Phase 2

Trade of Motor Mechanic

Module 4

Unit 2

Ignition & Transducers

Produced by

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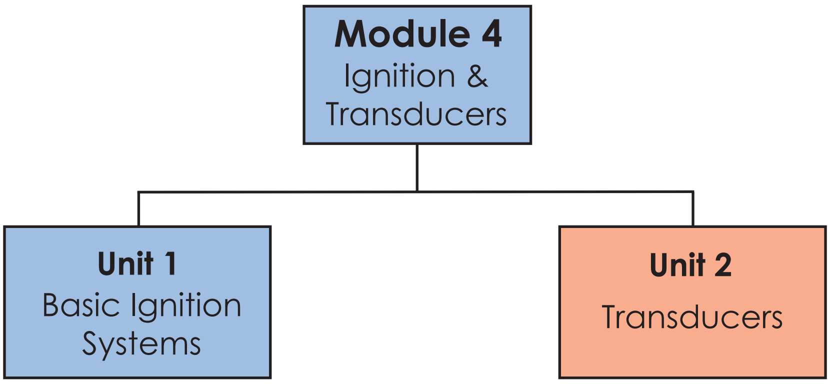
Introduction

There are 2 Units in this Module. Unit 1 covers Basic Ignition Systems and Unit 2 covers Transducers.



Module 4 of this course covers the Ignition and Transducers aspect of automotive technology. This is the second unit in module 4 and introduces Transducers.

A transducer is a device, usually electrical or electronic, that converts one type of energy to another for the purpose of measurement or information transfer. These sensors and the relative information will be covered within this unit. Health and safety issues related to this unit will also be covered.

Unit Objective

By the end of this unit each apprentice will be able to:

- Define the terms; Sensor, Electronic Control Unit, Actuator
- State the basic relationship between; Sensors, Control Unit and Actuator
- Describe the basic operating principle of the following; Wiper potentiometer, Inductive signal generator, Hall effect signal generator, Hot wire/Hot film airmass flow meters, reed switch
- Define the terms; Thermistor, Negative Temperature Coefficient (NTC) Positive Temperature Coefficient (PTC), waveform, amplitude, frequency and pulse width
- State the primary sensors/signal generating devices used in spark ignition (S.I.) electronic engine management systems
- Use an oscilloscope to display electrical waveforms from input and output transducers for comparison/basic fault analysis to manufacturers recommended patterns
- Write a basic, illustrated technical report on the identity, location and basic function of the primary sensors and actuators, circuit/harness layout and connections to the ECU
- Define the terms; Fault Memory, Fault Description, Fault Code, data link interface socket, on board diagnostic (O.B.D.) (E.O.B.D.) socket as applied to the automotive ECU
- Describe the use of 'blink' fault code display/retrieval from ECUs
- State the precautions necessary to avoid damage to the ECU when fault finding on its associated circuits
- Locate and display engine management system fault code data
- Describe a manufacturer's recommended procedure to remove, de-activate and store a steering wheel airbag and seat belt pre-tensioner unit

1.0 Sensor, Electronic Control Unit, Actuator

Key Learning Points

- Sensors (input transducers) Actuators (output transducers)
- Transducers; convert a physical or chemical quantity (usually non-electrical) into an electrical quantity or the reverse
- ECU; embedded micro computer (integrated circuit) system used as a control element in automobile systems
- Control unit; non-volatile memory (permanent memory), operate on a designed programme, process data, accept feedback, e.g. throttle position and exhaust gas oxygen data, provide high power drive for external actuators

1.1 Terminology

Sensors

A *transducer* is a device, usually electrical or electronic, that converts one type of energy to another for the purpose of measurement or information transfer. Most transducers are either sensors or actuators. In a broader sense, a transducer is sometimes defined as any device that converts energy from one form to another.

Most sensors are electrical or electronic, although other types exist. A sensor is a type of transducer.

An *actuator* is the mechanism by which an agent acts upon an environment. A mechanism that puts something into automatic action is called an actuator. They are devices which transform an input signal (mainly an electrical signal) into motion

Some examples of actuators of these various agents include:

Electrical motors, relays, pneumatic actuators, hydraulic pistons, piezoelectric actuators, solenoids

In automotive electronics, an *electronic control unit* (ECU) is an embedded system that controls one or more of the electrical subsystems in a vehicle. Some modern cars have more than 70 ECUs.

1.2 Sensors

Most sensors are electrical or electronic. A sensor is a type of transducer. Sensors are either direct indicating or are paired with an indicator so that the value sensed becomes human readable. In the modern automobile there is a range of sensors that are used in the various vehicle systems. The most common use however is in the powertrain management systems such as ignition, emission and transmission.

All of these sensors contribute to the efficient operation of the powertrain systems by feeding signals (data) to the vehicles on board electronic controller (more commonly know as an the electronic control unit (ECU) which interprets the data and makes adjustments to the various systems via actuators.

Sensors used in automotive applications are commonly of the:

- optical
- inductive
- magnetic
- heat sensitive
- proximity

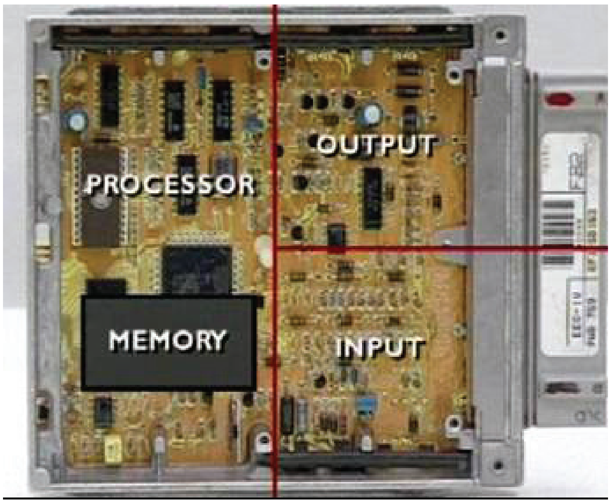
The particular type used, depends on the application.

1.3 Electronic Control Unit – ECU

The ECU is a micro-computer. It is constructed from printed circuitry and contains a large number of electrical components, including many semiconductor devices.

Its input devices receive data as electrical signals. They come from sensors and components at various locations around the engine. Its processing unit compares incoming data with data stored in a memory unit. The memory unit contains basic data about how the engine is to operate i.e. Operate on a designed programme. And an output device pulses the electrical circuit of the solenoid-type injection valves.

It is normally located in a safe place, behind a kick-panel in the foot-well, under the passenger seat, or in the boot and connected by a multi-plug, or plugs, to the vehicle's wiring harness.



The core function of a basic ECU in an EFI system is to control the pulse width of the injector. More sophisticated models also control other functions such as idle speed, ignition timing and the fuel pump. These wider systems are called engine management systems. The more precise control they allow is very effective in reducing fuel consumption and exhaust emissions.

The ECU adjusts quickly to changing conditions by using what are called programmed characteristic maps, stored in the memory unit. They are programmed into the ECU, just as data is programmed into a computer. Characteristics mean the engine's operating conditions. They are called maps because they map all of the operating conditions for the engine.

They are constructed first from dynamometer tests then fine-tuned to optimise the operating conditions and to comply with emission regulations. This data is stored electronically.

Ignition timing is crucial in this process. Between one spark and the next, the ECU uses data it receives on engine load and speed to determine when the next ignition point will occur. It can also correct the map value, using extra information such as engine coolant temperature, intake air temperature, or throttle position. Putting all of this together, it arrives at the best ignition point for that operating condition.

1.4 Actuators

In automotive engineering, actuators are a subdivision of transducers. They are devices which transform an input signal from a sensor (mainly an electrical signal) into either motion or a warning signal that can be observed by the vehicle driver. Typically, electrical motors, pneumatic actuators, hydraulic pistons, relays, piezoelectric actuators, relays and solenoids are some examples of such actuators.

Electric motors are mostly used when circular motions are needed as a result of a sensor signal, but can also be used for linear applications by transforming circular to linear motion with a bolt and screw transducer. Equally, some actuators are intrinsically linear, such as piezoelectric actuators which are used in some fuel injection systems.

2.0 Relationships Between; Sensors, Control Unit and Actuator

Key Learning Points

- Sensors; passive - varies its internal resistance, active – voltage generating

2.1 Passive/Active sensors

Passive sensor receives signals only e.g. the temperature sensor. The temperature sensors resistance changes depending on the surrounding temperature.

Active sensor generates an output e.g. crank angle sensor.

Control unit and actuators covered in section 1.0

3.0 Operating Principle of Specific Transducers

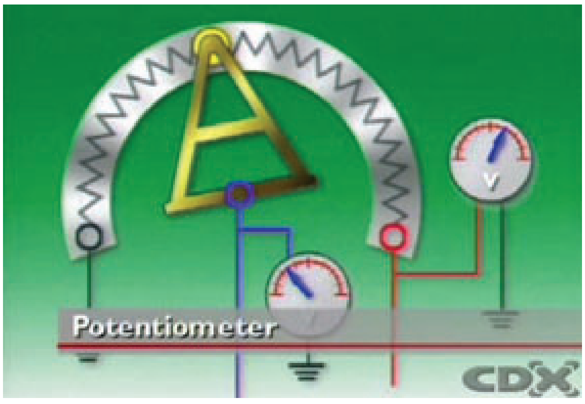
Key Learning Points

- Wiper potentiometer e.g. petrol tank sender unit, pedal travel sensor
- Inductive EMF generation (relative motion between a magnetic field and a conductor)
- Hall effect; (current flow across a semiconductor material changing direction due to a magnetic field being applied)
- Hot wire/Hot film Airmass Flow Meters
- Reed Switch

3.1 Wiper Potentiometers

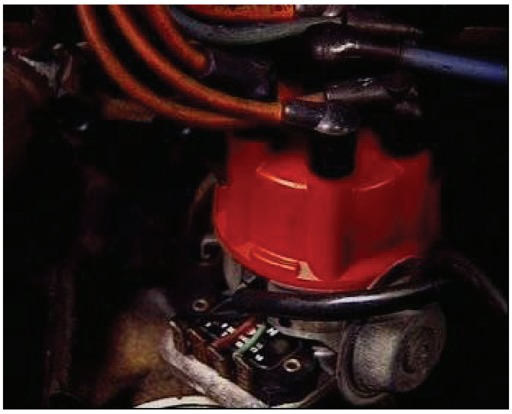
A potentiometer is a variable resistor. A potentiometer generally has three wires or terminals. Two are simply the connections to the ends of the resistive element. The remaining terminal connects to a moveable contact called the wiper. The wiper slides along the surface of the resistive element as the potentiometer's shaft is moved. As the wiper is moved closer to one end of the resistive element, the resistance between the wiper terminal and that end terminal decreases.

Two typical applications of a "wiper" type potentiometer in automotive use are in the dash light "brightness" control and in the fuel tank "fuel level tank unit".



3.2 Induction Signal Generation

In electronic ignition systems the contact breaker is eliminated and the switching or triggering of the primary circuit is carried out electronically.



In induction type systems, the pulse generator has a stator mounted on the distributor body and a rotor unit, called a reluctor, attached to the distributor shaft. The stator has a circular permanent magnet with a number of projections or teeth corresponding to the number of engine cylinders and a stationary coil of fine enamelled copper wire wound on a plastic reel and positioned inside the magnet. The reluctor has the same number of teeth as the stator and, as it rotates, these teeth approach and leave the stator teeth, changing the air gap between them. As this occurs, the strength of the magnetic field changes, increasing as the teeth approach, reaching a maximum when they are in alignment and decreasing as they move away.

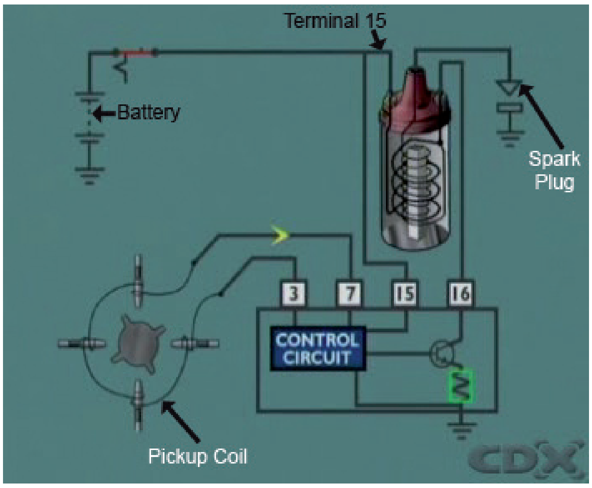
As the stationary winding is influenced by the magnetic field, then, in accordance with Faraday's Law, a voltage is induced across the ends of the winding, each time the magnetic field changes. And if the winding forms part of a complete circuit, the voltage will cause a current to flow.

As the teeth approach, the strength of the magnetic field is increasing. This induces a voltage and current flow in the winding. The polarity of the voltage is said to be positive as it produces a current flow in a certain direction. When the teeth are in alignment, the magnetic field is at its strongest but; at that point, it is not changing. Voltage and current now fall to zero.

As the teeth move away, the strength of the magnetic field changes again and once again voltage and current flow is induced in the winding. This time, current flow is in the opposite direction and the polarity is now said to be negative. Since polarity changes every time the teeth approach and leave the stator teeth, the voltage produced is an A.C. voltage and current flow is an alternating current.

3.3 Inductive Signal Operation

After the positive pulse is received, a dwell control section of the control circuit determines when the primary circuit will be switched on and how long current will flow in the primary winding. The dwell period can thus be varied according to engine speed, improving coil efficiency. At low engine speeds, the dwell period is short. As engine speed rises the dwell period increases.



Ignition coils employed with electronic systems are referred to as low inductance coils, because their primary winding resistance and number of turns is low. Current flow is much higher than with contact breaker systems and reaches its optimum level sooner. A current limiting device within the control circuit limits maximum current flow to a safe value.

Ignition advance according to engine speed and load is provided by centrifugal and vacuum advance mechanisms.

Overview

In an electronic ignition, a rotating reluctor and magnetic-pickup coil replace the traditional cam, breaker points and condenser in the distributors of cars equipped for electronic ignition. This system reduces the time between tune-ups. The high spots of the reluctor interrupt the magnetic field of the pickup coil and the permanent magnet. These interruptions, or pulses, are transmitted from the pickup to a nearby electronic control unit. There, the pulses signal a transistor to break the low-voltage sub-circuit and release high voltage from the coil to the spark plugs.

Electronic Ignition System Components

The components of a basic electronic ignition system all perform the same functions. Manufacturer has their own preferred terminology and location of the components.

