

Education
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The Ultimate
Driving Machine



BMW Young Academy

In-car Technology

Lesson 1: Automotive Sensors

Student Workbook

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About Young Academy

Discover the skills needed to work in the automotive industry and learn about the science and technology behind the cars with Young Academy, BMW Education's online resource for 14 to 16 year olds.

Young Academy is a series of lessons based on BMW Academy's own award-winning apprenticeship programme. By working through the lessons, you will take a journey from learning about the principles of electrical theory, to developing an understanding of the skills and knowledge needed to become a motor industry technician.

The Young Academy lessons are available from the BMW Education website at: www.bmweducation.co.uk/Academy

This information booklet has been provided as an accessible alternative to the interactive lessons.

About In-car Technology Lesson 1: Automotive Sensors

When you are in a car, you might not realise that you are surrounded by sensors – in the seat belts, the car doors and the rear view mirror to name a few. Sensors respond to physical or chemical triggers, such as pressure, temperature or distance, and convert them into an electrical signal.

In this lesson you will explore different types of sensors and learn about four areas that use sensor technology, including parking distance control, digital compasses, night vision and car temperature regulation.

At the end of this lesson you should be able to:

- Describe the operation of a Hall sensor
- Describe the operation of an inductive sensor
- Describe the operation of an ultrasonic transducer
- Explain the operation of the digital compass
- Explain the operation of the night vision system
- Describe how coolant temperature sensors work

Lesson 1: Automotive Sensors

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Lesson 1: Automotive Sensors

Objectives

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Lesson 1: Automotive Sensors

Introduction

A large number of sensors are installed within BMW vehicles. Acting as perception elements, the sensors have the task of converting a physical or chemical variable (trigger) - e.g. pressure, temperature, distance, gas - into an electrical variable (signal).

Together with the actuators, the sensors (periphery) form the interfaces between the vehicle and control units (processing unit). For example, the outside temperature is registered by a temperature sensor, evaluated by the instrument cluster and shown in the display. Motor vehicle sensors must meet the following requirements:

- High degree of reliability
- Favourable manufacturing costs (i.e. not too expensive)
- High degree of accuracy
- Remain fully functional even under extreme operating conditions
- Compact design

The sensors can be distinguished according to various aspects:

- Task and application
- Type of characteristic
- Type of output signal

In this lesson, you will learn about four specific areas that utilise sensor technology:

- Park Distance Control
- Digital Compass
- Night Vision
- Coolant Temperature Sensor

Lesson 1: Automotive Sensors

Before starting to learn about these four systems, let's learn about some of the key sensors that are utilised on motor vehicles – Hall sensors and Inductive sensors.

Hall Sensors

Hall sensors are often used for the purpose of detecting or registering the position of moving components.

The advantages of Hall sensors:

- They involve contactless operation (they do not wear out through contact and are therefore maintenance free)
- They are unaffected by temperature fluctuations
- They are unaffected by vibration.

Hall sensors make use of the Hall effect. When a magnetic field acts on a current carrying semiconductor, an electrical voltage (Hall voltage) will be produced at its end faces. If the current strength through the semiconductor remains constant, the strength of the generated voltage will only depend on the strength of the magnetic field. If the strength of the magnetic field changes, the Hall voltage will also change.

When used as position sensors for magnetic parts, Hall sensors are of particular advantage when the change in the magnetic field is comparatively slow or zero. In these cases, a coil used as the sensor would supply no significant induction voltage.

In BMW vehicles, Hall sensors are used in a wide variety of applications, e.g. in the seat belt buckle, door closing system or as a position sensor for convertible top movement.

Inductive Sensors

Three things are required for the principle of inductive sensors to operate:

- A coil (winding)
- A magnetic field
- Movement

The crankshaft sensor measures the engine speed. It consists of a permanent magnet and an induction coil with a soft iron core. A ring gear is mounted on the flywheel to serve as the pulse generator (movement). There is only a small air gap between the inductive sensor and ring gear. The magnetic flux through the coil depends on whether there is a gap or a gear tooth opposite the sensor. A tooth bundles the stray flux of the magnet while a gap weakens the magnetic flux.

Engine speed is an important variable for engine management computers because it is used to calculate the air/fuel mixture and for ignition timing.

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Park Distance Control

BMW first introduced Park Distance Control (PDC) on the 7 series (E32) in 1992. PDC is a driver assistance system that facilitates parking and manoeuvring in confined spaces.

The rear area of the vehicle is monitored by four ultrasonic transducers that are integrated into the rear bumper. On some vehicles, the front area of the vehicle is also monitored by four additional ultrasonic transducers in the front bumper.

