

Self-diagnosis of system faults

Reasons for self-diagnosis (on-board diagnostics)

Since the mid-1980s, an increasing number of European market vehicles have been equipped with some form of self-diagnosis. Self-diagnosis systems were in use earlier, but mainly on American market products.

Self-diagnosis is the capacity of a vehicle system (or more precisely the system ECU) to detect system operating faults, and provide an indication that a specific fault exists.

Self-diagnosis was initially fitted to fuel and ignition systems, but it has become increasingly fitted to most vehicle systems with electronic control. Self-diagnosis is now found on vehicle systems such as ABS (and other vehicle stability control systems), automatic gearboxes, air conditioning, airbags and other safety systems. Self-diagnosis is a function of the system computer or ECU, which monitors and assesses all the input signals (from sensors) as well as providing the output control signals. The system ECU is able to distinguish correct from incorrect signals (and operation) for much of the system that is being controlled.

Self-diagnosis was introduced to overcome a number of potential problems.

- 1 One aim of self-diagnosis is to overcome the problems of working and diagnosing faults associated with 'new technology'. This is especially important as each new vehicle system is introduced. Repair technicians need to be able to identify faults relatively quickly and easily.
- 2 Fast and accurate diagnosis should help to reduce warranty costs, while retaining customer loyalty and satisfaction.
- 3 The self-diagnosis system can be used during vehicle assembly to ensure that each vehicle leaves the assembly plant without detectable faults.
- 4 Importantly, modern engine management systems and emission control systems are fitted to vehicles to ensure that emission levels remain low and within legislated limits. Many faults that would result in unacceptable emissions can remain undetected by the driver. With a self-diagnostic system, it is possible to provide a warning to the driver or the workshop technician, along with an indication of what the fault is.
- 5 Modern vehicle systems rely on complex software programs within the ECU as well as electrical and electronic systems. In a high percentage of cases, technicians are not familiar with these 'new' technologies. Self-diagnostic systems are designed to support technicians on unfamiliar aspects of a new motor vehicle.

Self-diagnostic facilities should help to reduce the length of time that faults remain undetected.

Self-diagnosis systems form only a small part of the whole facility. The next section highlights other functions that can be implemented by the system computer to further assist in reducing emissions when faults occur, and to assist a technician to test or check vehicle system operation. The self-diagnosis facility is often referred to as OBD (on-board diagnostics).

Vehicle manufacturers appoint authorised dealers or repair workshops to sell and maintain vehicles. These usually have very sophisticated, dedicated equipment containing code reading or scan tools as part of the overall equipment package. However, independent repair workshops usually purchase general purpose code reading equipment, designed to function on many makes and models of vehicle. The general purpose equipment is usually designed so that cartridges or pods can be inserted into the code reader; the different cartridges contain different software programs that enable the code reader to communicate and operate with different vehicles.

Fault codes, blink codes and fault related messages

Once the ECU has recognised that a fault exists on a vehicle system, it is able to implement other functions.

The following list covers the common functions performed by the ECU when a fault is recognised.

- 1 The ECU can illuminate a dashboard warning light to indicate to the driver that a fault exists.
- 2 A system failure, such as a sensor fault, could cause the engine to run poorly and generate high emissions. Under these conditions, the ECU might be able to control the engine management system so that it operates in a 'limp home' or 'fail safe' mode. When the ECU implements limp home operation, it normally substitutes a preset value for the failed sensor, which should ensure reasonable engine operation.
- 3 The ECU can provide some form of coded output (fault code) which is accessed or retrieved by a 'fault code reader' or through other means such as a 'blink code' transmitted via the dashboard warning light or via an LED based test tool. A fault code usually consists of a number (or series of numbers), although some systems provide a series of letters or even a short message. As explained later in this section, some standardisation has been adopted across all vehicles for fault code systems, whereby specific faults are allocated a dedicated code number. This standardisation generally only applies to emissions related faults, but inevitably embraces the engine management system.

Methods of retrieving fault codes

As mentioned above, fault codes can be retrieved from the vehicle ECU using a fault code reader which, when connected to the ECU, displays a code number related to the fault.

Many systems, however (especially older systems and non-engine management systems), provide what is often referred to as a 'blink code'. A blink code can be output by the ECU to the dashboard warning light, and the number of flashes on the warning light corresponds to the relevant code number. Some systems use an LED light (often located on the ECU) or codes might be accessed by connecting a separate LED tester (or a volt or dwell meter). When a fault code number has been retrieved, the technician refers to the appropriate information source to look up the code number and establish the nature of the fault. Most code readers indicate the messages within the code reader software.

To access a blink code, it is normally necessary to perform a set procedure which effectively 'instructs' the ECU to output the code. The procedure may involve linking two terminals on a connector plug or other similar procedures which will then cause the ECU to output the code.

When a code reader is connected to the appropriate connector plug, it communicates with the vehicle ECU, and by following the instructions supplied with the code reader (or the instructions on the code reader screen display), the technician can make the code reader transmit an instruction to the ECU which causes the ECU to output the codes. The instruction from the code reader may take the form of a password, when the

instruction or password is sent to the ECU, the ECU provides the coded output, thus allowing the code reader to display the code number.

Although some inexpensive code readers effectively act as a means of accessing the simple blink code (i.e. they simply provide a code number), most elaborate readers also display a message which details the nature of the fault associated with the displayed code.

When a blink code is read via a warning light or LED, it is normal practice to count the number of times the light flashes. When more than one code exists, different systems will use slightly different methods of separating the different codes. There are different methods of displaying a code number. For instance, code 12 could simply be displayed by 12 flashes, but alternatively could be displayed by providing one flash, a pause, then two flashes.