The basic components of an electronic ignition system are as follows:

- *Trigger Wheel:* The trigger wheel, also known as a reluctor, pole piece, or armature, is connected to the upper end of the distributor shaft. The trigger wheel replaces the distributor cam. Like the distributor cam lobes, the teeth on the trigger wheel equal the number of engine cylinders.
- *Pickup Coil:* The pickup coil, also known as a sensor assembly, sensor coil, or magnetic pickup assembly, produces tiny voltage surges for the ignition systems electronic control unit. The pickup coil is a small set of windings forming a coil.
- *Electronic Control Unit Amplifier:* The ignition system electronic control unit amplifier or control module is an "electronic switch" that turns the ignition coil primary current ON and OFF. The ECU performs the same function as the contact points. The ignition ECU is a network of transistors, capacitors, resistors and other electronic components sealed in a metal or plastic housing.

ECU dwell time (number of degrees the circuit conducts current to the ignition coil) is designed into the electronic circuit of the ECU and is NOT adjustable manually.

3.4 Hall Effect Sensors

A typical Hall Effect Sensor has three wires or terminals: one for ground, one for supply or reference voltage and one for the output signal. To produce an output signal, a Hall Effect Sensor must be supplied with a reference voltage from the vehicle's onboard computer (which may be 5 to 12 volts depending on the application). The supply voltage is necessary to create the switching effect that takes place inside the sensor.

Hall Effect Sensors are sometimes referred to as "switches" rather than sensors because of the on-off "digital" voltage signal they produce. Unlike magnetic sensors that produce an alternating current (AC) signal which varies in voltage with speed, Hall Effect

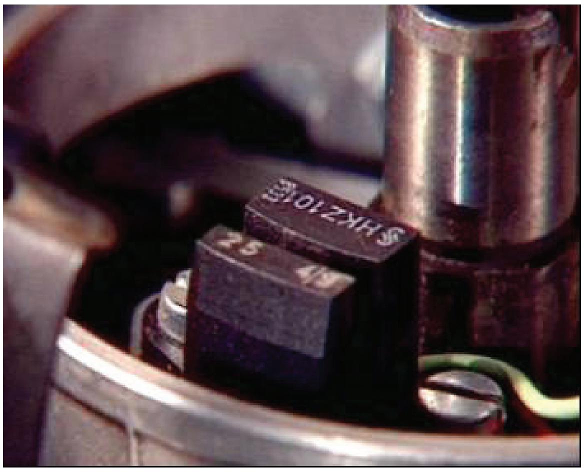
Sensors produce a constant voltage signal that can change abruptly from maximum voltage to nearly zero and back again regardless of engine speed. This produces a square wave output signal that can be easily used by the onboard computer for timing purposes.

Hall Effect square wave signal

In electronic ignition systems, the contact breaker is eliminated therefore switching and triggering of the primary circuit is carried out electronically.

3.5 Hall Effect Sensor Application

One application of a Hall Effect sensor is in the ignition system. Hall Effect systems, a Hall Effect generator can be located inside the distributor to signal an electronic control unit to turn the primary circuit "on" and "off". Hall Effect generators operate by using a potential difference or voltage created when a current carrying conductor is exposed to a magnetic field.



If a magnetic field is applied at right angles to the direction of current flow in a conductor, the lines of magnetic force permeate the conductor and the electrons flowing in the conductor are deflected to one side. This deflection creates a potential difference across the conductor.

The stronger the magnetic field, the higher the voltage. This is called the Hall Effect voltage. If the magnetic field is alternately shielded and exposed, it can be used as a switching device. Hall devices are made of semi-conductor material because it produces a better effect.

In a distributor, the Hall Effect generator and its integrated circuit or IC, are located on one leg of a "U" shaped assembly, mounted on the distributor base plate. A permanent magnet is located on the other leg and an air gap is formed between them. An interrupter ring, which has the same number of blades and windows as engine cylinders, is rotated by the distributor shaft, moving the blades through the air gap.

When a window is aligned with the assembly, the magnetic field is at its strongest, then its lines of magnetic force permeate the Hall generator and its integrated circuit. This allows the generator to switch to ground the low current signal voltage applied to it.

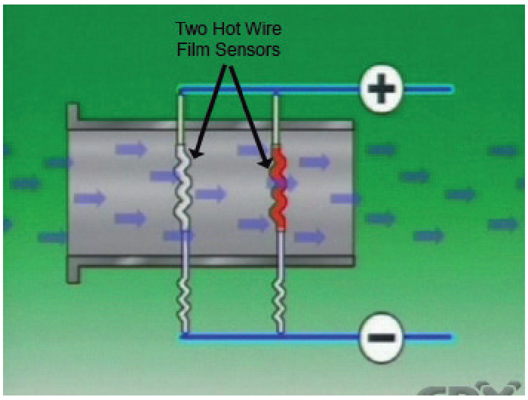
When the interrupter ring rotates so that the blade aligns with the assembly, the magnetic field is shielded from the generator and the signal voltage is not switched to ground.

With continuous rotation, the blades repeatedly move in and out of the air gap and the signal voltage will appear to turn on and off repeatedly. This can be used to control the operation of the ignition coil primary circuit.

3.6 Hot Wire/Hot Film Air Mass Flow Meters

The mass type airflow sensor detects the mass of air flowing into the intake manifold. By measuring the mass of the air, it prevents changes in air density affecting the air-fuel mixture.

The airflow meter has an electrically-heated wire, mounted in the air stream. A control circuit is linked to the wire and current is supplied to the wire to keep its temperature constant. The higher the airflow, the more the temperature of the wire falls - and the higher the current needed in the wire to keep its temperature constant. So how this current varies is a measure of what is happening to the air flow.



Current flow variation is then read as an output voltage and converted by the ECU to an intake air signal. This determines the basic fuel quantity needed for injector pulse duration. The airflow meter can have a self-cleaning function that burns dust and other contaminants from the hot wire. This is done by the control unit heating the wire to 1000°Celsius for approximately 1 second. This happens 5 to 10 seconds after the ignition is switched off. This function operates only when certain conditions have been met. For example, the engine must have reached operating temperature and the vehicle must have been travelling above 10 kilometres an hour.

In some types of sensors, the hot wire is mounted in a sub passage connected to the main passage. This allows maximum airflow through the main passage. The hot wire may be sealed in a glass envelope. This protects the wire and eliminates the need for burn-off. In others, the heating element is a ceramic plate.

Some of the benefits of a hot-wire MAF compared to the older style vane meter are:

- responds very quickly to changes in air flow
- low airflow restriction
- smaller overall package
- less sensitive to mounting location and orientation
- no moving parts improve its durability
- less expensive
- separate temperature and pressure sensors are not required (to determine air mass)

There are some drawbacks:

Dirt and oil can contaminate the hot-wire deteriorating its accuracy.

3.7 Reed Switch

A reed switch is a form of relay. A relay is an electrical switch that opens and closes under control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of electrical amplifier.

- These contacts can be either normally-open, normally-closed, or change-over contacts.
- Normally-open contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.
- Normally-closed contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.
- Change-over contacts control two circuits: one normally-open contact and one normally-closed contact.

A reed relay has two, usually normally open, contacts inside a vacuum or inert gas filled glass tube. This protects the contacts against atmospheric corrosion. The two contacts are closed by magnetism from a coil around the glass tube, or a permanent magnet moved towards it.

Operation

When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current is switched off, the armature is usually returned by a spring to its resting position.

4.0 Term Definitions

Key Learning Points

- Thermistor - NTC, PTC opposite changes in electrical resistance with temperature change
- Waveform, Pulse width - signal frequency, rate of voltage signal change over time

4.1 Thermistors (Including NTC & PTC)

Thermistors are semiconductor resistors. Their electrical resistance varies according to temperature. This makes them suitable for temperature measurement and for electronic control operations.

Negative temperature coefficient resistors, also called NTC resistors, conduct current more readily when they are hot than when they are cold. NTC resistors are commonly used as part of temperature sensors in engine management systems.

Positive Temperature Coefficient or PTC thermistors are of the “switching” type, which means that their resistance rises suddenly at a certain critical temperature.

Applications

- PTC thermistors can be used as current-limiting devices for circuit protection, as replacements for fuses, temperature measurement, temperature control and over-temperature protection.
- NTC's are often used in simple temperature detectors and measuring instruments.

4.2 Basic Oscilloscope Patterns

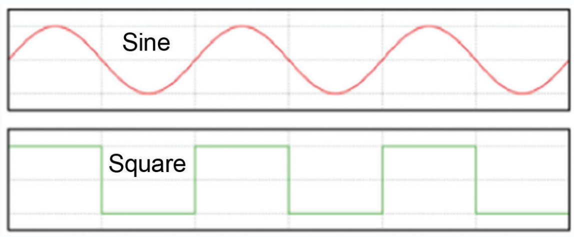
Note: Please refer to your instructor for additional information e.g. sample wave forms, which is available from the automotive technical manuals.

Waveform, Amplitude, Frequency, Pulse-Width Modulation

Waveform means the shape and form of a signal, such as a wave moving across the surface of water

In many cases the medium in which the wave is being propagated does not permit a direct visual image of the form. In these cases, the term 'waveform' refers to the shape of a graph of the varying quantity against time or distance. An instrument called an oscilloscope can be used to pictorially represent the wave as a repeating image on a CRT or LCD screen.

By extension of the above, the term 'waveform' is now also used loosely to describe the shape of the graph of any periodically varying quantity against time.

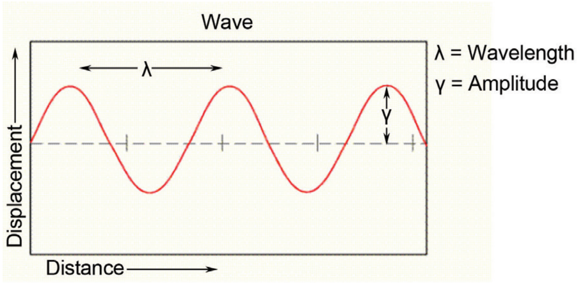


Examples of waveforms

An *oscilloscope* (or scope) is a piece of electronic test equipment that allows signal voltages to be viewed, usually as a two-dimensional graph of one or more electrical potential differences (vertical axis) plotted as a function of time or of some other voltage (horizontal axis).

Amplitude

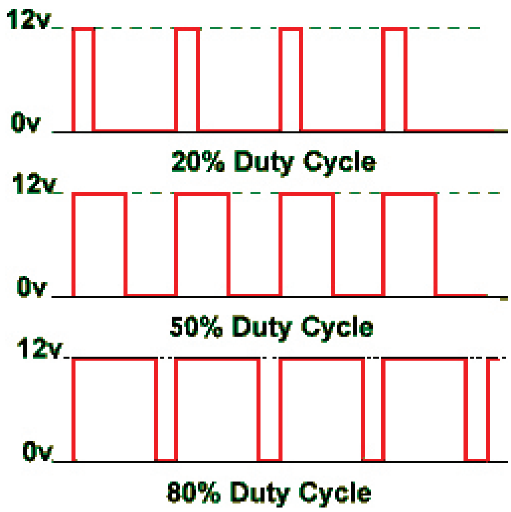
Is a nonnegative scalar measure of a wave's magnitude of oscillation, that is, magnitude of the maximum disturbance in the medium during one wave cycle. This is shown in the following diagram.



Frequency

Measuring the frequency of sound, electromagnetic waves (such as radio or light), electrical signals, or other waves, the frequency in hertz is the number of cycles of the repetitive waveform per second. If the wave is a sound, frequency is what mainly characterizes its pitch.

Pulse-Width Modulation



Pulse-width modulation control works by switching the power supplied to the component on and off very rapidly. The DC voltage is converted to a square-wave signal, alternating between fully on (example shown - 12V) and zero, giving the component a series of power pulses.

By adjusting the duty cycle of the signal (modulating the width of the pulse, hence the 'PWM') Duty cycle is the proportion of time during which a component, device, or system is operated.

5.0 Spark Ignition Engine Sensors Signal Generating Devices

Key Learning Points

- Primary sensors; crank and cam position, volume/mass air flow, engine temperature
- Primary actuators; ignition coil(s) switching system, fuel injectors, pump, relays etc.

5.1 Primary Sensors in Engine Management Systems

The primary sensors used in engine management systems are:

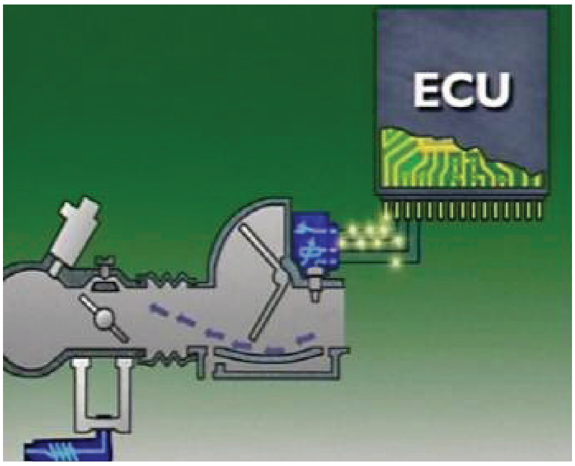
- Mass airflow sensor
- Manifold absolute pressure sensor (MAP)
- Air vortex sensor
- Temperature sensor
- Throttle position sensor
- Exhaust gas oxygen sensor
- Crank angle sensor
- Knock Sensor

The following shows the each of these in detail and provides information on how the operate.

5.2 Fuel System Sensors Overview

An air flow meter varies its signal by the deflection of a vane as air enters the engine. Deflecting the vane moves contacts across a potentiometer, to signal its position and thus, the amount of air entering the system.

The temperature sensor uses material with a negative temperature coefficient of resistance (NTC). Its resistance is high when it's cold, but it falls as its temperature rises. It is called a thermistor. This is the opposite of a normal resistor, which increases its resistance as temperature rises.



The coolant temperature sensor is immersed in coolant, in the cylinder head.

The air temperature sensor is in the air intake - at the airflow meter, or in the manifold.

Throttle position can be signalled by a potentiometer attached to the throttle shaft. It provides a continuous, varying signal, through the entire range of throttle position. Throttle position can also be signalled by a contact-type switch, but it signals the idle and fully open positions only.

Engine speed can be detected by a connection from the ignition system primary circuit, or by a pulse generator-type sensor, on the crankshaft. The pulses are computed by the control unit, into an engine RPM figure. They can also be used to trigger the injectors.

