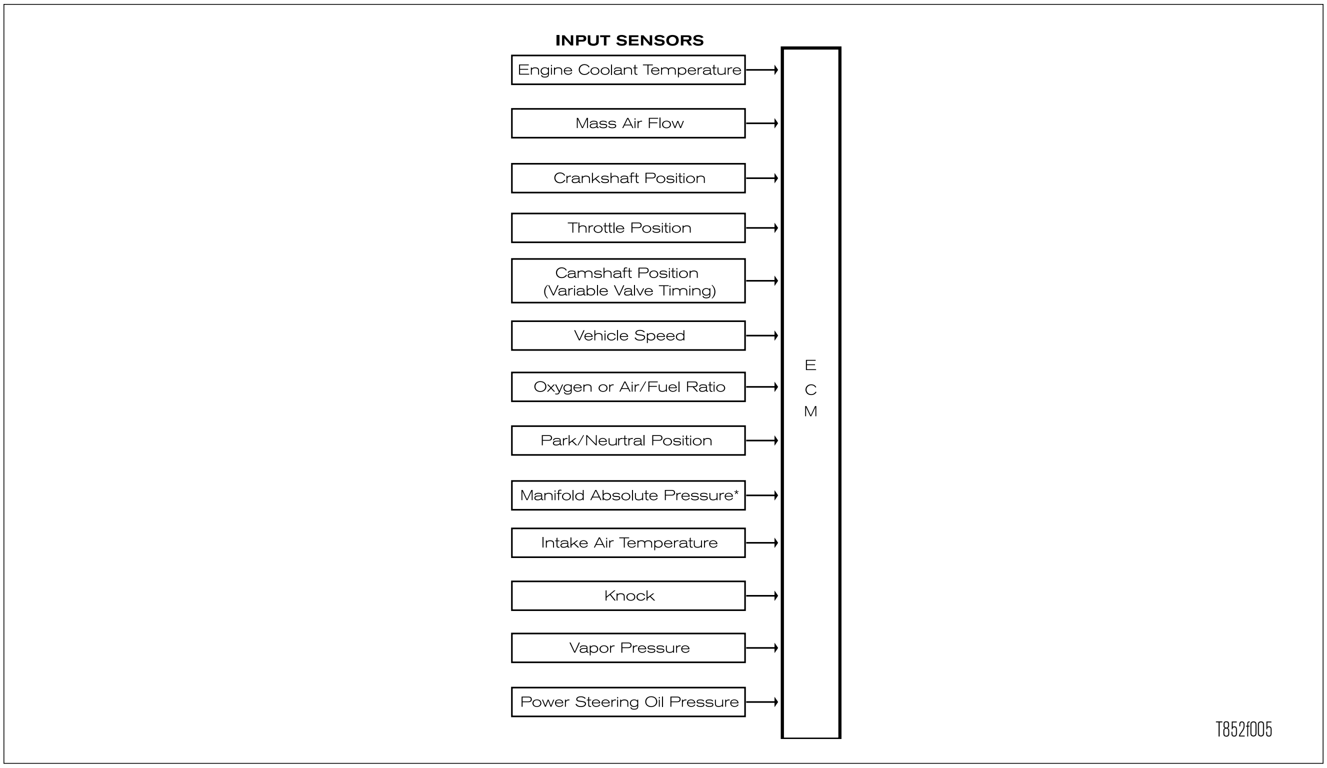
Section 2

Inputs - Sensors



Lesson Objectives

1. Determine the condition of input sensors and circuit based on their signal output
2. Determine the root cause of the failure(s) using appropriate diagnostic procedures

Notes

Inputs - Sensors

Position/Mode Sensors and Switches

For many components, it is important that the ECM know the position and/or mode of the component. A switch is used as a sensor to indicate a position or mode. The switch may be on the supply side or the ground side of a circuit.

Power Side Switch

On a power side switch, with the switch open, there is no voltage at the ECM.

Fig. 2-01
T852f019

Switch Closed

With the switch closed, voltage is present at the ECM.