The example in Figure 3.82 shows how two codes might be displayed (i.e. code 12 and then code 23). A brief pause is provided between the 'tens and units' as is the case between the 1 and the 2 of code 12, and between the 2 and the 1 of code 23. However, a longer pause (in this case 2 seconds) is provided between the two different codes, as is the case between codes for 12 and 23.

Some inexpensive code readers simply provide a flashing LED; the flashes are counted in the same way as a normal blink code. Most code readers provide a display screen that indicates the code as a number. A code reader might provide a relevant message in addition to the code number.

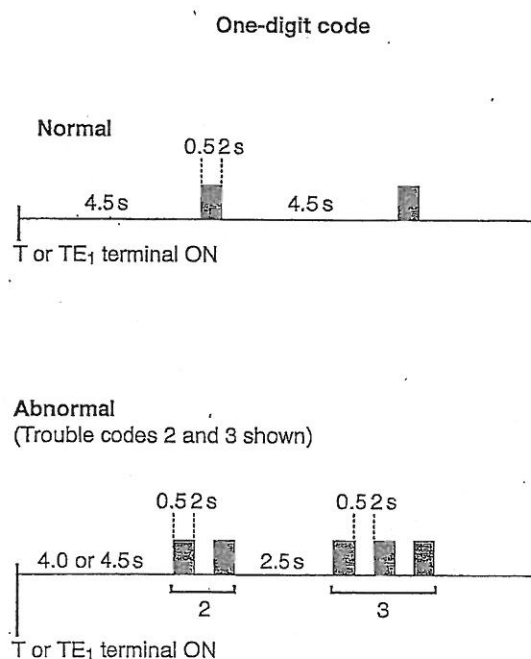
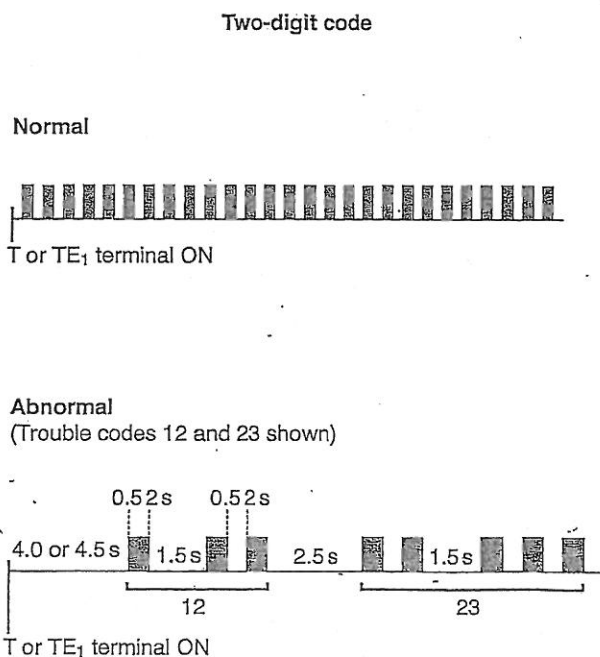


Figure 3.82 Example of a blink code (code 12 followed by code 21)

How the ECU recognises and overcomes system faults

Expected operating values

Virtually all the circuits connected to the system computer (ECU) carry a voltage or signal that should lie within certain operating values. These values are programmed into the ECU, which can compare actual signal values with expected or programmed values.

For example, the power supply for the ECU might be expected to fall between lower and upper limits of 9 volts and 15 volts. If the voltage is above or below the expected limits, this would be recorded as a fault by the ECU – the starting point for self-diagnosis.

Many sensors on computer controlled vehicle systems operate by providing a voltage or signal voltage that should normally lie within certain easily defined limits. The ECU can thus recognise that a fault exists, assuming that the fault causes the signal voltage to fall outside the expected limits or tolerance.

Example of fault detection using a simple temperature sensor circuit

One example of a sensor circuit that should usually provide a voltage within defined limits is the engine coolant temperature sensor. It functions by changing its resistance as the coolant temperature changes. The sensor forms part of a series resistance circuit, which means that when the resistance of the sensor changes, it affects the voltage in the circuit (Figure 3.83).

The ECU provides a reference voltage to the temperature sensor circuit which, on modern systems, is normally 5 volts. When the circuit is complete (sensor plug connected) the voltage on the section of the circuit between the ECU and the sensor is reduced (by the action of the resistances). The exact voltage depends on the value of the resistances and, although the ECU resistance remains the same, the sensor resistance changes, thus affecting the voltage in the circuit.

On nearly all temperature sensor circuits, a typical operating value is around 3.0–3.5 volts when the coolant temperature is low (a cold engine). The voltage then falls to around 0.3–0.7 volts when the engine is hot. It is possible for the voltage to reach higher or

lower values, but this would mean an extremely cold or hot engine.

Assuming that the sensor and associated wiring are in good condition, and that extreme cold and hot temperatures are reached, it is possible (although very unlikely) for the voltage in the circuit to reach as high as 4.5 volts or as low as 0.2 volts. These values can be used by the ECU as maximum and minimum values, and the only likely situation that would cause the voltage to lie outside this range would be a fault in the wiring, sensor or ECU itself. In reality, a tolerance must be allowed slightly outside of the expected maximum and minimum values: in our example we will use 0.1 volts as the minimum and 4.8 volts as the maximum. Figure 3.84 shows typical values for normal operation and for detecting a fault.