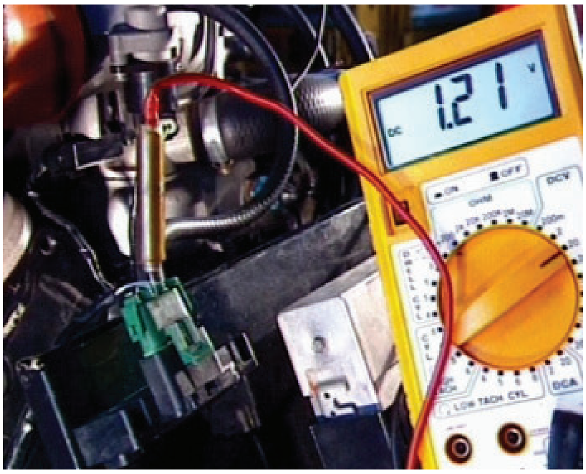
5.3 Mass Airflow Sensor

Covered in Section 3.6.

5.4 MAP Sensor

Changes in engine speed and load cause changes in intake manifold pressure. This sensor measures these pressure changes and converts them into an electrical signal. It's called a manifold absolute pressure or MAP sensor.

The signal may be an output voltage, or a frequency.



By monitoring output voltages, the control unit senses manifold pressure and uses this information to provide the basic fuel requirement.

It can use a piezoelectric crystal. If there is a change in the pressure exerted on this crystal, it changes its resistance. This alters its output signal.

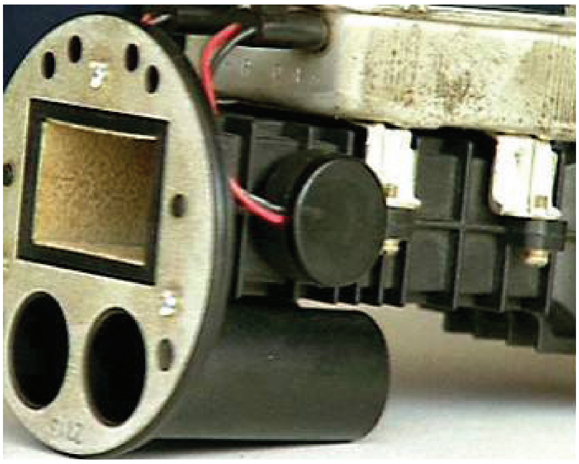
The sensor is connected to the intake manifold by a small-diameter, flexible tube. The control unit sends a 5 volt reference signal to the sensor. As manifold pressure changes, so does the electrical resistance of the sensor and this in turn produces change in the output voltage.

During idling, manifold pressure is low, which produces a comparatively low MAP output. With wide open throttle, manifold pressure is closer to atmospheric, so output is higher.

5.5 Air Vortex Sensor

The air vortex sensor uses whirlpools of air, or vortices, to measure the volume of air entering the engine. A triangular, vortex-generating rod disturbs the airflow and causes whirlpools of air to form in the body of the sensor.

The vortices alternate from clockwise to anticlockwise rotation and they are staggered as they pass through a transmitter-receiver area. When there is no airflow, this transmitter emits a constant signal of ultrasonic waves to the receiver.



When the engine is running, the vortices distort the ultrasonic waves. This modulates the ultrasonic waves reaching the receiver. This modulated wave is converted to an electrical pulse signal which is directly proportional to the airflow. This is then used by the ECU to determine the basic fuel requirement.

An air regulator or rectifier is located at the entry to the sensor. It reduces turbulence in the airflow passing the vortex generator.

5.6 Temperature Sensor

To maintain the air-fuel ratio within an optimum range, the control unit must take account of coolant temperature and air temperature. Extra fuel is needed when the engine is cold and when the air is colder and therefore denser.

The coolant temperature sensor is immersed in coolant in the cylinder head. It consists of a hollow threaded pin which has a resistor sealed inside it. This resistor is made of a semiconductor material whose electrical resistance falls as temperature rises.

The signal from the coolant temperature sensor is used to control the mixture enrichment when the engine is cold and is processed in the control unit.

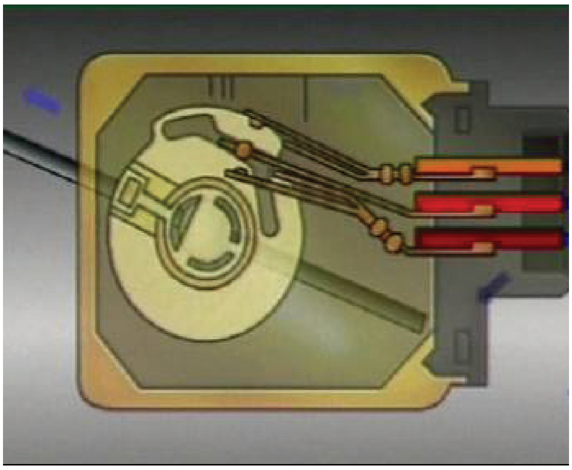
Enrichment occurs during engine cranking and then slowly reduces he engine warms up. This ensures a steady engine response immediately after releasing the starter. The control unit continually monitors coolant temperature during engine operation.

If the air temperature sensor is installed in the airflow sensor, it's positioned in the airstream and it's called an intake air temperature sensor, or (IAT). When it's installed in the intake manifold it's located in one of the intake runners and it's called a *manifold air temperature sensor*, or MAT.

In both cases it relays information on temperature and therefore the density of the air. The control unit can then vary the setting accordingly.

5.7 Throttle Position Sensor

This sensor gathers information on throttle positions, to allow the control unit to make adjustments according to operating conditions. It is located on the throttle body and operated by rotation of the throttle spindle or shaft. Throttle position is sensed by a contact type switch, or a potentiometer. The switch type has 2 contacts - idle and full load. It can be supplied with a voltage to the centre terminal of its connector.



At idling speeds, the full load contacts are open. The idle contacts are closed and the signal to the computer provides for a mixture to maintain idle quality and stability. Slightly rotating the throttle shaft opens the idle contacts. As the throttle approaches the wide-open position, the full load contacts close. The ECU reads the full-load signal and enriches the mixture to suit.

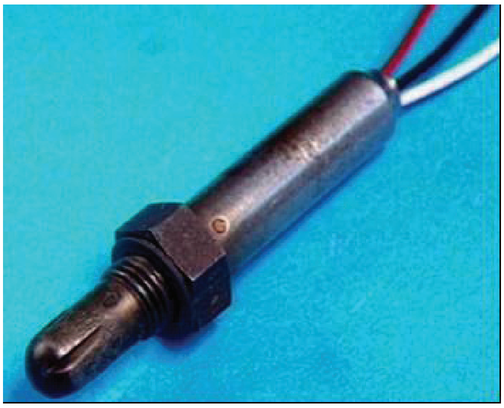
The "idle contacts closed" signal can also be used, with the engine RPM signal to the control unit, to stop fuel delivery on engine over-run. This can be done, for example, if engine speed is above 2500 RPM on deceleration. If the ECU reads a figure above this and also receives a throttle closed signal, it opens the injector electrical circuit and stops fuel delivery. As RPM falls below, say, 2100 RPM, the circuit is restored. Injection then recommences, to maintain drive ability.

A potentiometer-type sensor monitors throttle position over its full range. One end has a 5 volt reference voltage from the control unit. The other is connected to control unit earth. A third wire runs from a sliding contact in the throttle position sensor, to the input circuits of the control unit. The sensor then works like a variable resistor. As the angle of the throttle valve changes, so does the voltage signal along the third wire.

At closed throttle, the reading is usually below 1.25 volts. As the throttle valve opens, the voltage signal rises. At wide-open throttle, it's about 4.5 volts. This ongoing monitoring of throttle position provides more data for the control unit. This allows control over a wider range of operating conditions.

5.8 Exhaust Gas Oxygen Sensor

The oxygen sensor, also called a lambda sensor, is mounted in the exhaust manifold, or the exhaust pipe. Its sensing portion is exposed to the stream of exhaust gas. It detects left-over oxygen in the exhaust gas and sends the data to the control unit.



The control unit uses it to fine-tune the pulse it sends to the fuel injectors.

Most sensors consists of a tube closed at one end and made of Zirconia ceramic, or Titanium ceramic. Its inner and outer surfaces are coated with platinum. The outer closed end is covered by a louvered metal shroud that protects it from breakage but still lets the exhaust gas contact the tube. Its inner surface is in contact with the air. A wire contacts the inner surface of the tube through a spring and an electrode bush. This provides the electrical link to the control unit.

The inner and outer surfaces of the ceramic tube are coated with porous platinum. The side facing the exhaust gas has a highly porous ceramic layer on top of the platinum, which lets oxygen through.

The ceramic tube with its platinum electrodes is now a porous, solid electrolyte. At temperatures around 350° C, it becomes a conductor. One side detects the level of oxygen in the exhaust gas. The other detects its level in ordinary air. If the levels are different, a voltage is generated between the 2 sides.

The control unit compares this voltage to a pre-set level. Below the level indicates a lean mixture, above it means a rich mixture. The control unit may then adjust the pulse to the injectors, to maintain correct mixture. This fine tuning is needed for the catalytic converter to function properly.

Some sensors have a built-in heating element powered by the vehicle's electrical system. It helps them reach operating temperatures quickly.

5.9 Crank Angle Sensor

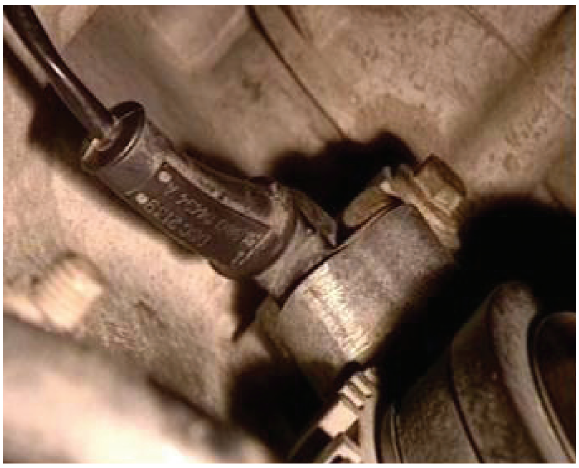
Crank Angle Sensing uses information on the speed and position of the crankshaft to control ignition timing and injection sequencing. The control unit can then trigger the ignition and injection, to suit operating conditions.

The position sensor may be mounted externally on the crankcase wall, or it may be inside the housing of the ignition distributor.

There are different kinds of crankshaft and camshaft position sensors.

Note: Always refer to manufacturer's specification before checking sensors.

Inductive-type sensors sense the movement of the ring gear teeth on the flywheel, or a toothed disc on the crank pulley. These sensors do not make physical contact. The sensor is mounted on the crankcase wall. It consists of a stator, with a central permanent magnet and a soft iron core surrounded by an induction winding. The housing around all of these components is insulated from them. The stator is positioned so that it has a very small clearance, or air gap, between the end of the soft iron core and the flywheel teeth.



As the flywheel rotates, the teeth approach and leave, the stator and the air gap changes. As this occurs the strength of the magnetic field changes. The winding is part of a complete circuit, so changing the magnetic field produces an alternating voltage and current.

As the tooth approaches the stator, the strength of the magnetic field is increasing. This induces a voltage and current flow, in the winding. The polarity of the voltage is said to be positive, as it produces a current flow in the winding in a certain direction.

When the tooth aligns with the stator, the magnetic field is at its strongest, but at that point, it is not changing. Voltage and current flow fall to zero.

As the tooth moves away from the stator, the strength of the magnetic field changes again and once again voltage and current flow is induced in the winding. This time, current flow is in the opposite direction and the polarity of the voltage is now said to be negative.

Since polarity changes every time a tooth approaches and leaves the stator, the voltage produced is an AC voltage and the current flow in the winding is an alternating current. Similarly with the toothed disc as the tooth approaches the stator, the magnetic field is changing. It reaches a maximum when the tooth aligns with the stator, then changes again, decreasing as the tooth moves away. An alternating voltage is produced.

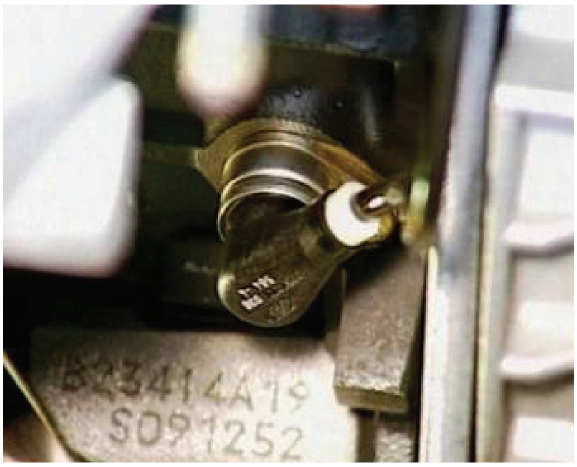
It is the frequency of this alternating voltage that is used by the control unit to calculate engine RPM.

Crankshaft position is detected by a separate sensor, also an inductive-type. It sends a signal to the control unit when a pin or bore passes and generates one pulse per revolution. It signals the control unit that the number 1 piston is, for example, 80° before top dead centre.

Ignition timing is then decided according to the operating conditions and triggered to fire a certain number of degrees from that point.

When only 1 sensor is used, the pulse inductor is shaped to provide information on both crankshaft speed and position. A disc attached to the crankshaft pulley has a number of equally spaced ribs around its circumference, but 2 ribs are omitted. The frequency of the pulse from each rib gives engine speed in RPM, but on each revolution, the pulse alters as the gap from the 2 missing ribs passes the sensor. This again gives the position of the number 1 piston.

Hall-effect sensors can also provide a voltage signal and like the inductive-type, can be mounted on the crankcase wall, or inside the housing of the distributor. *See section 3.4 fore more information..*



5.10 Detonation and Anti-Knock Devices

Normal Combustion

Under ideal conditions the common piston internal combustion engine burns its fuel air mix in the cylinder in an orderly and controlled fashion. The combustion is started by the spark plug some 15–40 crankshaft degrees prior to TDC (top dead centre) the point of maximum compression. This ignition advance allows time for the combustion process to develop peak pressure at the ideal time for maximum recovery of work from the expanding gases. This point is typically 14–18 crankshaft degrees ATDC (after top dead centre).

In *normal combustion* this flame front moves throughout the fuel air mix at a predictable rate. Pressure rises smoothly to a peak and then falls as combustion completes, burning nearly all the available fuel. In normal combustion this produces a rapid increase in cylinder pressure as the piston passes TDC and begins to move down the cylinder.