Ultrasonics is the term used to describe sound above the human hearing range at frequencies between 20 kHz and 1000 MHz. Sounds at even higher frequencies are known as hypersonic. Sounds below the human hearing range are referred to as infrasonic.

The distance between the vehicle and an obstacle is measured by way of ultrasonic signals and audibly signalled by a warning tone. This tone sequence changes continuously corresponding to the distance between vehicle and obstacle, indicating to the driver the distance to the obstacle. The shorter the distance of the vehicle from the obstacle the faster the tone sequence. A continuous tone sounds at a distance of less than 25 cm. To distinguish the sounds, the pitch is different at the front and rear.

In addition to the audible signal, depending on the vehicle and vehicle equipment, the distance from the obstacle is also shown visually on the display in the vehicle, in the form of a schematic representation of the vehicle and the distance to the obstacles.

Ultrasonic Principles

Operation of the ultrasonic transducers is based on the echo-sounding principle. Short ultrasonic pulses are sent out by the ultrasonic transducer, reflected from objects in the vicinity and received again by the ultrasonic transducer.

The ultrasonic transducer sends the period of time required between sending the ultrasonic pulse and receiving the first echo to the PDC unit which, in turn, calculates the distance to the nearest object from this period of time.

Ultrasonic waves propagate at different speeds in gases, liquids and solids. The approximate speed of ultrasonic waves through air at 15 °C is 340 miles per second.

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Ultrasound cannot be heard by humans as the human ear does not pick up frequencies above 20 kHz. Some animals, including dogs, dolphins and some insects can hear ultrasound. Bats have the best hearing capabilities as they not only hear ultrasound but they also generate it and can determine their location from the echoes.

Ultrasonics is used in a wide variety of technical and medical applications.

Echo Sounding

The echo depth sounder is a device that uses the reflection of sound or ultrasonics to determine the water depth.

The depth sounder determines the depth of the water by measuring the time between transmitting and receiving the sound pulse.

Modern devices are capable of indicating not only depth but also shape so that shoals of fish or structures of the seabed can be represented.

Transducer

Send Mode

The ultrasonic transducer behaves as a 'speaker' in send mode (from 40 to 50 kHz). The electronics of the ultrasonic transducer produces electrical pulses to set the piezoceramic element in motion (conversion of electrical energy to mechanical energy). The piezoceramic element is located on the inside of the outer diaphragm. The outer diaphragm vibrates in line with the resonance frequency and produces ultrasonic waves.

The short pulse sequences hit an obstacle and are bounced back (reflected).

Receive Mode

The ultrasonic transducer behaves as a 'microphone' in receive mode. After the outer diaphragm has settled (~ 1 ms), the ultrasonic transducer receives the ultrasonic waves reflected by the obstacle. The outer diaphragm and the piezoceramic element oscillate and send the electrical pulses to the electronic circuitry of the ultrasonic transducer (conversion of mechanical energy to electrical energy). The electrical measured signal is digitised and transferred to the control unit.

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Activation

The PDC control unit performs a system test after the ignition has been turned on. The parking aid is ready for operation on successful completion of the system test. The parking aid is activated automatically by engaging reverse gear. A delay of approximately 1 second is programmed on both automatic and manual transmission vehicles.

The purpose of the delay in activating the PDC when engaging reverse gear on vehicles with an automatic transmission is to prevent unintentional activation of the PDC when passing through the R-position when changing the drive stage.

The delay on manual transmission vehicles serves the purpose of ensuring a uniform operating concept. Illumination of the function indicator in the PDC button (depending on the vehicle equipment) indicates that the parking aid and therefore the distance recognition function is active. If required, the distance to the obstacle is additionally indicated visually on vehicles equipped with control display or central information display.

Summary

You should now be able to describe the operation of an ultrasonic transducer.

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Digital Compass

BMW vehicles (depending on the model) can be fitted with a digital compass that is integrated into the rear view mirror.

The compass also has additional uses in the USA. In large American cities, the streets are frequently arranged according to the points of the compass. The signposts are also arranged following the points of the compass.

However, the points on the compass can also help you to orientate yourself in European cities.

The digital compass uses the natural phenomenon of the earth's magnetic field to display the direction in which the compass is pointing.

The following factors can influence the display of the compass reading:

- Cosmic factors, such as sun storms or meteorite showers
- Different magnetic field forces in the earth's magnetic field, such as the composition of the soil
- External influences, such as mountain effect of the magnetic field sensor or the strong external magnetic field.

The Earth

The earth's magnetic field has two magnetic poles. These magnetic poles are the magnetic South Pole and North Pole.

The earth's magnetic poles are located at approximately 12° offset from the earth's geographical poles. At the magnetic North Pole, the gridlines of the magnetic field are vertical to the earth's surface. The needle of a compass, for example, will point to this magnetic pole.