There are two main faults that the ECU will easily identify: a break in the circuit and a short in the circuit. Figures 3.85 and 3.86 show a circuit break (open circuit) and a short circuit. In both cases the fault is shown as a wiring problem. However, any part of the circuit, including the sensor resistance itself, could suffer a short circuit or a circuit break, which would provide the same results.

Figure 3.84 Example of temperature sensor circuit operating voltages and voltages that would be regarded as a fault condition

Condition	Sensor signal voltage
Extremely hot (engine running at very high temperature but this condition must be allowed for)	minimum value may be as low as 0.2 volts
Extremely cold (engine running at very low temperature but this condition must be allowed for)	maximum value may be as high as 4.5 volts
Fault condition (ECU detects voltage values that are outside normal expected values)	less than 0.1 volt or greater than 4.8 volts

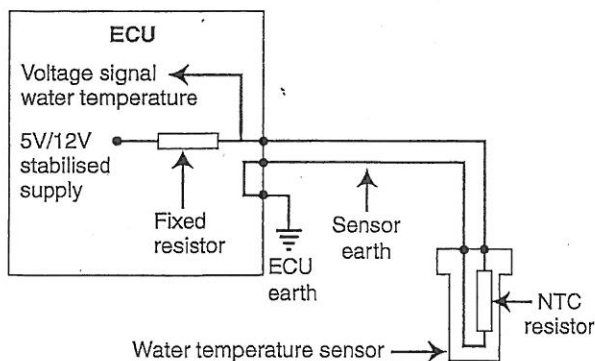


Figure 3.83 Schematic layout of temperature sensor circuit

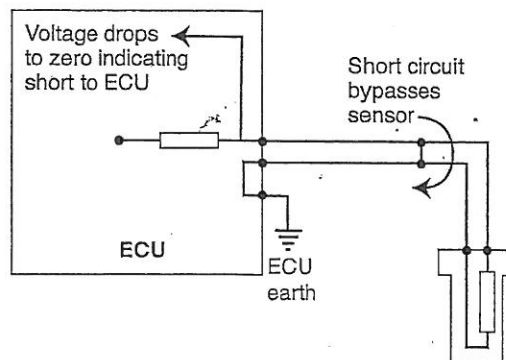


Figure 3.85 Temperature sensor circuit with a short to earth

Short circuit

When there is a short circuit (Figure 3.85) that results in the signal wire shorting through to earth, the 5 volt reference supplied by the ECU is connected directly to earth. The current has already flowed through the resistance in the ECU, so, when the circuit is connected to earth, the voltage falls to zero.

The circuit is now the same as a light circuit in which a voltage is applied to a bulb and then from the bulb to earth. The voltage on the earth side of the bulb is zero. The resistance in the ECU acts in the same way as the light bulb.

The ECU monitors the voltage in the signal circuit, which would normally sit within acceptable operating limits of 0.2–4.5 volts. Because the voltage detected is now zero, the ECU recognises this as a fault. The ECU is able to allocate a fault code to this particular fault.

Note that the ECU might provide a fault code for a fault on the sensor circuit. However, many systems will provide a code that states: 'the voltage level in the temperature sensor circuit is too LOW'.

The ECU cannot determine the exact nature of the fault; it can only establish that a fault exists causing a low voltage. Therefore the technician must still carry out a detailed investigation of the circuit.

Open or broken circuit

A broken or open circuit (Figure 3.86) prevents the flow of current through the circuit. Without a current flow, a resistance does not have any effect on the voltage level in the circuit. Therefore, the 5 volts, applied as a reference voltage by the ECU, remains at 5 volts.

The ECU is again monitoring the voltage at point A (this is the voltage in the signal circuit which would normally be within the acceptable operating limits of 0.2–4.5 volts). Because 5 volts is now detected at point A, the ECU recognises this as a fault, and allocates an appropriate fault code.

Note that the ECU might provide a fault code which indicates that a fault exists on the sensor circuit. However, many systems will provide a code that states: 'the voltage level in the temperature sensor circuit is too HIGH'.

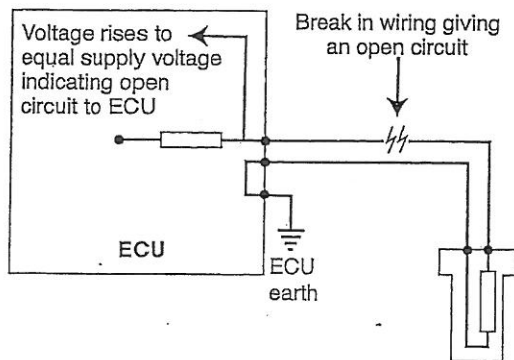


Figure 3.86 Temperature sensor circuit with a break in the wiring (open circuit)

The ECU cannot determine the exact nature of the fault: it can only establish that a fault exists, causing a high voltage. Therefore the technician must still carry out a detailed investigation of the circuit.

Self-diagnosis on other types of sensor or circuit

The system ECU is able to monitor any of the circuits connected to it. The ECU is effectively pre-programmed with the acceptable values for the various circuits, and is therefore able to identify a fault when values lie outside acceptable limits.

Many sensors on a system provide a digital signal, i.e. a signal that consists of on/off pulses, such as the signal from a Hall effect trigger used for vehicle speed sensors, ignition triggers, etc. The ECU can monitor the pulses and detect the correct operating voltage for the signal, or whether the pulse is acceptable or unavailable.

Other sensors provide analogue signals, which again might consist of a series of pulses. A crankshaft speed/position sensor usually provides a series of pulses which the ECU is able to detect as being at a certain voltage. Again, the ECU can detect whether the signal is acceptable or unavailable.