The Detonation Process

Detonation is an abnormal combustion process where some of the fuel air mix burns in an out-of-control manner at extremely high speeds. This creates a violent jump in cylinder pressure when the piston is nearly stationary near TDC and cannot effectively transfer the load to the crankshaft.

As a result of this very rapid release of energy, cylinder pressures briefly spike to several times normal, causing a characteristic sound which gives engine detonation its common names. When it occurs under low rpm high load conditions it produces a knocking rattle sound. At high rpm it could progress to a sharp ping or pink sound that leads to the other common name of "Pink" or "Pinking". The sound was caused by the ringing of the entire engine due to the sudden hammer blow of high pressure to the piston and cylinder head, caused by the detonation.

Detonation can be prevented by:

1. The use of a fuel with higher octane rating
2. Reduction of cylinder pressure by increasing the engine revolutions (lower gear), decreasing the manifold pressure (throttle opening) or reducing the load on the engine, or any combination.
3. Retardation of spark plug ignition.
4. Improved combustion chamber design that concentrates mixture near the spark plug and generates high turbulence to promote fast even burning.
5. Use of a spark plug of colder heat range in cases where the spark plug insulator has become a source of pre-ignition leading to detonation.

Correct ignition timing is essential for optimum engine performance and fuel efficiency.

Knock Sensors

A knock sensor consists of a small piezoelectric microphone, on the engine block, connected to the engine's ECU. Special analysis is used to detect the trademark frequency produced by detonation at various RPM. When detonation is detected the ignition timing is retarded, reducing the knocking and protecting the engine. Retarding the ignition timing will delay the timing of the spark, which also moves you away from your detonation threshold.

6.0 Oscilloscope Patterns Used in Fault Analysis

Key Learning Points

- Oscilloscope use; selection of appropriate settings and connections, basic interpretation of waveforms to manufacturer's patterns

6.1 Basic Oscilloscope Patterns

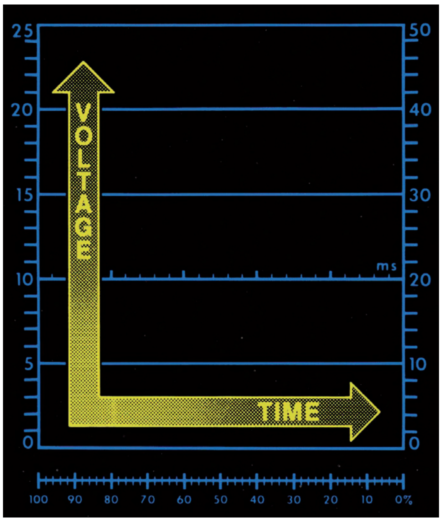
Waveform, Amplitude, Frequency, Pulse-width modulation

Note: Please refer to your instructor for additional information, which is available from Autodata® oscilloscope testing.

Waveform means the shape and form of a signal, such as a wave moving across the surface of water

In many cases the medium in which the wave is being propagated does not permit a direct visual image of the form. In these cases, the term 'waveform' refers to the shape of a graph of the varying quantity against time or distance. An instrument called an oscilloscope can be used to pictorially represent the wave as a repeating image on a LCD screen.

By extension of the above, the term 'waveform' is now also used loosely to describe the shape of the graph of any periodically varying quantity against time.



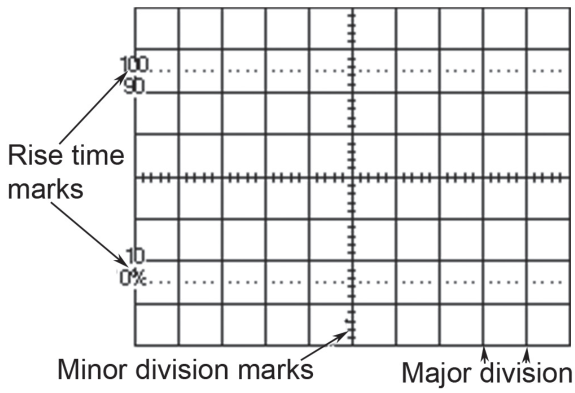
An oscilloscope allows us to measure the changes in voltage, test individual sensors and actuators. It gives us a voltage versus time graph. The greater the voltage the higher the pattern will travel up the screen. Horizontal movement of the pattern gives us the time measurement.

The two most basic measurements you can make are voltage and time measurements. Many digital oscilloscopes have internal software that will take these measurements automatically. Therefore instruction must be given on the specific oscilloscope been used.

The Display

While looking at the oscilloscope display notice the grid markings on the screen. Each vertical and horizontal line constitutes a *major division*. The screen is usually laid out in an 8-by-10 division pattern. Labelling on the oscilloscope controls (such as volts/div and sec/div) always refers to major divisions. The tick marks on the centre horizontal and vertical screen lines (see Figure 1) are called minor divisions.

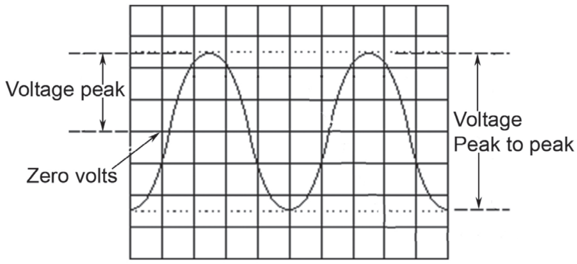
Many oscilloscopes display on the screen how many volts each vertical division represents and how many seconds each horizontal division represents. Many oscilloscopes also have 0%, 10%, 90% and 100% markings on the screen to help make rise time measurements.



An Oscilloscope Screen

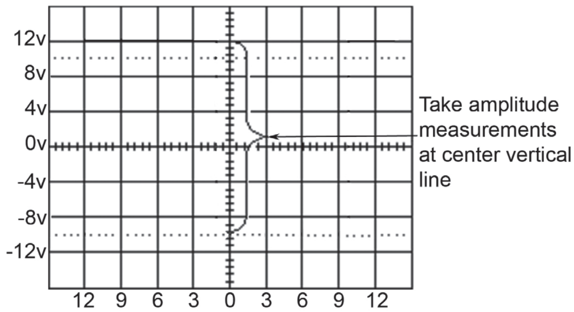
Voltage Measurements

Voltage is the amount of electric potential, expressed in volts, between two points in a circuit. Usually one of these points is ground (zero volts) but not always. Voltages can also be measured from peak-to-peak - from the maximum point of a signal to its minimum point. You must be careful to specify which voltage you mean. The oscilloscope is primarily a voltage-measuring device.



Voltage Peak and Peak-to-peak Voltage

You take voltage measurements by counting the number of divisions a waveform spans on the oscilloscope's vertical scale. Adjusting the signal to cover most of the screen vertically, then taking the measurement along the centre vertical screen line having the smaller divisions makes for the best voltage measurements. The more screen area you use, the more accurately you can read from the screen.

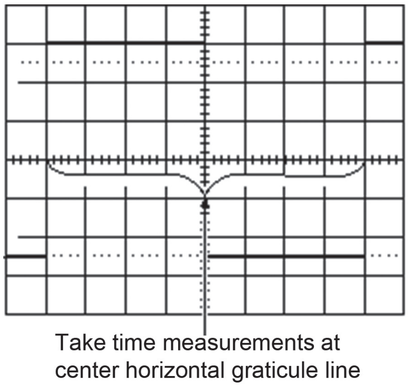


Measure Voltage on the Centre Vertical Screen Line

Many oscilloscopes have on-screen cursors that let you take waveform measurements automatically on-screen, without having to count screen marks. Basically, cursors are two horizontal lines for voltage measurements and two vertical lines for time measurements that you can move around the screen. A readout shows the voltage or time at their positions.

Time and Frequency Measurements

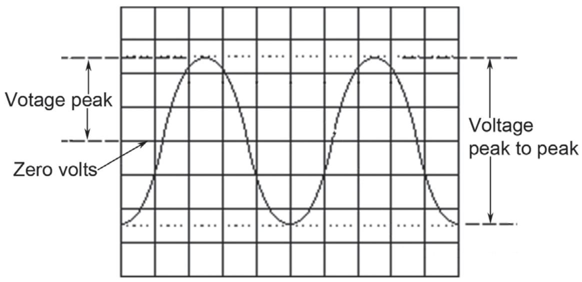
You take time measurements using the horizontal scale of the oscilloscope. Time measurements include measuring the period, pulse width and timing of pulses. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal to be measured to cover a large area of the screen. Taking time measurement along the centre horizontal screen line, having smaller divisions, makes for the best time measurements.



Pulse and Rise Time Measurements

In many applications, the details of a pulse's shape are important. Pulses can become distorted and cause a digital circuit to malfunction and the timing of pulses in a pulse train is often significant.

Standard pulse measurements are pulse width and pulse rise time. Rise time is the amount of time a pulse takes to go from the low to high voltage. By convention, the rise time is measured from 10% to 90% of the full voltage of the pulse. This eliminates any irregularities at the pulse's transition corners. This also explains why most oscilloscopes have 10% and 90% markings on their screen. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50% of full voltage.



Rise Time and Pulse Width Measurement Points

6.2 Oscilloscope Testing

Courtesy of Autodata®

Oscilloscopes

- Digital multi-meters are entirely satisfactory for checking circuits in a static condition and for instances where any change in reading is a gradual one, but for dynamic checking and the diagnosis of intermittent faults, the oscilloscope is a very powerful workshop tool.
- Unlike older analogue oscilloscopes dedicated to HT ignition testing, a modern digital oscilloscope has a variable voltage scale, enabling low voltages (typically 0-5 V or 0-12 V) to be displayed and also an adjustable time scale, enabling any wave form to be displayed in the ideal manner.
- Most oscilloscopes designed for automotive use can be hand-held and are therefore ideal for use in the workshop. They can also be used inside the car, while the vehicle is driven, to capture dynamic data.
- Usually it is possible to store wave forms and associated data in an internal memory and then print out or download the information onto a PC, enabling the scope patterns to be studied in detail.
- The oscilloscope display can show the amplitude, frequency, pulse width, shape and pattern of the signal received, by effectively drawing a graph of voltage (vertically) and time (horizontally).
- It is easy to connect (normally just two leads) and the speed of sampling can be far in excess of even the best of digital multi-meters.
- This fast response time enables diagnosis of intermittent problems and also enables the effect of disturbing parts of the system to be observed. When necessary, the response time can be slow enough to display signals such as the throttle position sensor.
- Once the cause of a problem has been diagnosed and rectified, the repair can be verified by retesting with the oscilloscope.

- The oscilloscope can also be used to check the overall condition of an engine management system equipped with a catalytic converter, by monitoring the activity of the oxygen sensor.
- The complex electronic engine management systems fitted to catalyst equipped vehicles are designed to maintain the mixture level between quite close tolerances so that the oxygen sensor is able react to small changes in the exhaust oxygen level and feed this information back to the ECM in the form of a voltage signal. By watching the oxygen sensor signal with an oscilloscope any irregularity in the overall system performance can be detected. If the wave form displayed is satisfactory this is a reliable indication that the whole system is operating correctly.
- Currently available oscilloscopes are easy to connect and use, enabling a trace to be displayed on the screen without any specialist knowledge or experience. The interpretation of this trace can be greatly assisted by reference to the typical wave forms illustrated in this chapter.

Wave Forms

Each oscilloscope wave form has one or more of the following parameters:

- *Amplitude* - voltage (V) The signal voltage at a certain moment in time
- *Frequency* - cycles per second (Hz). The time between points of the signal
- *Pulse width* - duty cycle (%). The period during which the signal is ON - expressed as a percentage (%) of the total
- *Shape* - spike, curve, saw-tooth etc. The overall 'picture' of the signal
- *Pattern* - repeated shapes. The pattern of repetition of the overall shape of the signal
- The oscilloscope will show all these parameters in one display and by comparing the scope traces from the vehicle under test with those illustrated, a judgement can be made about the condition of each circuit and its components.
- The scope trace for a faulty circuit or component will usually appear very different to that for a satisfactory one, thus simplifying fault identification.

The five parameters listed above can be categorised as follows:

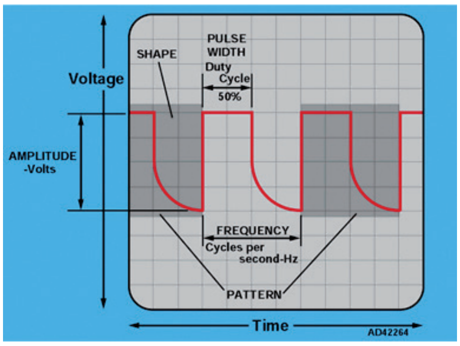


Fig 1 - Wave form parameters

Direct Current (DC) Voltage Signals - Amplitude Only

Analogue signal voltages from components such as:

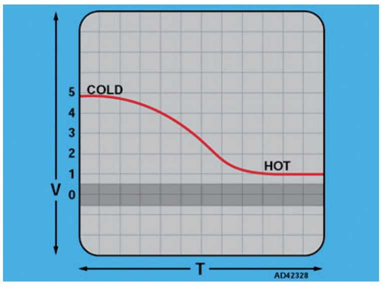


Fig 2 - Engine coolant temperature (ECT) sensor

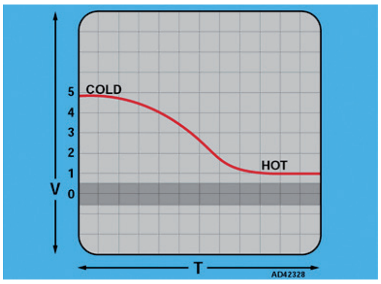


Fig 3 - Intake air temperature (IAT) sensor

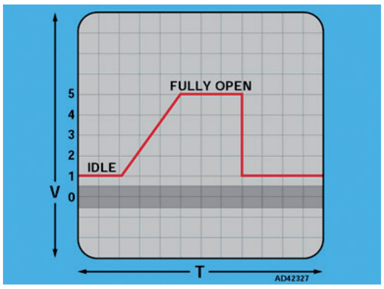


Fig 4 - Throttle position (TP) sensor

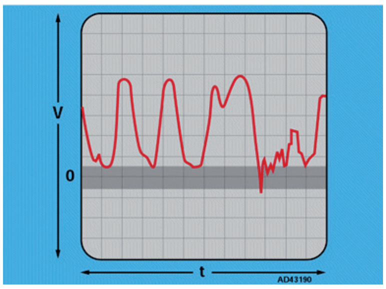


Fig 5 - Heated oxygen sensor (HO2S)

