>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
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<td>ISO</td>
<td>J</td>
<td>Japanese Industrial Standards</td>
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<td>JIS</td>
<td>J/B</td>
<td>Junction Block</td>
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<td>J/C</td>
<td>L</td>
<td>Left</td>
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<tr>
<td>L</td>
<td>LCD</td>
<td>Liquid Crystal Display LED Light Emitting Diode</td>
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<td>LHD</td>
<td>LIN</td>
<td>Local Interconnect Network</td>
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<td>LSPV</td>
<td>LO</td>
<td>Low</td>
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<td>LSPV</td>
<td>Load Sensing Proportioning Valve</td>
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<td>M</td>
<td>MAF</td>
<td>Mass Air Flow</td>
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<td>MAF</td>
<td>MAP</td>
<td>Manifold Absolute Pressure</td>
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<tr>
<td>MAP</td>
<td>Max</td>
<td>Maximum</td>
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<tr>
<td>Max</td>
<td>MFI</td>
<td>Multiport Fuel Injection</td>
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<tr>
<td>MFI</td>
<td>Min</td>
<td>Minimum</td>
</tr>
<tr>
<td>Min</td>
<td>MIL</td>
<td>Malfunction Indicator Lamp (“CHECK ENGINE” Light or “SERVICE ENGINE SOON” Light)</td>
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<tr>
<td>MIL</td>
<td>M/T</td>
<td>Manual Transmission, Manual Transaxle</td>
</tr>
<tr>
<td>M/T</td>
<td>G</td>
<td>Ground</td>
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<tr>
<td>GND</td>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GPS</td>
<td>H</td>
<td>Heating, Ventilating and Air Conditioning</td>
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<tr>
<td>HVAC</td>
<td>HC</td>
<td>Hydrocarbons</td>
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<tr>
<td>HC</td>
<td>HFC</td>
<td>Hydro Fluorocarbon</td>
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<td>HFC</td>
<td>HI</td>
<td>High</td>
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<tr>
<td>HI</td>
<td>HO2S</td>
<td>Heated Oxygen Sensor</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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<tr>
<td>N</td>
<td>Nitrogen Oxides</td>
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<tr>
<td>NOx</td>
<td>On-Board Diagnostic system</td>
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<tr>
<td>O</td>
<td>On-Board Diagnostic system</td>
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</tr>
<tr>
<td>ODM</td>
<td>Occupant Classification Module</td>
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<tr>
<td>OCV</td>
<td>Oil Control Valve</td>
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<tr>
<td>O/D</td>
<td>Overdrive</td>
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<tr>
<td>OHC</td>
<td>Over Head Camshaft</td>
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<tr>
<td>O2S</td>
<td>Oxygen Sensor</td>
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<tr>
<td>P</td>
<td>Powertrain Control Module</td>
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<tr>
<td>PCV</td>
<td>Positive Crankcase Ventilation</td>
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<tr>
<td>PM</td>
<td>Particulate Mater</td>
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<td>PNP</td>
<td>Park / Neutral Position</td>
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<tr>
<td>P/S</td>
<td>Power Steering</td>
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<tr>
<td>PSP</td>
<td>Power Steering Pressure</td>
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<tr>
<td>R</td>
<td>Right</td>
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<tr>
<td>RAM</td>
<td>Random Access Memory</td>
<td></td>
</tr>
<tr>
<td>RHD</td>
<td>Right Hand Drive Vehicle</td>
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<tr>
<td>ROM</td>
<td>Read Only Memory</td>
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<tr>
<td>RPM</td>
<td>Engine Speed</td>
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</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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</tr>
<tr>
<td>SDM</td>
<td>Sensing and Diagnostic Module (Air Bag Controller, Air bag Control Module)</td>
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</tr>
<tr>
<td>SDT</td>
<td>Smart Diagnostic Tester</td>
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<tr>
<td>SFI</td>
<td>Sequential Multiport Fuel Injection</td>
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<tr>
<td>SI</td>
<td>System International</td>
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<tr>
<td>SOHC</td>
<td>Single Over Head Camshaft</td>
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<tr>
<td>SRS</td>
<td>Supplemental Restraint System</td>
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<tr>
<td>T</td>
<td>Torque Converter Clutch</td>
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<tr>
<td>TCC</td>
<td>Transmission Control Module</td>
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<tr>
<td>TCM</td>
<td>Traction Control Support System</td>
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</tr>
<tr>
<td>TCSS</td>
<td>Top Dead Center</td>
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</tr>
<tr>
<td>TP</td>
<td>Throttle Position</td>
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</tr>
<tr>
<td>TPMS</td>
<td>Tire Pressure Monitoring System</td>
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</tr>
<tr>
<td>TWC</td>
<td>Three-Way Catalytic converter</td>
<td></td>
</tr>
<tr>
<td>UART</td>
<td>Universal Asynchronous Receiver / Transmitter</td>
<td></td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
<td></td>
</tr>
<tr>
<td>VFD</td>
<td>Vacuum Fluorescent Display</td>
<td></td>
</tr>
<tr>
<td>VIN</td>
<td>Vehicle Identification Number</td>
<td></td>
</tr>
<tr>
<td>VSS</td>
<td>Vehicle Speed Sensor</td>
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</tr>
<tr>
<td>VVT</td>
<td>Variable Valve Timing</td>
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<tr>
<td>WU-OC</td>
<td>Warm Up Oxidation Catalytic converter</td>
<td></td>
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<tr>
<td>WU-TWC</td>
<td>Warm Up Three-Way Catalytic converter</td>
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</tr>
<tr>
<td>2WD</td>
<td>2-Wheel Drive</td>
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<tr>
<td>4WD</td>
<td>4-Wheel Drive</td>
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Note: ESP is a trademark of Daimler AG
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Well done, you have now completed the “ABS system” online training course

Please complete the online exam