The ECU also provides operating signals to actuators such as injectors or idle speed control valves. If the actuator and associated circuits are good, an electric current will flow through the ECU in order to control the actuator. The ECU is therefore able to recognise many of the faults owing to the fact that, if there is a fault, the current flow might be incorrect, or there might be no current flow at all if the circuit is broken.

In all cases where a fault is identified by the ECU, the technician should attempt to gain as much information as possible about the operation of the system. Knowledge of the way in which the ECU detects particular faults and provides substitute values can assist in accurate diagnosis.

Limp home/emergency operation

In a large number of cases when a fault is detected by the ECU in a sensor circuit the ECU might be able to substitute a value for the failed circuit. If the temperature sensor signal voltage is outside the expected values, the ECU will detect the fault. The ECU has programmed substitution values for certain faults, which can be used to ensure that the engine can still run. With a temperature sensor fault, the ECU could substitute a temperature value, such as a warm running value, that enables the car to be driven to a repair workshop. However, the engine would be difficult to start from cold because the substituted value is for a warm engine.

Modern systems can implement a more complex substitution process. Again using the temperature sensor fault as the example, the ECU timer facility enables it to calculate the length of time the engine has been running, and then internally substitute a temperature value depending on that time period (e.g. if the engine has been running for an hour, the substitution value would be equivalent to normal

engine temperature). When the engine is switched off for a long period, the ECU would calculate that the engine was cold, and provide a cold running temperature value. At various time intervals, the ECU can substitute progressively warmer temperature values until the engine is assumed to be at normal operating temperature.

It is possible for the ECU to use substitution values for many of the sensors. It is often the case that the substitution process allows the engine to operate without any indications that there is a fault. The driver would often be unaware that a fault exists, except that the warning light on the dashboard illuminates.

There are however a number of faults that will not allow a substitute value to be used. An obvious example is a power supply or earth circuit fault. Another sensor that cannot be easily substituted is the main crankshaft position/speed sensor. Without the signal from this sensor, the ECU has no reference to engine speed or exact crankshaft position, but if additional position sensors are fitted to the engine (such as a camshaft or cylinder identification sensor) these can allow the ECU to provide a limited means of operating the engine systems.

There are a number of terms used to describe the process whereby an ECU substitutes operating values; examples include:

- limp home
- limited operating strategy (LOS)
- emergency operating strategy.

Faulty signal values that are within expected limits

Basic self-diagnosis and fault code systems (including many of the systems produced before the end of the 1990s) have certain limitations, because they only define a fault when the signal is outside expected or acceptable limits. This method of diagnosis can lead to situations where a fault does exist, but the ECU cannot recognise it.

Again, using the temperature sensor circuit as an example, if the sensor itself failed in such a way that the sensor resistance remained at a value corresponding to a normal engine temperature, the voltage in the sensor circuit would also be at an acceptable value. The ECU would not then recognise this failure.

If, for example, the sensor failed, so that the resistance of the sensor (and therefore the voltage in the circuit) corresponded to 40°C (a warm engine) the ECU would only detect this value, and provide a slightly rich fuel mixture which is applicable to the warm engine temperature. That the voltage in the circuit is 'stuck' at this value will not be registered as a fault by these older systems.

However, as described in the previous paragraphs dealing with limp home/emergency operation, most modern systems now have a facility to recognise that the value is unchanging: the ECU can then provide a substitute value.

Many systems up until the late 1990s (and possibly later) did not have the facility to recognise faults for which the value remained within acceptable limits. Therefore technicians should always be prepared for self-diagnosis and fault code systems that do not indicate a fault, even if a fault exists in the system.

Overcoming the limitations of less sophisticated self-diagnosis systems

The previous paragraphs highlighted the fact that less sophisticated systems have certain limitations that must be accounted for when carrying out diagnosis. However, most of these limitations have now been overcome by the system manufacturers, by increasing the capability of the self-diagnostic section of the computer.

More capable systems operate on what is sometimes referred to as 'improbable or implausible'. In effect, the ECU is programmed with a degree of 'intelligence', which enables it to judge whether a signal or value on a circuit is probable or plausible.

For example, a temperature sensor value not altering from a cold value when the engine has been running for a considerable amount of time would be regarded as improbable or implausible. The ECU can use more than one item of information from the other sensors or from programmed logic to make a judgment. An example of programmed logic would be: 'a cold temperature value cannot be correct when the engine has been running for a long time'.

A signal would not be plausible if:

- 1 the throttle position sensor indicates that the throttle has just opened fully
- 2 the engine speed has increased
- 3 the airflow sensor indicates that there has been no change in the air being drawn into the engine.

The above situation would indicate a likely airflow sensor fault, which could in fact be overridden by the ECU; in this case, it could ignore the airflow sensor fault and rely on throttle position and engine speed as a means of calculating the fuelling and ignition requirements. Therefore, the ECU on a modern system has far better ability to diagnose a fault and, where necessary, override the faulty inputs.

Adaptive strategy

Adaptive strategy provides the ECU with the ability to relearn the values provided by the sensor circuits.

A simple example is the signal voltage provided by a throttle position sensor when the throttle is in the idle or closed position. The ECU might initially be programmed to expect a certain voltage, e.g. 0.5 volts (with a small tolerance or range), when the throttle is closed or in the idle position.

However, wear in the linkage and other changes that can occur over a period of time, can result in a change in the voltage when the throttle is closed. If, over a period of time or at a set time during the system operation, the ECU is able to detect that this voltage is

now different, it can replace the original expected value with the new value.