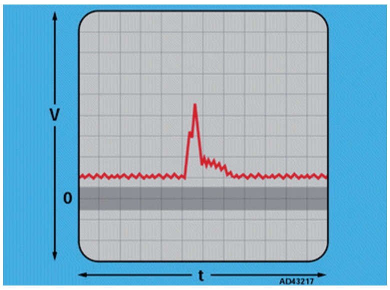


Fig 6 - Volume air flow (VAF) sensor

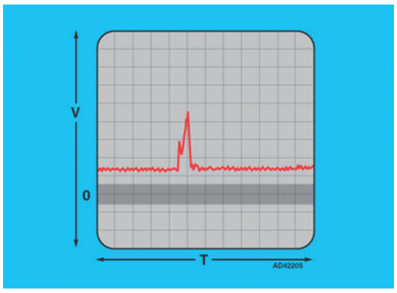


Fig 7 - Mass air flow (MAF) sensor

Alternating Current (ac) Voltage Signals - Amplitude, Frequency and Shape

AC voltage signals are generated by components such as:

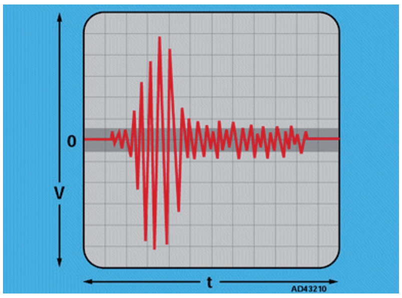


Fig 8 - Knock sensor (KS)

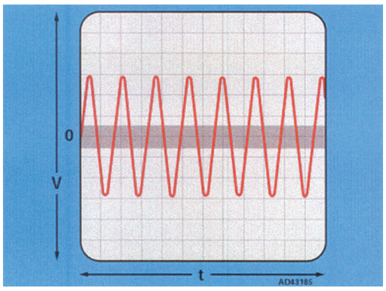


Fig 9 - Engine speed (RPM) sensor - inductive type

Frequency Modulated Signals -Amplitude, Frequency, Shape and Pulse Width

Frequency modulated signals are generated by components such as:

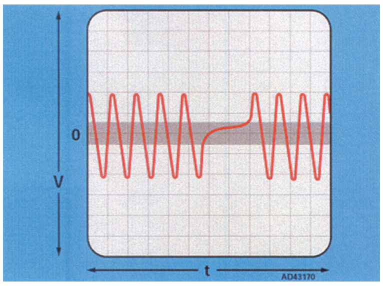


Fig 10 - Crankshaft position (CKP) sensor - inductive type

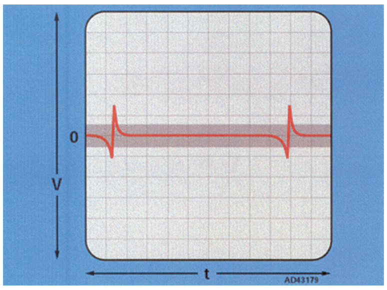


Fig 11 - Camshaft position (CMP) sensor - inductive type

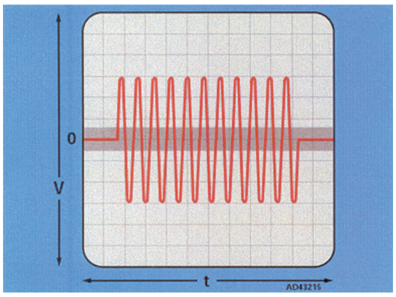


Fig 12 - Vehicle speed (VSS) sensor - inductive type

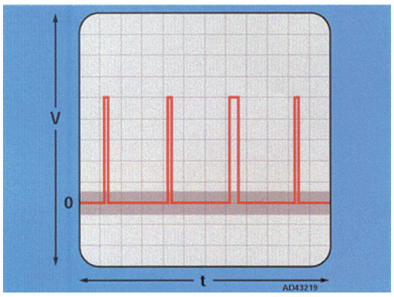


Fig 13 - Hall effect speed and position sensors

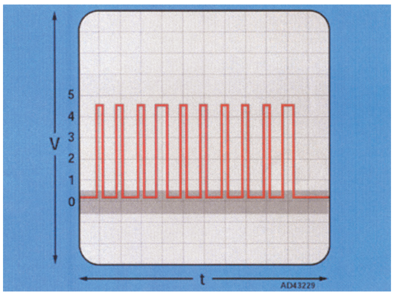


Fig 14 - Optical speed and position sensors

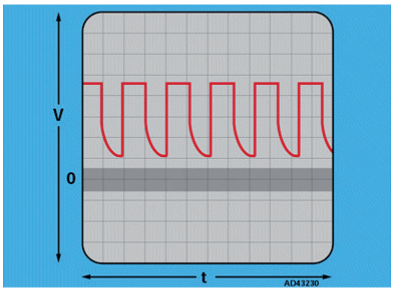


Fig 15 - Mass air flow (MAF) and manifold absolute pressure (MAP) sensors - digital type

Pulse Width Modulated Signals - Amplitude, Frequency, Shape, Pulse Width

Pulse width modulated signals from components such as:

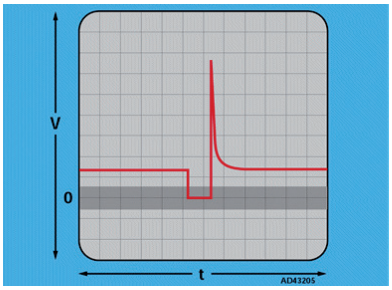


Fig 16 - Injectors

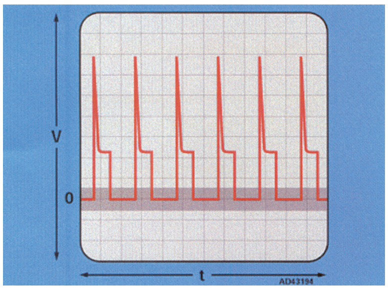


Fig 17 - Idle air control (IAC) devices

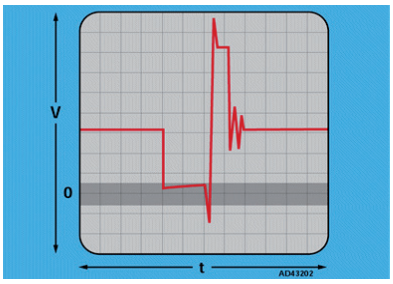


Fig 18 - Ignition coil primary circuits

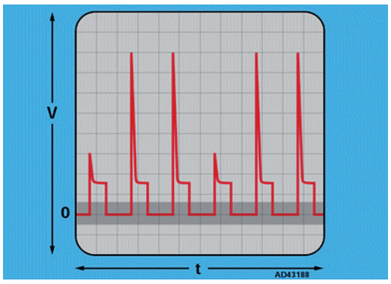


Fig 19 - Evaporative emission (EVAP) canister purge valve

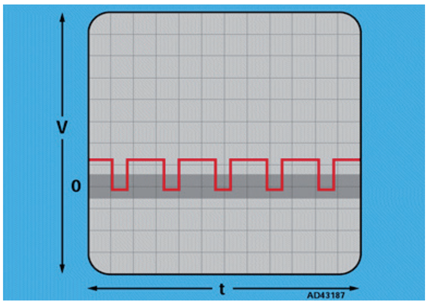


Fig 20 - Exhaust gas recirculation (EGR) valves

Serial Data - Amplitude, Frequency, Shape, Pulse Width and Pattern

- Serial data signals will be generated by the engine control module (ECM), if it has a self-diagnosis facility - *Fig 21*.
- By noting the pulse width, pattern and frequency, the short pulses can be counted in groups and interpreted as a trouble code, in this case 1223.
- The amplitude and shape remain constant and the pattern will be repeated until the trouble code has been erased.

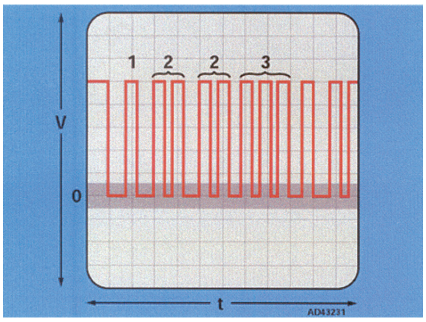


Fig 21 - Trouble code wave form

Interpreting Wave Forms

Typical Wave Worms

Oscilloscope wave form patterns can vary greatly and are dependent on many factors. Therefore prior to making a diagnosis or changing components the following points should be considered when the wave form obtained does not appear to be correct when compared with the 'typical' wave form.

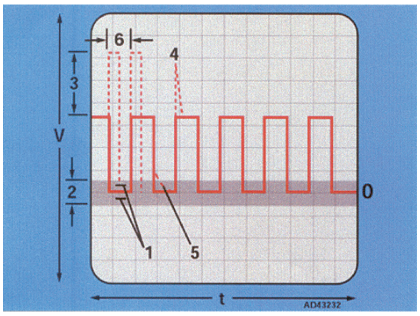


Fig 22 - Digital wave form

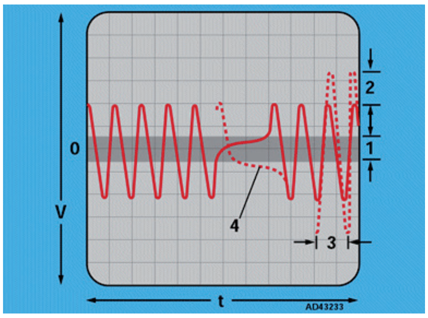


Fig 23 - Analogue wave form

Voltage

Typical wave forms indicate the approximate position of the wave form in relationship to the 'zero grid', but this may vary *Fig 22 [1]*, dependent on the system being tested and may be positioned anywhere within the approximate 'zero range' *Fig 22 [2] & Fig 23 [1]*.

- The amplitude or overall height of the pattern (the voltage) *Fig 22 [3] & Fig 23 [1][2]*, will depend on the circuit's operating voltage.
- For direct current (DC) circuits this will depend on the voltage being switched, for example, idle speed control device voltage will be constant and will not vary with engine speed.
- For alternating current (ac) circuits this will depend on the speed of the signal generator, for example, an inductive crankshaft position (CKP) sensor's output voltage will increase with engine speed.
- Therefore if the oscilloscope pattern is too high (or the upper part is missing) increase the voltage scale to obtain the view required. If the pattern is too low decrease the voltage scale.
- Some circuits operating solenoid components, for example idle speed control devices, may display voltage spikes *Fig 22 [4]*, when the circuit is switched off. This voltage is generated by the component and can normally be ignored.
- Some circuits that have a square wave type of typical wave form may display the voltage decaying at the end of the switching period *Fig 22 [5]*. This is a characteristic of some systems and can normally be ignored, as it does not by itself indicate a fault.

Frequency

- The overall width of the pattern (the frequency), will depend on the circuit's operating speed.
- The typical wave forms illustrated show the wave form viewed with the oscilloscope's time scale set to enable detailed observation.
- In direct current (DC) circuits the time scale will be dependant on the speed at which the circuit is switched *Fig 22 [6]*, for example, the frequency of an idle speed control device will vary with engine load.

- In alternating current (ac) circuits the time scale will depend on the speed of the signal generator *Fig 23 [3]*, for example, an inductive crankshaft position (CKP) sensor's frequency will increase with engine speed.
- If the oscilloscope pattern is too compressed, decrease the time scale to obtain the view required. If the pattern is too expanded, increase the time scale.
- If the pattern is reversed *Fig 23 [4]*, this indicates that the system being tested has its component connected in the opposite polarity to the typical wave form shown and can normally be ignored as it does not by itself indicate a fault.

Component testing

- Wave forms for a variety of components can be displayed. A few of the more common examples are described below.
- Most modern oscilloscopes have just two test leads, used with a variety of interchangeable test probes. The red lead is the positive and is normally connected to the ECM pin. The black lead is the negative and is normally connected to a good earth.
- If the leads are inadvertently connected with the wrong polarity, usually the only consequence is that the wave form will be displayed upside down.

Injectors

- All electronically controlled intermittent injection systems operate by varying the opening time of the injectors to match the quantity of fuel supplied with the engine operating conditions.
- The duration of the electrical impulses from the control unit is measured in milliseconds (ms) and typically ranges from 1 to 14. The oscilloscope on most engine testers can be used to display the injector pulse, enabling the duration to be measured.
- A typical oscilloscope trace is shown in *Fig 24*.
- A series of smaller pulses, which hold the injector open after the initial negative pulse and a sharp positive voltage spike may be displayed as the injector closes.
- It is therefore possible to check that the control unit is operating correctly by observing the changes in injector opening times during various engine operating conditions.
- Pulse duration during cranking and at cold idle will be higher than at hot idle, and will increase as engine load increases.
- This effect will be particularly evident if the throttle is 'blipped'.

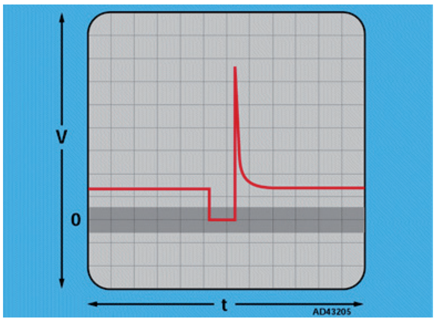


Fig 24 - Injector wave form

Injector Pulse

- Using a thin probe, connect the oscilloscope test probe to the ECM injector terminal and the second test probe to earth.
- Crank the engine and check the wave form.
- Start engine and observe the wave form at idle speed.
- Open the throttle rapidly to increase engine speed to around 3000 rpm.

- The measured pulse duration should increase during acceleration and then stabilise at a reading equal to or slightly below the idle speed value.
- Close the throttle rapidly and the trace should become a straight line with no pulse indicating that injection has been cut-off (for systems fitted with overrun injection cut-off).
- When the engine is started from cold the quantity of fuel required is increased and therefore the pulse duration or dwell will be greater.
- During warm-up the injection period should progressively decrease until the engine reaches normal operating temperature.
- Systems without a cold start injector usually give additional injector pulses during the cold start, which may be seen as long and short pulses on the scope.

Condition	*Duration*
Idle speed	1-6 ms
2000-3000 rpm	1-6 ms
Full throttle	6-35 ms

Typical Injector Duration Periods

Inductive Sensors

The general procedure is as follows:

- Select sensor pin from pin data list with wave form reference.
- Connect oscilloscope probe to ECM pin and second probe to earth.
- Start engine and observe test conditions.
- Compare scope trace with wave form reference.
- Raise the engine speed and watch for the voltage (amplitude) display to increase.