At the magnetic South Pole, the magnetic lines leave the earth's surface. The earth's magnetic field does not run parallel to the earth's surface. It meets the earth surface at a variety of angles.

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Compass Zones

The earth's magnetic field is divided into 15 compass zones. The compass zones illustrate the deviations from the earth's ideal magnetic field. The magnetic North Pole is the precise indicator of the compass point 'North'. The earth's magnetic field is influenced by the composition of the soil. This means that the magnetic field is not distributed evenly over the earth. The geographical compass zone for the digital compass can be also adjusted.

Functional Overview of Digital Compass

A magnetic field sensor, which identifies the direction in which the compass is pointing, is located in the base of the rear view mirror. The signal from the magnetic field sensor is processed by control electronics and then transferred to the display.

The magnetic field sensor at the base of the rear view mirror consists of a sensor board with:

- Two solenoid coils
- A plug-in connection to the rear view mirror board
- Electronic components

The compass in the rear view mirror works as follows:

The solenoid coils display the earth's magnetic field along longitudinal and latitudinal axes.

Each solenoid coil has a specific inductivity and is a part of the resonant circuit. The inductivity changes in response to the effects of the earth's magnetic field. The resonant circuit changes its frequency depending on the inductivity of the solenoid coils.

The changes in the frequency correspond to the changes in the external magnetic field. The direction of the magnetic field is calculated from the frequency changes of the resonant circuit in both solenoid coils.

Summary

You have now completed this section about the rear view mirror compass.

You should now be able to explain the operation of the digital compass.

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Night Vision

All objects have a certain temperature and emit waves of thermal energy called infrared radiation.

Infrared radiation is not visible but humans can sense it as heat.

The hotter an object, the more energy waves are emitted. A thermal imaging system converts these energy waves into an image that will normally display a black and white picture. The display works by showing the hottest objects as white, the coolest objects as black, and features of other objects show as varying shades of grey.

Heat radiation is absorbed and dissipated by virtually every solid or liquid body. Heat radiation, however, is not visible to the human eye because it belongs in the long-wave infrared range.

From a physical standpoint, this represents electromagnetic waves with a wavelength of $8\mu\text{m}$ to $15\mu\text{m}$.

This long-wave infrared radiation is known as Far Infrared (FIR).

Visible light is a very small portion of what is called the 'Electromagnetic Spectrum'. The Electromagnetic Spectrum includes all types of radiation.

Infrared is one type of radiation but there are several other different types, all of which have different wavelengths. Examples include:

- Gamma (gamma rays have a very short wavelength)
- X-Ray
- Ultraviolet
- Visible light
- Infrared
- Microwave radiation
- Radio waves (radio waves have the longest wavelength)

Short wavelength radiation is of the highest energy and can be very dangerous.

Thermal Imaging

The BMW Night Vision system provides the driver with a black-and-white image of the driving environment ahead of the vehicle in the control display.

BMW Night Vision is a 100% passive system without active infrared illumination. Objects situated ahead of the vehicle are shown in varying degrees of brightness depending on the temperature of these objects.

This enables the driver to detect in good time heat-emitting objects such as people, animals and other vehicles.

There are several advantages of thermal imaging:

1. Improved vision in conditions of dusk and darkness
2. No dazzling by the headlights of oncoming vehicles
3. Highlighting of unilluminated, heat-emitting objects such as pedestrians, cyclists, vehicles and deer
4. Enlarged depiction thanks to the zoom function of objects in the far distance at high speeds
5. Illumination of bends/curves thanks to the bend/curve mode (pivoting of image detail)
6. Illumination of dark courtyard and garage entrances

Summary

You have now completed this section about BMW Night Vision.

You should now be able to:

- describe the advantages and benefits of using night vision systems on motor vehicles
- explain the electromagnetic spectrum and provide examples
- explain the operation of the night vision system.

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Coolant Temperature Sensors

A thermistor is a type of receptor used to measure temperature change by relying on the change in its resistance with changing temperature. Thermistor is a combination of the words 'thermometer' and 'resistor'

On most automotive applications the thermistor changes resistance as the engine's coolant temperature changes. The sensor's output is monitored by the engine computer to control various functions. Some of these functions can include:

- Ignition
- Fuelling
- Cooling fan operation
- Thermostat operation

In the PTC (Positive Temperature Coefficient) type of sensor, resistance goes up with temperature. In the more common NTC (Negative Temperature Coefficient) type, resistance goes down as heat goes up.

Summary

You have now completed this section about coolant temperature sensors.

You should now be able to describe the operation of temperature sensors

Well done!

You have now finished learning about Automotive Sensors.