Although not directly related to fault code reading, it is worth noting that an adaptive strategy can have a major effect on the way the system identifies or deals with a fault. Additionally, it will have a direct effect on the success of rectification work. The particular example of the throttle position sensor voltage (and many other examples of the ECU being able to relearn values) may not have a direct effect on the self-diagnostic process but if a sensor or a circuit does fail on the vehicle and a new sensor or component is fitted, the ECU must go through a period of 'relearning' the new values in order to be able to provide the correct control over the engine.

It is worth noting that, after rectification work is carried out, or even if a battery has been disconnected, the ECU might need to relearn the values of the sensors, etc. For example, some engine management systems can take more than 16 km (10 miles) to relearn sensor values. It is also a common requirement that an engine must go through a full cycle of operation, such as cold start, load and cruise conditions, etc., before it can fully relearn the system signals. The engine may therefore not perform properly until the ECU has relearned and adapted to the new values.

When a vehicle battery is disconnected the ECU might suffer memory loss, so it is advisable to test drive the vehicle after the battery has been reconnected to ensure that the engine is performing normally.

Live data/serial data and other additional functions of self-diagnostic systems

Live data/serial data

In addition to providing fault codes, modern systems can give other information to the technician about the operation of the vehicle system. Engine management systems, for example, are able to provide live data via the fault code reading equipment.

The ECU is already monitoring the circuits of the engine management system in order to control the system. The ECU relies on signals from the sensors, etc. to control fuelling, ignition timing, emissions and other functions. It is relatively easy for the ECU to output or transmit those same signal values to a code reader or similar item of test equipment.

If a capable code reader is connected to the engine management system diagnostic plug, the code reader is able to display a considerable range of measurements relating to the operation of the engine management system. Different systems provide different items of data, but the following list indicates just a few of the sensor measurements that can be accessed via the live data systems, with the use of a suitable code reader or similar equipment:

- battery voltage
- engine speed
- airflow sensor signal voltage
- coolant temperature sensor signal voltage
- throttle position sensor voltage
- lambda (oxygen) sensor signal voltage
- air temperature sensor signal voltage
- MAP (vacuum) sensor signal.

Additionally, the ECU can also provide control signal values covering:

- ignition timing
- injection control
- EVAP system solenoid control
- idle speed valve control duty cycle (on/off ratio).

In fact, a wide range of control signal values and sensor signal values can be accessed on modern systems. Additionally, operational information can be accessed, such as whether the system is operating in closed or open loop for emission control (see section 3.5.7).

With the live data information, it is possible for the technician to check on ECU operation and ensure that the system is operating as intended.

Note that some of the values may be converted by the code reader into a more acceptable form. The coolant temperature sensor voltage could be displayed in the normal way, as a voltage, but can be converted to give the coolant temperature in degrees, e.g. 0.9 volts = 85°C.

Live data allows the technician to view a considerable range of readings that would otherwise need to be accessed by more traditional measurement tools, such as multimeters or oscilloscopes.

In addition to the examples of live data shown above, the ECU can also output information about computer or ECU calculations. This can include the calculated load and other values which are usually displayed in a format that does not assist technicians unless they have access to dedicated data.

The live data output and other information delivered by the ECU is often referred to as 'serial data' or 'data stream information'. These terms simply refer to the way in which a code reader or other test equipment communicates with the ECU. As with personal computers, data communication (such as between the PC and a printer) is achieved by transferring information in series along a wire, i.e. with one piece of information following another.

Using live data for diagnosis

There is no doubt that live data is an aid to diagnosis. In previous sections we have noted that fault codes are primarily of use if the fault causes the signal values to lie outside acceptable limits. However, if a fault results in signal voltages or values that are within acceptable limits, it may not be recognised by the ECU. Therefore, if an engine management system has an undetected or unrecognised fault, but the engine is obviously not

running properly, it is possible to examine the live data to see if the signal values are correct for the engine operating conditions.

Again referring to the coolant temperature sensor as an example, the sensor signal voltage might indicate '0.9 volts = 85°C', but this could not be correct if the engine had not been run for some hours. In other words, the engine is cold but the temperature sensor is indicating that the coolant is almost up to the hot operating temperature. The values would not be recognised as a fault on many systems, but the live data display allows the technician to compare values against what should be expected for the conditions.

As another example, if the ECU detects a signal that is not plausible or probable, such as the airflow sensor signal discussed previously (see section 3.7.2), the ECU might not provide a fault code that indicates the exact fault. However, reference to the live data should enable an experienced technician to identify that the airflow sensor signal is incorrect under certain operating conditions.

Snapshot or playback mode

Various terms are used to describe the snapshot or playback facility. This facility enables the fault code reader to display fault codes, or in some cases live data that were recorded earlier.

The exact capability varies depending on the system; however, it is possible for the code reader (in conjunction with the ECU) to capture codes or data at a time when a fault occurred. This facility is extremely useful when trying to trace intermittent faults that do not necessarily show up during workshop tests. The test equipment can be connected to the vehicle, which is driven until the intermittent fault occurs.

It is often the case that the code reader/ECU combination can record a range of measurements or live data at the time a fault occurs. The measurements and data are monitored while the vehicle is being driven or the engine is running. It may be necessary for someone to press a start button on the code reader when the fault occurs (such as a noticeable misfire). The measurements received from just prior to the fault until just after it are stored.

Some vehicle systems might have already registered a fault code relating to an intermittent fault. The code reader/ECU combination can be programmed to capture and store the data next time the particular intermittent fault occurs. In some cases, the ECU will automatically store applicable data when a fault occurs, and it is then simply a matter of connecting the test equipment at some later stage to obtain the data that was stored at the time the fault occurred.