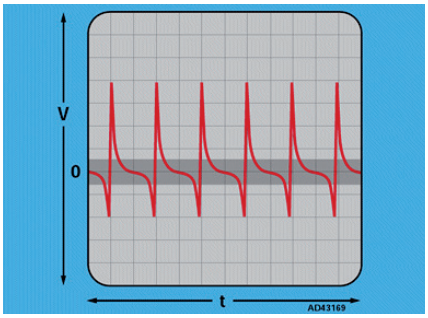


Fig 25 - Inductive sensor wave form

Idle Air Control (IAC) Valve

- Idle air control (IAC) valves come in many different types, each with a different wave form.
- In each case the duty cycle (or ON time) of the valve should increase when any additional engine load starts to reduce the idle speed.
- If the duty cycle varies but the idle speed is not maintained under load, this indicates a faulty valve.
- If the wave form shows a straight line around the zero mark, or the line is constant at the 5 V or 12 V level, this indicates a fault in the IAC valve circuit or ECM signal output.
- The commonly used 4 pin stepper motor type is described below. Two and three pin IAC valves can be tested in a similar way, but will of course generate very different wave forms.
- The stepper motor responds to an oscillating signal from the ECM, enabling small adjustments to be made to the engine idle speed, in reaction to variations of operating temperature and load.

- This voltage signal can be checked by connecting the oscilloscope test probe to each of the four stepper motor ECM pins in turn.
- Ensure engine is at normal operating temperature.
- Start the engine and allow idle speed to stabilise.
- Increase the load on the engine by switching on the headlights, air conditioning or by turning the steering (power steering only).
- The idle speed should momentarily drop, but then be stabilised by the action of the IAC valve.
- Compare scope trace with wave form reference *Fig 26*.

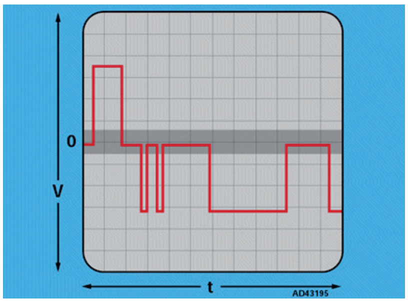


Fig 26 - Idle air control (IAC) valve wave form

Oxygen Sensor (O2S)

Note: The following voltage figures refer to the almost universally used Zirconium type O2S, without a 0,5 V control reference. A few recent models are fitted with a Titanium sensor which has an operating range of 0-5 volts and shows a high voltage signal with a weak mixture and a low voltage signal with a rich mixture.

- Connect oscilloscope test probes between oxygen sensor ECM pin and earth.
- Ensure engine is at normal operating temperature.
- Compare scope trace with wave form reference *Fig 27*.
- If the trace shows no wave form but instead is a straight line, this usually indicates a weak mixture if the voltage is approximately 0-0,15, or a rich mixture if the voltage is approximately 0,6-1 - refer to the CD for possible causes of this condition.
- If the wave form is satisfactory at idle, open the throttle briefly several times in succession.

- The wave form should show the signal voltage 'cycling' between approximately 0-1 Volt.
- The increasing voltage corresponds to the engine speed rising and the decreasing voltage corresponds to the engine speed falling.

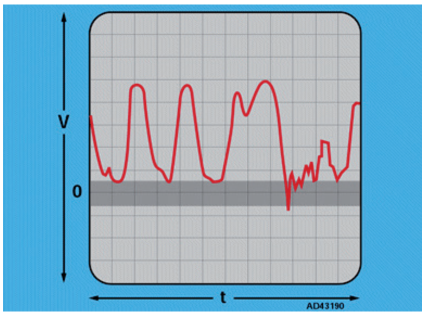


Fig 27 - Oxygen sensor (O2S) wave form

Knock Sensor (KS)

- Connect oscilloscope test probes between knock sensor ECM pin and earth.
- Ensure engine is at normal operating temperature.
- Briefly snap throttle open.
- Wave form should display an ac signal showing a considerable increase in amplitude *Fig 28*.
- If this signal is not distinctly displayed, tap the cylinder block lightly in the region of the sensor.
- If the signal is still not satisfactory this indicates a faulty sensor or associated circuit.

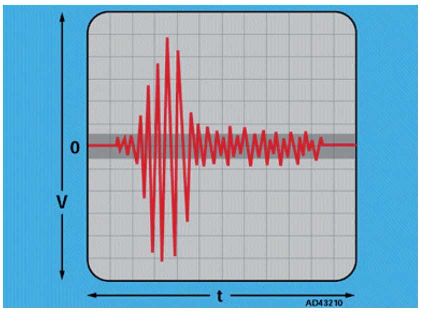


Fig 28 - Knock sensor (KS) wave form

Ignition Amplifier

- Connect oscilloscope test probes between ignition amplifier ECM pin and earth.
- Ensure engine is at normal operating temperature.
- Start the engine and allow to idle.
- The signal should show a digital DC voltage pulse.
- Compare scope trace with wave form reference *Fig 29*.
- If the signal is satisfactory the amplitude, frequency and shape of each pulse should be closely matched.
- Increase the engine speed and check that the signal frequency increases in proportion to the engine rpm.

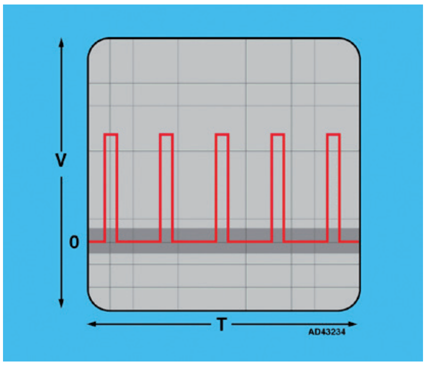


Fig 29 - Ignition amplifier wave form

Ignition Coil - Primary

- Connect oscilloscope test probes between ignition coil ECM pin and earth.
- Ensure engine is at normal operating temperature.
- Start the engine and allow to idle.
- Compare scope trace with wave form reference *Fig 30*.
- Positive voltage spikes should be of even amplitude.
- Major differences of amplitude could indicate either a high resistance in the secondary circuit or a faulty spark plug or HT lead (where applicable).

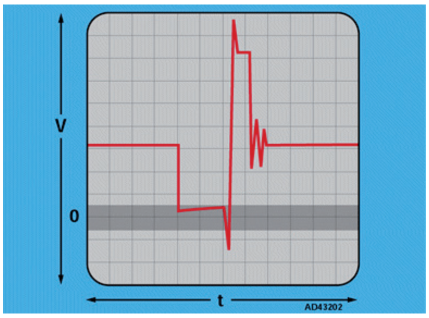


Fig 30 - Ignition coil wave form

Electronic Control Modules

- Without specialist equipment and data no testing of control modules is possible, except by self-diagnosis (if applicable) or substitution.
- Several companies operate a repair or exchange service for control modules and some offer a diagnosis service via a modem link to an appointed agent.

7.0 Technical Report on Primary Engine Censors

Key Learning Points

- Basic testing and illustrated report, including a block/line circuit diagram of the primary engine management sensors, actuators and control unit of a training vehicle/unit

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

8.0 Terms as Applied to the Automotive ECU

Key Learning Points

- Fault code/description (Fault data retained in the ECU memory). Data link/OBD socket; location in various training vehicles/units, VIN information, EOBD, erasure of fault codes

8.1 Precautions with 'On-Board Electronic Systems'

Introduction

As with all automotive electronic systems, the connection and used of the Scan Tool must be undertaken by following the instructions in the workshop manual. Failure to do so could result in causing a catastrophic failure in the vehicle as for instance the ECU could be "spiked" with excessive voltage and as a result fail. In some instances the replacement of an ECU can sometimes cost more that the current value of the vehicle.

Use of Equipment

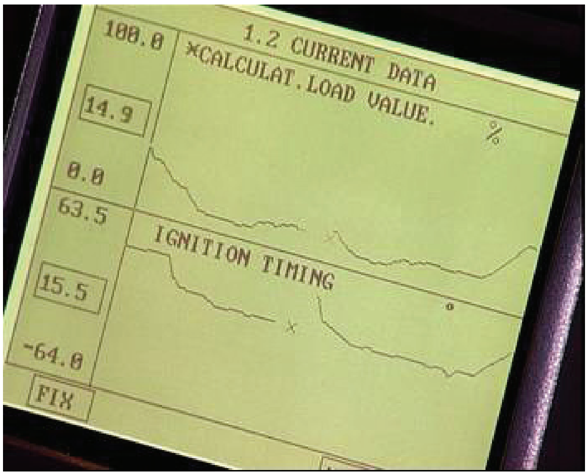
Follow the equipment (Scan tool) manufacturer's user manual for the correct procedure and operation of the equipment. This process will provide you with the best information that the tool can obtain when running a diagnostics test and therefore assist you in making the correct determination of the system condition/fault.

8.2 OBD Systems

On-Board Diagnostic systems use the vehicle's computers to detect problems with its emission components and other systems. It informs the vehicle operator when a fault occurs and assists the technicians in identifying and repairing malfunctioning circuits.

There are two different types of On Board Diagnostic systems. OBD 1, which operates under manufacturer standards and OBD 2, which operates under a standard set by the Society of Automotive Engineers.

OBD I is a system that identifies faults in the vehicle's emission and powertrain.



It has been superseded by OBD II, an enhanced On-Board diagnostic system that identifies faults in the vehicle's emission and powertrain and also tests the vehicles operational system to determine faults that do not affect the vehicles driveability but may affect its safety or emission efficiency.

Both systems provide a common standard that all vehicle manufacturers adhere to. This means that any generic OBD II compatible scan tool can access most vehicle data.

A scan tool is used to access the on-board diagnostic information and the data link connector allows for the scanner to be connected to the car. This connector is a common size and shape and its location is also standardised, under the driver's side of the instrument panel.

8.3 OBD & EODB

On-Board Diagnostics, or OBD, in an automotive context, is a generic term referring to a vehicle's self-diagnostic capability. If the vehicle's onboard diagnostic system detects a malfunction, a *DTC* (*diagnostic trouble code*) corresponding to the malfunction is stored in the vehicle's computer and in certain cases will illuminate the *MIL* (*malfunction indicator light*, or *check engine light*). A service technician can retrieve the DTC, using a "scan tool" and take appropriate action to resolve the malfunction.

Prior to the advent of digital powertrain control modules which enabled the OBD feature, repairing a vehicle relied solely upon the technician's skill and service literature from the auto manufacturer.

Overview

A modern vehicle has several hundred DTC's, each of which addresses a particular malfunction. A simple malfunction may be that an electrical connector is disconnected, or the fuel cap is not properly installed. A DTC may indicate a component has worn out or failed. Some DTC's indicate an entire sub-system, such as the catalyst system, is not functioning properly.

- Prior to OBD, auto manufacturers did not standardize DTC's.
- OBD-I begins standardized DTC's c. 1989.
- OBD-II adds specific tests to determine the vehicle's emission performance, c. 1996.
- OBD-III adds more features and is in the regulatory development phase.

Goal

The regulatory intent of OBD is to force the auto manufacturers to design reliable emission control systems that remain effective for the vehicle's "useful life". Each vehicle's emission performance deteriorates and the rate of deterioration varies widely depending on a number of factors such as, age, mileage, usage, geography and design. The most sophisticated features of an OBD-II system determine if the vehicle's emission performance has deteriorated below a regulated level of performance; if so, the MIL will illuminate.

It is cost prohibitive for auto manufacturers to design an emission control system that is "deterioration proof".

EOBD (European On-Board Diagnostics) is a diagnostic system that is able to detect and store emission related failures. A fault in EOBD will trigger a "freeze frame" and a "TROUBLE CODE" (TC), after the correct drive cycle.

In Europe the EOBD (European On-Board Diagnostics) system was mandated by European Directive 98/69/EC for all petrol vehicles made from 1 January 2001.

Modern EOBD implementations use a standardized fast digital communications port to provide real-time data in addition to a standardized series of *diagnostic trouble codes,* or DTCs, which allow you to rapidly identify and repair malfunctions within the vehicle. Fault codes are defined by the Society of Automotive Engineers (SAE) and binding for all EOBD systems.

System's Monitored by EOBD

- Catalytic converter efficiency
- Misfire detection. (ignition and crank angle)
- Fuel system
- O2 sensors
- (EVAP system) including tank ventilation feedback
- EGR system
- Tank contents (charcoal filter)
- PCM microprocessor

8.4 Diagnostic Trouble Codes

Diagnostic trouble codes are generic, as are the names used to describe components. Computers also communicate with each other using standardised languages. Therefore, all non-manufacturer specific codes are the same from each vehicle.

Standardised languages also allow the manufacturer to provide specific technologies to the vehicle in order to maintain a level of security in relation to theft deterrent and vehicle immobilisation.

The system reports that a fault exists by a Malfunction Indicator Lamp or MIL located in the instrument cluster or by a scan tool connected to the vehicles diagnostic plug.

The Malfunction Indicator Lamp also indicates, to the driver, that there is a problem in the system. When a malfunction occurs, the Malfunction Indicator Lamp will remain on until the system returns to normal or the fault is repaired or rectified.

A Diagnostic Trouble Code or DTC is then placed in the computers memory. The Diagnostic Trouble Codes inform the technician of the computers opinion of the location of a system fault.

The Diagnostic trouble codes are used in conjunction with Flow Charts found in the Manufacturers Service Manual, to assist technicians in determining the likely cause of the failure.

Both OBD I and OBD II monitor engine sensors, fuel delivery components and emission control devices that, if faulty, will cause exhaust emissions to rise.

Simpler OBD systems are normally limited to the detection of an open or short in a sensor circuit.

Whereas OBD II components and circuits are monitored for opens, shorts and abnormal operation.

Diagnostic trouble codes are generated by the on-board diagnostic system and stored in the computer's memory. They indicate the circuit in which a fault has been detected. Diagnostic trouble code information remains stored in the engine control module or ECM long-term memory regardless of whether a hard or intermittent fault caused the code to set

The diagnostic trouble code uses a series of letters and numbers to identify which system, component and circuit is at fault. This allows each code relating to a particular system or sensor to be arranged together.

The first part of the code is a letter that identifies whether the fault is located within the powertrain, body, chassis controller, or the communication system (P, B, C and U).

The second part consists of numbers starting with 0 or 1. 0 indicates an OBD code. 1 indicates a manufacturer code. The following 3 numbers identify the system and component related to the fault.

On-board diagnostic systems store a diagnostic trouble code in the computer's "Keep Alive Memory" or KAM. These codes will remain in the vehicle's memory until power is disconnected.

The OBD II system continually monitors the performance of the vehicles emission system. The malfunction indicator lamp must light when a failure will cause the vehicle's emission levels to rise.