The final result is that the data can be analysed after an intermittent fault has been noticed, thus enabling the technician to perform an accurate diagnosis.

Not all vehicle systems and not all code readers allow the snapshot or playback facility to function.

Service adjust mode

Some vehicle systems, notably engine management systems, have a service adjust mode which can be used for some basic service set procedures. On some older systems, idle speed and other operating values could be set or adjusted, but with most modern systems this facility is not required.

There are occasions, however, when some basic settings can be altered, such as in a country with low quality fuel. It is possible on some vehicles to effectively reprogram the ECU so that it alters the timing and fuelling characteristics to suit different fuel qualities. In reality, the ECU has a number of programmed characteristics already located in its memory: it is simply a matter of selecting the appropriate program by using the code reader or other suitable equipment.

Actuator simulation tests

It is becoming increasingly common for systems to incorporate an actuator test facility. As well as monitoring the electrical circuits for an actuator such as an injector, modern ECUs are able to provide a control signal to the actuator (in effect a simulation of the actuator signal). This control signal has a known value, so that the operation of the actuator can be checked. It is usual to implement this facility using the code reader: the technician selects the appropriate function, which causes the actuator signal to be transmitted from the ECU to the actuator, which then operates.

With modern systems, the ECU can provide a control signal to a number of components or actuators in the system. In engine management systems, for example, the ECU can control the injectors, the idle valve, the EVAP canister purge valve and possibly other items (such as the exhaust gas recirculation system valve). During an actuator test, the ECU is instructed to operate these components independently and normally, when the engine is not running.

In this way it is possible for the technician to hear or observe operation of the various actuators, which helps to establish whether these components are functioning correctly, and that the associated wiring is good.

When an actuator test is carried out on the injectors, it is likely that fuel will be injected into the intake manifold or into some cylinders. It is advisable that the fuel pump is disconnected to prevent excessive fuel entering the engine. As a minimum precaution, the spark plugs should be removed and the engine cranked over to evacuate excess fuel.

'Set procedure' testing

Several engine management systems rely on the technician following a set procedure or test routine that requires a number of actions to be performed by the technician. These set procedures are usually dictated to the technician via the code reader. In effect, instructions are provided for the actions that the technician must perform.

When the code reader is connected to a diagnostic plug, various messages displayed on the code reader provide the technician with relevant instruction to perform a certain task, before going on to the next phase of testing. On some systems, the whole self-diagnostic routine is based around the need for the technician to perform certain procedures all the way through the test sequence.

Typical procedures that need to be carried out include altering the engine speed, turning the steering (to check power steering pressure switch operation) and depressing the brake pedal (to check brake switch operation).

If the procedures are not carried out as instructed, the test results will be incorrect, and the ECU might diagnose a fault that does not in fact exist. In other cases, the ECU will not proceed to the next set of tests until the correct responses or readings have occurred or been recorded.

Clearing codes

It is important that, when a fault has been rectified, the original fault codes are removed from the ECU memory. The process for clearing codes varies with each make and model of vehicle, and will also depend on whether blink codes are being accessed or a code reader is being used.

Reference should always be made to the specific information on each vehicle to ensure that the correct process is used to clear old fault codes.

Common problems with the use of code reading equipment

Although self-diagnostic systems, code reading and retrieval of live data are generally reliable facilities, a number of problems can arise which are often blamed on the code reader, but may in fact be due to common problems such as operator error or system faults that prevent good test results being obtained.

The following lists those common faults that often result from what are termed 'communication errors' between the code reader and the system ECU.

- 1 All instructions provided by the equipment manufacturer might not have been followed exactly. When certain procedures are not performed in the correct order or as instructed, the ECU might not allow further tests to continue or might provide incorrect results.
- 2 Instructions provided on the code reader display might not be followed accurately. If any procedure is carried out incorrectly or not at the correct time, the ECU might not allow tests to continue or incorrect results might be obtained.

Minor changes are often made to systems because of modifications that occur throughout the production life of a vehicle. This can result in small changes to the procedures that have to be carried out by the technician when accessing fault codes, etc. Although the technician might be conversant

with a particular system, a variant of that system might require slightly different procedures or even use different fault codes.

- 3 All connections between the code reader and the diagnostic plug must be checked. Some systems and code readers require a separate power supply or earth connection to be made (usually an adapter lead or harness is provided to connect the equipment to the battery). Check whether the system being tested requires the use of a separate harness.
- 4 The code reader or the application cartridge/card must be correct for the system being tested. It is unfortunately not uncommon for a code reader (or the application cartridge) to be designed to operate with a particular range of systems, and for the vehicle manufacturer to then modify the system in production, which can prevent communication with the original code reader or cartridge.
- 5 All wiring between the code reading equipment and the diagnostic plug, and between the plug and the ECU must be checked. It is also necessary to check for poor earth connections to the ECU and check the power supply to the ECU and to the code reader.

A reduced power supply (flat battery) can cause communication to cease if the voltage level falls below a certain limit.

Different terminology for code reading equipment

A scanner or scan tool is another term (often used to describe American equipment) applied to code reading equipment. In general, the term code reader is applied to something that simply extracts codes from the vehicle system. A scanner is an item of equipment which effectively scans the ECU memory for information.

However, the terms code reader and scanner are loosely used by the industry as product names, as well as being general terms to identify equipment that communicates with a vehicle system ECU.

Use of test equipment to access fault codes

The test equipment (code reader or scan tool) provides specific instructions about equipment operation and the connection processes. It is useful to understand some typical processes for equipment use and for accessing blink codes, fault codes and live data.

Blink codes via the dashboard warning lights

A blink code is the simplest form of fault code reading, especially when displayed via the dashboard warning light. Dashboard warning lights are now fitted to virtually all passenger vehicles, with a typical appearance as shown in Figure 3.87.

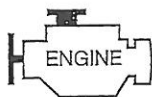


Figure 3.87 Dashboard warning light

It is necessary to refer to the specific vehicle information to find out how its blink codes can be retrieved, but the following example shows how blink codes are retrievable on one particular range of vehicles.

Example of blink code retrieval

In this example, it is necessary to instruct the ECU to provide a blink code output to the dashboard warning light. Here the instruction to the ECU is provided by linking two terminals on the diagnostic harness plug (Figure 3.88). When the two terminals are linked and the ignition is switched on, the ECU causes the warning light to flash an appropriate number of times, depending on whether there is a fault code stored in the ECU memory.

As discussed in section 3.7.1, the number of flashes of the warning light represents the fault code: counting the flashes enables the technician to read the code.

There are many other methods used by vehicle manufacturers for instructing the ECU to output fault codes via the warning light, so refer to specific instructions for each vehicle.

Retrieving blink codes via a vehicle system LED

Some vehicles use an LED located on the ECU (or in other locations on the vehicle) to enable a blink code to be read by the technician. As with the warning light blink codes, a specific procedure needs to be performed to instruct the ECU to output the code to the LED light.

Accessing blink codes using an LED probe

On some vehicles (mainly older models), it is possible to access the blink code using an LED probe (Figure 3.89). The process usually involves connecting the probe tip to a terminal or connection of the ECU, or to a terminal of a wiring harness plug, while the other connection for the probe (the crocodile clip in Figure 3.89) remains connected to earth.

As with blink code retrieval using the warning light, it is usually necessary to instruct the ECU to output the codes. Refer to specific vehicle information for the correct procedure and to establish where the LED probe tip should be connected.

One example of a procedure for instructing the ECU to output a blink code using an LED probe is where two terminals on a connector or harness plug are linked using a switch. This process was used in some older generation Audi models.

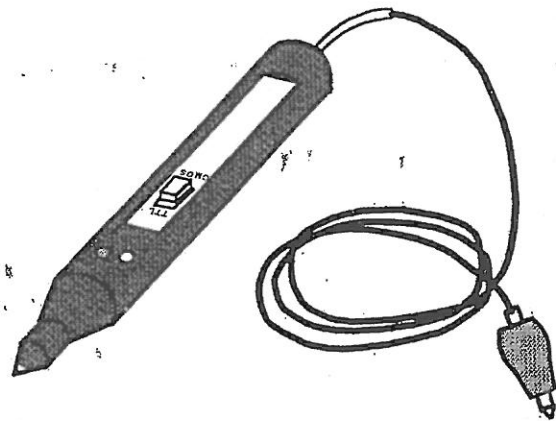


Figure 3.89 An LED probe for accessing the blink code

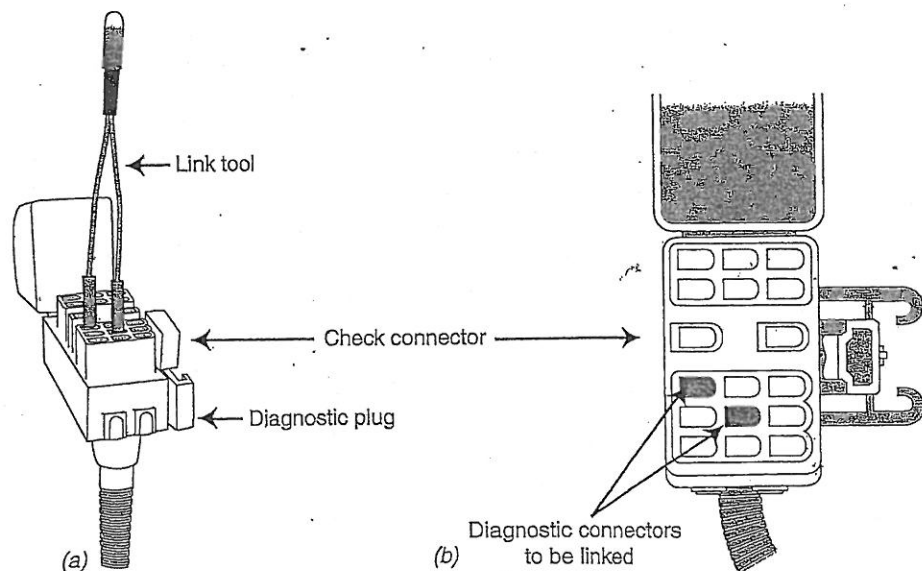


Figure 3.88 Example of linking terminals on the diagnostic plug to instruct the ECU to provide blink code output
a Link tool inserted into connector to initiate diagnostic sequence
b Plan view of connector terminals

A switch is connected across the two specified terminals, and then the LED probe connected across two other terminals of the harness plug. The specific instructions will indicate when the switch should be closed or open. This action makes or breaks the circuit across the two terminals. If the switch is opened and closed at the appropriate times, the ECU will output the fault codes as a blink code on the LED probe.

Obtaining codes and fault related information using a code reader/scan tool

Using a code reader/scan tool is the most informative method of retrieving fault related information from the ECU.

A code reader/scan tool must be connected to the ECU to obtain the information; connection is made to a diagnostic plug (Figure 3.90), which in most modern vehicles (with engine management systems) is located inside the passenger compartment. However, some other vehicle systems, such as ABS, have a diagnostic plug located in the engine compartment or elsewhere.

Note that European regulations now specify that the engine management diagnostic plug is to be located within a defined region of the passenger compartment; this is explained more fully in section 3.7.5.