For example, catalytic converter efficiency is monitored and, if its efficiency is out of range, the malfunction indicator lamp will illuminate and a diagnostic trouble code will set.

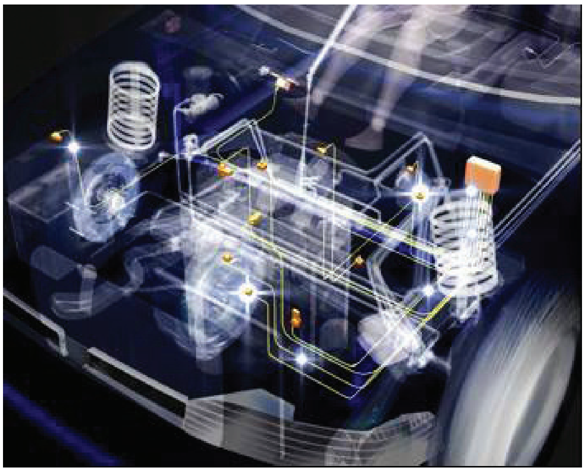
Trouble Codes	
The First Character	
Letter System	
B	Body
C	Chassis
P	Powertrain
U	Network
Second Character	
Code Type	Explanation
Generic (normally P0xxx)	The definition for the code is defined in the EOBD/OBD11 standard and will be the same for all manufacturers.
Manufacturer specific (normally P1xxx)	Where manufacturers feel that a code is not available within the generic list, they can add their own codes. The definitions fro these are set by the manufacturer.
Third Character	
Third Digit	System or Sub-System
1	P0100-Mass Or Volume Air Flow Circuit High Input
2	P0201-Cylinder 1 Injector Circuit Open
3	P0303-Cylinder 3 Misfire Detected
4	P0403-Exhaust Gas Recirculation Circuit High Voltage
5	P0500-Vehicle Speed Sensor Malfunction
6	P0615-Starter Relay Circuit Malfunction
7	P0727-Engine Speed Signal Malfunction
8	Transmission

8.5 Monitoring Emissions

Under the OBD II standard the vehicle's computer monitors the emission systems in two ways.

The first is referred to as "Continuous" where major emission causing faults such as Engine Misfire and incorrect Air/fuel mix are continually monitored.

The second is referred to as "Non-continuous". This is where checks are made only once each warm up cycle.



Each time the engine is started, the computer checks components such as the Oxygen sensor, catalytic converter and other engine systems are functioning correctly If a fault is detected the MIL is illuminated indicating that the vehicle needs attention.

If the condition is intermittent and the faulty system operates normally, the MIL will turn off after the vehicle has operated through three warm-up cycles, but the Diagnostic Trouble Code will remain in the computer memory for a set period.

If the fault does not re-occur within 40 drive cycles, the code will be automatically erased but will remain logged in the computer memory as a history code.

8.6 Connecting a Scan Tool & Obtaining Data

Obtaining & Interpreting Scan Tool Data-Preparation and Safety

Objective

Retrieve, record and clear stored OBD I & II diagnostic trouble codes using a scan tool.

Safety Check

If the vehicle is to be run inside the workshop use exhaust extraction hoses.

Output solenoids can be energized from the scan tool, activating components without warning. It is imperative that the operator should follow the service manual procedures.

Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Make sure that you follow service manual procedures for the vehicle you are working on.
- The standard procedure for retrieving codes for an OBD I vehicle, is to access the codes, write them down, clear the codes, start the vehicle and recheck for any codes that reset.
- The standard procedure for diagnosing an OBD II vehicle is different as it requires that the codes should NOT be cleared until the vehicle is repaired. Clearing the codes also clears all of the freeze frame data in the system that is useful for the diagnosis process.
- It may take several 'trips' for the code to reset, so with OBDII you must complete the diagnosis process first before clearing the codes.
- Always check for any applicable service bulletins when diagnosing computer related problems, as they can provide valuable information about new faults that emerge on vehicles as their operational characteristics change as the vehicles get older.

Step-by-Step Instruction

1. *Connect the scan tool:* Locate the scan tool access point and connect the scan tool using the appropriate connector for the vehicle. Turn on the vehicle ignition. Turn on the scan tool. Run the scan tool diagnostic program and navigate through each of the different systems in turn to access the diagnostic trouble codes from the vehicles electronic control module. Note your findings for each vehicle system.

2. *Check your findings:* Look up what each code means and present the information to your instructor. Any fault indicated by the diagnostic trouble codes will need to be corrected before you clear the codes.

3. *Clear fault codes:* To clear the fault codes from the vehicle, select the delete codes option on the scan tool. Check that the codes have cleared and turn off the vehicle ignition.

4. *Recheck for fault codes:* Turn on the vehicle ignition. Run the scan tool diagnostic program and navigate through each system again to check the codes do not reactivate. If the fault codes reactivate, take your findings to your instructor. Turn off the vehicle ignition. Turn off the scan tool and disconnect from the access point.

9.0 Use of 'Blink' Fault Code Display/Retrieval from ECUs

Key Learning Points

- Blink/flash code-number of flashes between each pause, use of LED tester/analogue voltmeter or STAR tester
- Location and use of manufacturer data on 'blink' or 'flash' trouble codes/data/fault diagnosis assistance

9.1 Blink Fault Codes

Prior to the introduction of OBD II many vehicles systems could be diagnosed using "Blink Codes". The system worked by using "jumper wires" between designated connections in the vehicles electrical system (normally at a junction/scan tool connection point and counting the blinks of the check engine light or "MIL" to determine the fault. Most manufacturers provide this information in their workshop manuals; however with the advent of more sophisticated monitoring systems being introduced into the vehicles the use of system scan tools to determine faults has almost become mandatory.

10.0 Fault Finding Precautions on the ECU

Key Learning Points

- ECU precautions; possibility of damage by external voltage sources, excessive removal/refitting of wiring harness terminations/connections. Circuit connections; incorrect fitting (mixing of gold plated to tin plated connectors).

10.1 ECU Precautions

When removing an engine ECU care must be taken not to damage the connecting pins or locking tabs. Be aware of static electricity that may be present, therefore remove all static electricity before touching ECU. Store the ECU in a clean dry environment. Follow manufactures instructions when working on any electronic component.

11.0 Engine Management System Fault Code Data

Key Learning Points

- Locate and display fault code data on a training vehicle/unit with a pre-determined fault (installed) in the engine sensor/actuator section of the ECU memory, code reader/scan tool connected correctly, input of vehicle/unit identifying details, locate, display and record the relevant fault description/code data, use of regulated voltage type battery chargers to maintain battery voltage.

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

12.0 Air Bag and Seat Belt Pre-Tensioner Precautions

Key Learning Points

- Manufacturer's recommendations on airbag, seat belt pre-tensioners removal, de-activation and storage e.g. battery disconnected, correct removal procedure, de-activation carried out in safety system/cage, hearing protection worn etc., units handled and disposed of appropriately, caution on heat and possible sodium hydroxide residue findings to manufacturer's specifications

12.1 Precautions When Working on SRS Systems

Introduction

Supplemental Restraint System or SRS is designed to work in conjunction with the standard three-point safety belts to reduce injury in a collision.

The SRS primary crash airbag sensors are connected to the airbag module controllers and determine when the airbags are deployed. During a collision, the sensors quickly inflate the airbags to reduce injury by cushioning the driver and passenger from striking the dashboard, windshield, steering wheel and any other internal hard surfaces. The airbag inflates so quickly, in a fraction of a second, that in most cases it is fully inflated before the vehicle occupants start to move during an automotive collision.

Since the SRS is a complicated and essentially important system, its components are constantly being continually tested by a diagnostic monitor computer, which illuminates (sometimes flashing) the airbag indicator light on the instrument cluster for approximately 6 seconds when the ignition switch is turned to the RUN position when the SRS is functioning properly. After being illuminated for the 6 seconds, the indicator light should then normally turn off.

If the airbag light does not illuminate at all or stays on continuously, or flashes at any time during a normal drive cycle, it normally means that a problem has been detected by the diagnostic monitor computer.

Service Precautions

Whenever working around, or on, an airbag supplemental restraint system, *always* adhere to the following warnings and cautions.

Refer to the latest information from the vehicle manufacture when working on the SRS system.

Beware that static electricity will trigger airbag systems so ensure that there is no static electricity present when working an these systems.

Always wear safety glasses when servicing an airbag vehicle and when handling an airbag module.

Carry a live airbag module with the bag and trim cover facing away from your body, so that an accidental deployment of the airbag will have a small chance of personal injury.

Place an airbag module on a table or other flat surface with the bag and trim cover pointing up.

Wear gloves, a dust mask and safety glasses whenever handling a deployed airbag module. The airbag surface may contain traces of sodium hydroxide, a by-product of the gas that inflates the airbag and which can cause skin irritation.

Ensure to wash your hands with mild soap and water after handling a deployed airbag.

All airbag modules with discoloured or damaged cover trim must be replaced, not repainted.

All component replacement and wiring service must be made with the negative and positive battery cables disconnected from the battery for a minimum of one minute prior to attempting service or replacement.

NEVER probe the airbag electrical terminals. Doing so could result in airbag deployment, which can cause serious physical injury.

If the vehicle is involved in a minor collision which results in a damaged front bumper or grille, inspect the airbag sensors before affecting the repair to ensure that they were not damaged in the collision.

If at any time, the airbag light indicates that the computer has noted a problem, run a full diagnostics test on the system.

Disarming the System

Always follow the exact directions shown in the vehicle workshop manual.

As a general rule the following is required as "part" of this procedure:

- Disconnect the negative battery cable from the battery.
- Disconnect the positive battery cable from the battery.
- Wait 20 minutes approx. This time is required for the back-up power supply in the airbag diagnostic monitor to completely drain.

The system is now normally disarmed.

Arming the System

Always follow the exact directions shown in the vehicle workshop manual.

As a general rule the following is required as "part" of this procedure:

- Connect the positive battery cable.
- Connect the negative battery cable.
- Stand outside the vehicle and carefully turn the ignition to the RUN position.
- Be sure that no part of your body is in front of the airbag module on the steering wheel, to prevent injury in case of an accidental airbag deployment.
- Ensure the airbag indicator light turns off after approximately 6 seconds. If the light does not illuminate at all, does not turn off, or continues to flash, call you instructor.

If the light does turn off after 6 seconds and does continue to flash, the SRS is now normally armed and should be working properly.

12.2 SRS – Safety Systems

Vehicle safety systems are designed to protect occupants during accidents and can be classified as primary or passive systems and secondary or active systems.

Primary systems are ready to use in any accident. They include bumper bars, body panels, seatbelts, crumple zones and collapsible steering columns.

A secondary system has to be activated to work and is only necessary in severe accidents. The two most popular types of secondary systems are supplemental restraint system airbags and seatbelt pre-tensioners.

Seatbelts locate and secure the occupant within the seat and vehicle cabin and in minor collisions perform their task well.

In a more severe impact inertia causes the occupant to move more and with greater force. This increases the possibility of injury caused by the restraining force exerted by the seatbelt or from the occupant striking interior fittings.

If a vehicle is fitted with an airbag, it deploys during a collision, offering a greater degree of protection from injury.

Airbags provide cushioning against the effects of inertia. The bag deploys towards the occupants approaching body, inflated rapidly by pressurized nitrogen gas. Typically this takes no longer than three hundredths, or 0.03 of a second.

The airbag is not a nice soft pillow, but a strong counter force to react against the inertia of the occupants. It is not designed to be comfortable. It is designed to minimize injury.

Immediately after absorbing the momentum, the airbag deflates having done its job.

12.3 SRS – Air Bags

An *airbag* is a flexible membrane or envelope, inflatable to contain air or some other gas. Airbags are most commonly used for cushioning, in particular after very rapid inflation in the case of a collision.

Automobile Airbags

The design is conceptually simple—accelerometers trigger the ignition of what is essentially solid rocket propellant to very rapidly inflate a nylon fabric bag, which reduces the deceleration experienced by the passenger as they come to a stop in the crash situation. The bag has small vent holes to allow the propellant gas to be (relatively) slowly expelled from the bag as the occupant pushes against it.

15,000 lives have been saved by airbags in last 20 years since. Initially, most vehicles featured a single airbag, mounted in the steering wheel and protecting the driver of the car (who is the most at risk of injury). During the 1990s, airbags for front seat passengers, then separate side impact airbags placed between the door and occupants, became common. Most jurisdictions now explicitly require at least driver airbags in all cars, or set passenger safety standards that can only be met by their use.

Statistics show that passengers in cars fitted with airbags have approximately 30% less chance of dying in an accident than in comparable cars without airbags fitted. Despite this, airbags have occasionally caused controversy, as the initial expansion of the bag is in itself a violent event and if an individual is too close to the airbag when it is initially triggered they can be seriously injured or killed.

This was partly due to American airbag designs triggering much more quickly than airbags designed for other countries, to protect occupants not wearing seat belts. Newer airbags trigger slightly less violently; nonetheless, passengers must remain at least 25 centimetres from the bag to avoid injury from the bag in a crash.

Airbags are supplemental restraints and operate best when the occupant is also using a seat belt. Airbags supplement the safety belt by reducing the chance that the occupant's head and upper body will strike some part of the vehicle's interior. They also help reduce the risk of serious injury by distributing crash forces more evenly across the occupant's body. Ensure that if there is aftermarket seat covers fitted they have if necessary the ability to "rip" to allow seat airbags deploy.

Airbag Design

The airbag system consists of three basic parts-an airbag module, crash sensors and a diagnostic unit. Some systems may also have an on/off switch, which allows the passenger airbag to be deactivated.

The airbag module contains both an inflator unit and the lightweight fabric airbag. The driver airbag module is located in the steering wheel hub and the passenger airbag module is located in the dash panel. When fully inflated, the driver airbag is approximately the diameter of a large beach ball. The passenger airbag can be two to three times larger since the distance between the right-front passenger and the instrument panel is much greater than the distance between the driver and the steering wheel.

The crash sensors are located either in the front of the vehicle and/or in the passenger compartment. Vehicles can have one or more crash sensors. The sensors are typically activated by forces generated in significant frontal or near-frontal crashes. Sensors measure deceleration, which is the rate at which the vehicle slows down. Because of this, the vehicle speed at which the sensors activate the airbag varies with the nature of the crash. Airbags are not designed to activate during sudden braking or while driving on rough or uneven pavement. In fact, the maximum deceleration generated in the severest braking is only a small fraction of that necessary to activate the airbag system.