Appropriate vehicle application software

Many code readers can use different cartridges, pods or software to enable them to function on different makes and models of vehicle and on different makes of vehicle system. Although some code readers are designed to operate on only one (or a few) makes and models, most have the facility to use different application software,

which can be purchased from the code reader manufacturer. Depending on the equipment design, the software is contained within replaceable pods or cartridges. In some cases new software can be downloaded via the Internet.

Most code readers are capable of operating with many different makes and models of vehicle. Software upgrades enable newer models to be covered without necessarily requiring a complete new code reader.

Starting the communication

For almost all vehicle systems, the ECU requires some form of password before it will output the fault codes or live data to the code reader. The password is usually an electronic code that is transmitted from the code reader to the ECU. In most cases, the appropriate software cartridge is installed in the code reader, or the appropriate vehicle is selected from the menu on the code reader, causing the correct password to be sent to the ECU. When the ECU has received the password, the ECU and the code reader can then communicate.

Retrieving fault codes and data

Once communication has been established between the code reader and ECU, the capacity to retrieve codes and information will depend on the equipment being used and the system being tested. In general, however, instructions are provided on the code reader display, or are included in an operator manual.

Following the correct procedures will then allow fault codes, messages or live data to be retrieved, as well as enabling other functions to be performed, such as actuator tests and intermittent fault detection.



Figure 3.90 Connection of a code reader to the vehicle diagnostic plug

Different vehicle systems will provide different levels of information. Some may provide only simple fault codes, whilst modern engine management systems provide a considerable depth of live data, etc. Additionally, lower cost code readers might not be able to display all of the information available from the ECU, and may not be able to initiate many of the other ECU test functions, such as actuator testing.

EOBD (European on-board diagnostics)

Emissions related legislation affecting on-board diagnostics

The term on-board diagnostics refers in general to the facilities already described relating to self-diagnosis. However, originally in America and more recently in Europe, legislation has imposed certain standards for on-board diagnostic systems, with particular regard to emission control systems. In reality, because emission systems are now under the control of the engine management system, the operation of the engine management system is influenced by the legislation.

The American market has had on-board diagnostic legislation for some years (OBD 1 and OBD 2). In Europe, legislation was introduced in January 2000 that applied to new models (subsequently embracing diesel engines as well as petrol engines). In Europe, the on-board diagnostic legislation is referred to as EOBD (European on-board diagnostics) and is an adaptation of the American OBD 2, which was originally introduced in 1996. EOBD is part of a range of regulations introduced by the EC aimed at controlling or reducing the emissions from motor vehicles. There are many aspects to EOBD regulations, but the relevant issues are discussed within this section.

Whilst the regulations are primarily aimed at emissions control systems/engine management systems, other vehicle systems also affect emission levels, such as the air conditioning. The air conditioning system may be operating at idle speed, thus causing the idle speed to reduce as well as demanding engine power. An engine management system must ensure that the idle speed is maintained, and also ensure the air-fuel ratio is controlled, so power can be developed without increasing emissions significantly. It is common to find fault codes on modern systems that embrace air conditioning functions, automatic transmission functions, and also codes for other vehicle systems that communicate or co-operate with the engine management system.

Long term monitoring of emissions from the vehicle

One objective of the regulations is to ensure that emissions levels from motor vehicles are maintained at acceptable levels for the operating life of the vehicle, and also that, when the emissions levels are

unacceptable because of a fault, vehicle systems are able to detect the incorrect emissions and identify the fault. In effect, the regulations impose a requirement for monitoring emissions and emissions control systems (including the engine management system). This requirement effectively defines the technical functions of the engine management system and some of the ECU diagnosis software. EOBD regulations resulted in the introduction of post-cat monitoring, i.e. an oxygen or lambda sensor located after the catalytic converter (section 3.5.7). This additional lambda sensor allowed the ECU to monitor the efficiency of the catalytic converter process. A second lambda sensor signal indicates the oxygen content of the exhaust gas in the catalytic converter.

The self-monitoring and self-diagnostic capability of the modern engine management ECU is highly complex, and the software program embraces many variables that can occur during engine management system operation. As a simple example, if the signal voltage from a temperature sensor exceeds the maximum programmed limit (e.g. 4.8 volts, as used in earlier examples in section 3.7.2), this would be regarded as a fault on older systems. However, EOBD systems must have a built-in tolerance that allows the signal voltage to exceed the maximum limit for a very brief period of time.

ECU programming must therefore permit an occasionally faulty signal, so long as it occurs only for an exceptionally short period and on a limited number of occasions; under these specified conditions, the ECU would not regard the fault as permanent, so no fault code would be stored and the warning light would not be illuminated.

Standardisation of fault codes, communication and diagnostic plugs

Standardised codes

Another significant aspect of EOBD is the standardisation of many engine system related fault codes. Prior to EOBD, vehicle manufacturers used their own coding system to indicate faults – there was no consistency across makes or models. Whilst vehicle manufacturers are still allowed to use their own fault code system and codes (which can be used in their authorised repair workshops in conjunction with the dedicated vehicle test equipment), there is a standardised list of codes and messages that apply to emissions related system faults. The standardised system of codes must be accessible to general purpose code reading equipment, so that equipment manufacturers can produce code reading equipment that provides the same fault codes and messages irrespective of the vehicle being tested.

The standardised codes, which number in excess of 500, are referred to as P Zero or P0 codes. Vehicle manufacturers' own coding systems are referred to as P1 codes. The P0 codes must still be accessible even if a vehicle manufacturer uses its own P1 coding system.