The diagnostic unit monitors the readiness of the airbag system. The unit is activated when the vehicle's ignition is turned on. If the unit identifies a problem, a warning light alerts the driver to take the vehicle to an authorized service department for examination of the airbag system. Most diagnostic units contain a device that stores enough electrical energy to deploy the airbag if the vehicle's battery is destroyed very early in a crash sequence.

Some vehicles without rear seats, such as pick-up trucks and convertibles, or with rear seats too small to accommodate rear-facing child restraints, have manual ON/OFF switches for the passenger airbag installed at the factory. ON/OFF switches for driver or passenger airbags may also be installed by qualified service personnel at the request of owners who meet government-specified criteria and who receive government permission.

Triggering Conditions

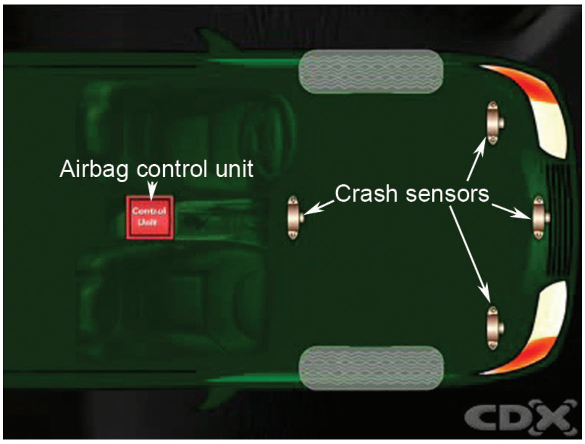
Airbags are typically designed to deploy in frontal and near-frontal collisions, which are comparable to hitting a solid barrier at approximately 8 to 14 miles per hour (mi/h) (13-22.5 km/h). Roughly speaking, a 14 mi/h barrier collision is equivalent to striking a parked car of similar size across the full front of each vehicle at about 28 mi/h. This is because the parked car absorbs some of the energy of the crash and is pushed by the striking vehicle. Unlike crash tests into barriers, real-world crashes typically occur at angles and the crash forces usually are not evenly distributed across the front of the vehicle. Consequently, the relative speed between a striking and struck vehicle required to deploy the airbag in a real-world crash can be much higher than an equivalent barrier crash.

Because airbag sensors measure deceleration, vehicle speed and damage are not good indicators of whether or not an airbag should have deployed. Occasionally, airbags can deploy due to the vehicle's undercarriage violently striking a low object protruding above the roadway surface. Despite the lack of visible front-end damage, high deceleration forces may occur in this type of crash, resulting in the deployment of the airbag.

The airbag sensor is a MEMS accelerometer, which is a small integrated circuit chip with integrated micromechanical elements. The microscopic mechanical element moves in response to rapid deceleration and this motion causes a change in capacitance, which is detected by the electronics on the chip, which then sends a signal to fire the airbag.

Most airbags are designed to automatically deploy in the event of a vehicle fire when temperatures reach 300 to 400 degrees Fahrenheit (150-200°C). This safety feature helps to ensure that such temperatures do not cause an explosion of the inflator unit within the airbag module.

Today, airbag triggering algorithms are becoming more and more complex. They try to remove risks of useless deployments (for example, at low speed, no shocks should trigger the airbag to help reduce damage to the car interior in conditions where the seat belt will be a convenient-enough safety device) and to adapt the deployment speed to the crash conditions. The airbag triggering algorithms are considered as very valuable intellectual property.



Front airbags are not designed to deploy in side impact, rear impact or rollover crashes. Since airbags deploy only once and deflate quickly after the initial impact, they will not be beneficial during a subsequent collision. Safety belts help reduce the risk of injury in many types of crashes. They help to properly position occupants to maximize the airbag's benefits and they help restrain occupants during the initial and any following collisions. So, it is extremely important that safety belts always be worn, even in airbag-equipped vehicles.

Deployment Mechanism

When there is a moderate to severe frontal crash that requires the frontal airbag to deploy, a signal is sent to the inflator unit within the airbag module. An igniter starts a chemical reaction, which produces a gas to fill the airbag, making the airbag deploy through the module cover. Some airbag technologies use nitrogen gas to fill the airbag while others may use argon gas. The gases used to fill airbags are harmless.

From the onset of the crash, the entire deployment and inflation process takes only about 1/20th of a second, faster than the blink of an eye. Because a vehicle changes speed so fast in a crash, airbags must inflate rapidly if they are to help reduce the risk of the occupant hitting the vehicle's interior.

Once an airbag deploys, deflation begins immediately as the gas escapes through vents in the fabric. Deployment is frequently accompanied by the release of dust-like particles in the vehicle's interior. Most of this dust consists of cornstarch or talcum powder, which are used to lubricate the airbag during deployment. Small amounts of sodium hydroxide may initially be present. This chemical can cause minor irritation to the eyes and/or open wounds; however, with exposure to air, it quickly turns into sodium bicarbonate (common baking soda). Depending on the type of airbag system, potassium chloride (a table salt substitute) may also be present.

For most people, the only effect the dust may produce is some minor irritation of the throat and eyes. Generally, minor irritations only occur when the occupant remains in the vehicle for many minutes with the windows closed and no ventilation. However, some people with asthma may develop an asthmatic attack from inhaling the dust. With the onset of symptoms, asthmatics should treat themselves as advised by their doctor, then immediately seek medical treatment.

Once deployed, the airbag cannot be reused and should be replaced by an authorized service department. Because the airbags only deploy once, the vehicle must not be driven until the airbags have been replaced.

Airbags must inflate very rapidly to be effective and therefore come out of the steering wheel hub or instrument panel with considerable force, generally at a speed over 100 mi/h. Because of this initial force, contact with a deploying airbag may cause injury. These airbag contact injuries, when they occur, are typically very minor abrasions or burns.

More serious injuries are rare; however, serious or even fatal injuries can occur when someone is very close to, or in direct contact with an airbag module when the airbag deploys. Such injuries may be sustained by unconscious drivers who are slumped over the steering wheel, unrestrained or improperly restrained occupants who slide forward in the seat during pre-crash braking and even properly restrained drivers who sit very close to the steering wheel. Objects must never be attached to an airbag module or placed loose on or near an airbag module, since they can be propelled with great force by a deploying airbag, potentially causing serious injuries.

An unrestrained or improperly restrained occupant can be seriously injured or killed by a deploying airbag. Children 12 and under should always ride properly restrained in a rear seat. A rear-facing infant restraint must never be put in the front seat of a vehicle with a front passenger airbag. A rear-facing infant restraint places an infant's head close to the airbag module, which can cause severe head injuries or death if the airbag deploys. Modern cars include a switch to turn off the airbag system of the passenger seat, in which case a child-supporting seat must be installed.

Advanced Airbag Design

Many advanced airbag technologies are being developed to tailor airbag deployment to the severity of the crash, the size and posture of the vehicle occupant, belt usage and how close that person is to the airbag module. Many of these systems will use multi-stage inflators that deploy less forcefully in stages in moderate crashes than in very severe crashes. Occupant sensing devices let the airbag diagnostic unit know if someone is occupying a seat in front of an airbag, whether the person is an adult or a child, whether a seat belt or child restraint is being used and whether the person is forward in the seat and close to the airbag module. Based on this information and crash severity information, the airbag is deployed at either a high force level, a less forceful level or not at all.

Many new vehicles are also equipped with side airbags. While there are several types of side airbags, all are designed to reduce the risk of injury in moderate to severe side impact crashes. These airbags are generally located in the outboard edge of the seat back, in the door or in the roof rail above the door.

Seat and door-mounted airbags all provide upper body protection. Some also extend upwards to provide head protection. Two types of side airbags, known as inflatable tubular structures and inflatable curtains, are specifically designed to reduce the risk of head injury and/or help keep the head and upper body inside the vehicle. A few vehicles are now being equipped with a different type of inflatable curtain designed to help reduce injury and ejection from the vehicle in rollover crashes.

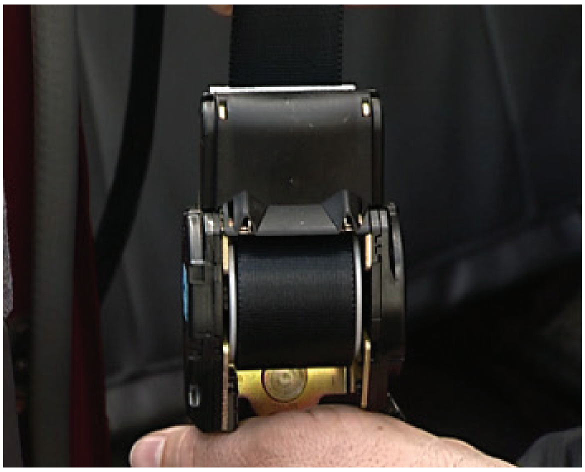
Other Information

On vehicles airbags are often marked SRS, which stands for Supplemental Restraint System, suggesting it should only be used in conjunction with a seatbelt and never alone.

The airbag represents a big problem for the rescue teams: when it does not trigger (i.e. when it is not a front collision), it may explode at any time during the paramedic's work inside the car and the extrication of occupants.

12.4 SRS – Seat Belt Pre-Tentioners

Seatbelt pre-tensioners are used to tighten the seatbelt in a severe frontal accident. Both mechanical and electronic control systems are available. The most common type relies upon an explosive charge that is detonated electronically by a sensor within the seatbelt tensioning mechanism.



This explosion moves a piston that pulls on a steel cable causing the belt to tighten by approximately 100 millimetres. The design allows for the belt to tension before the occupant has moved forward in the seat.

Mechanical systems rely on inertia to move a sensing mass. This releases a spring to pull on a cable, thus tightening the belt.

Once the pre-tensioner has triggered, a ratchet prevents the seatbelt from loosening. When the seat belt is removed from the buckle, it cannot be reinserted and the assembly should be replaced.

Rip stitching is used on seat belts in conjunction with an airbag and seat belt pre-tensioners. During a collision the pre-tensioners initially pull the seat belt tight, however the stitching gradually tears to allow the occupant to move forward into the airbag at a controlled rate.

For safety reasons, these belts must be replaced once they have had their stitching ripped. Manufacturers generally fit warning labels within the fold to indicate the belt is to be replaced when the label is revealed.

Self Assessment

Q1: Vehicles are fitted with two forms of safety system during their construction, these are: (Tick one box only)

❑ 1. Primary or passive systems and secondary or active systems

❑ 2. Chassis or passive systems and secondary or active systems

❑ 3. Primary or passive systems and secondary or inactive systems

❑ 4. Primary or inert systems and secondary or active systems

Q2: There are a number of different types of airbag, their size and location determined by the type of protection they offer. Which type is designed to protect from head injury during a side impact? (Tick one box only)

❑ 1. Centre of the steering wheel airbags

❑ 2. Side impact airbags

❑ 3. Curtain side airbags

❑ 4. All types

Q3: Crash sensors can be fitted in various positions throughout the vehicle. Their location depends upon the direction of deceleration they are designed to detect. Where are the side impact sensors likely to be found? (Tick one box only)

❑ 1. Behind the front bumper

❑ 2. In the doorsills or the "B" Pillar

❑ 3. Behind the headlights

❑ 4. Behind the dash

Q4: All seat belt pre-tensioners use pyrotechnics to actuate them. (Tick one box only)

❑ 1. True

❑ 2. False

Q5: On all vehicles, before an airbag deploys, the vehicle body controller runs a series of tests to ensure that deployment is necessary. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q6: When an airbag deploys, simultaneous reactions occur in which components to action the deployment? (Tick one box only)

- ❑ 1. The squib and igniter
- ❑ 2. The squib, igniter and gas generator
- ❑ 3. The crash sensor, igniter and gas generator
- ❑ 4. The crash sensor, squib and gas generator

Q7: What is an airbag made of? (Tick one box only)

- ❑ 1. Nylon
- ❑ 2. Linen
- ❑ 3. Cotton
- ❑ 4. Wool

Q8: When a MIL light comes on during operation of the vehicle, what does it indicate? (Tick one box only)

- ❑ 1. It is a MIL or check engine lamp and indicates that there is a fault in the system and can also indicate that a fault code has been logged in the ECU memory
- ❑ 2. It is a MIL or check engine lamp and indicates that there is a fault in the system and can also indicate the ECU memory needs replacing
- ❑ 3. It is a MIL or check engine lamp and indicates that there is no fault in the system
- ❑ 4. It is an oil level warning lamp and indicates that the engine oil needs replenishing

Q9: What does the MAP sensor do? (Tick one box only)

- ❑ 1. It measures intake manifold volume and converts it to an electrical signal input for the ECU
- ❑ 2. It measures intake manifold pressure and converts it to an electrical signal output from the ECU
- ❑ 3. It measures intake manifold pressure and converts it to an electrical signal input for the ECU

Q10: What does the Air vortex sensor use to measure the volume of air entering the engine? (Tick one box only)

- ❑ 1. Air mass
- ❑ 2. Air density
- ❑ 3. Oxygen
- ❑ 4. Whirlpools or "vortices"

Q11: The resistance of a temperature sensor (NTC): (Tick one box only)

- ❑ 1. Remains constant as temperature rises
- ❑ 2. Increases as temperature rises
- ❑ 3. Falls as temperature rises
- ❑ 4. Falls as temperature falls

Q12: Inductive-type crankshaft position sensors provide a signal output voltage when: (Tick one box only)

- ❑ 1. Magnetic field strength is changing
- ❑ 2. Magnetic field strength is not changing
- ❑ 3. The Hall Effect falls to zero
- ❑ 4. The photo diode is in focus

Suggested Exercises

1. . Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
2. . Write a basic illustrated technical report on automobile S.I. engine primary sensors and actuators as fitted to an identified training vehicle/unit
3. Use a generic Scan Tool to locate identified fault description/ code data from a training vehicle/unit
4. Use an oscilloscope to display electrical waveforms from transducers for comparison to manufacturer's recommended patterns
5. Use a multi-meter to measure NTC resistor (temperature sensor) values and compare

Training Resources

- Technical information in book/electronic form on, sensor-actuator, input-output transducer, operation and function as sensors and actuators to S.I. and C.I. automotive engine ECU, manufacturer's generic recommendations on airbag-seat belt pre-tensioners removal, planned deployment, handling and storage procedures
- Manufacturer's data on engine system sensor and actuator, basic function, location on vehicle/unit and operation
- Dedicated sensor technology training units/system/selection of current technology bench unit sensors and actuators
- Generic ECU scan tool/memory interrogator
- Oscilloscopes
- Training vehicle/unit complete with manufacturer relevant fault code data
- Multi-meter, thermometer
- Regulated voltage battery chargers

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

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