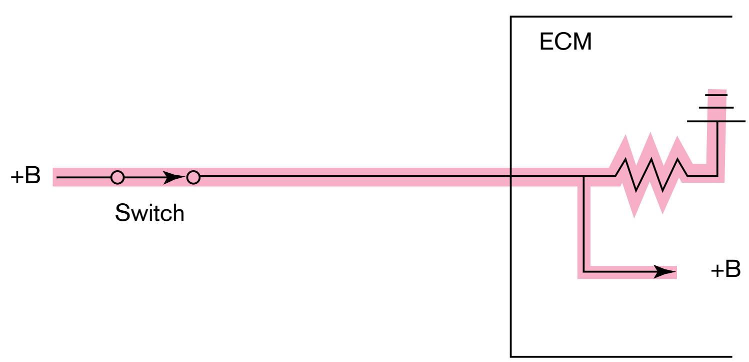


Fig. 2-02
T852f020

Power Side Switch Circuit

A power side switch is a switch located between the power supply and load. Sometimes the power side switch is called hot side switch because it is located on the hot side, that is, before the load, in a circuit. The Stop Lamp switch is a good example. When the brake pedal is depressed, the Stop Lamp switch closes sending battery voltage to the ECM. This signals the ECM that the vehicle is braking.

The following switches act as switches for the ECM. Usually, they are supply side switches. Note in the figure(s) their location between the battery and ECM. Many switches that commonly use battery voltage as the source are:

- Ignition Switch.
- Park/Neutral Switch.
- Transfer Low Position Detection Switch.
- Transfer Neutral Position Detection Switch.
- Transfer 4WD Detection Switch.

Stop Lamp Switch

The ECM receives a voltage signal when the brake pedal is depressed.

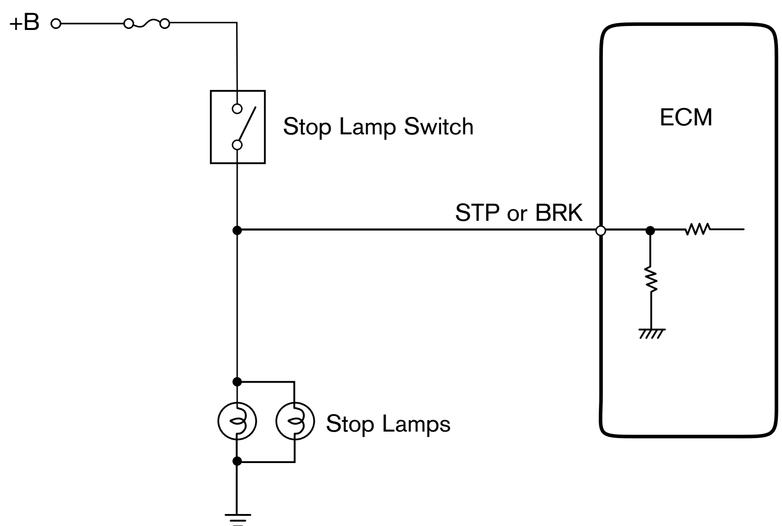


Fig. 2-03
T852f021

DVOM

A DVOM will measure 0 volts with the switch open.

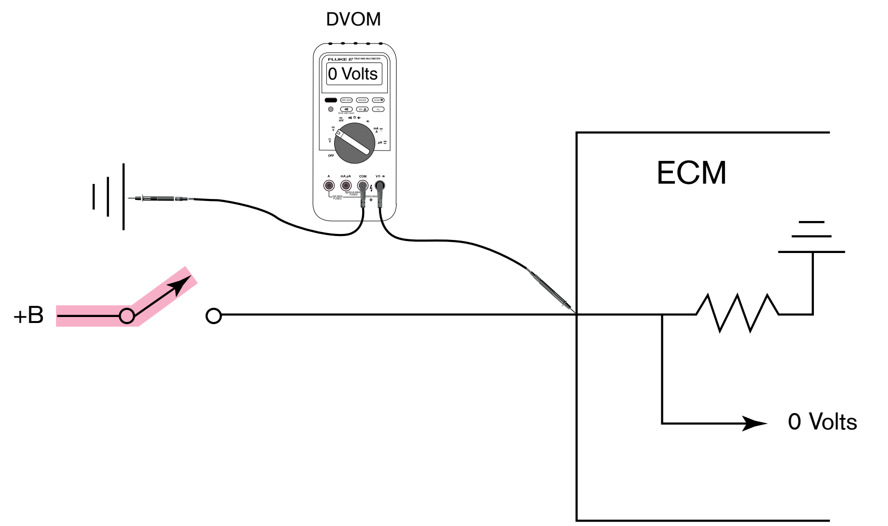


Fig. 2-04

T852f022

DVOM

Here the DVOM reads supply voltage when the switch closes. This indicates to the ECM a change has taken place. Using the DVOM confirms the circuit and switch are good.

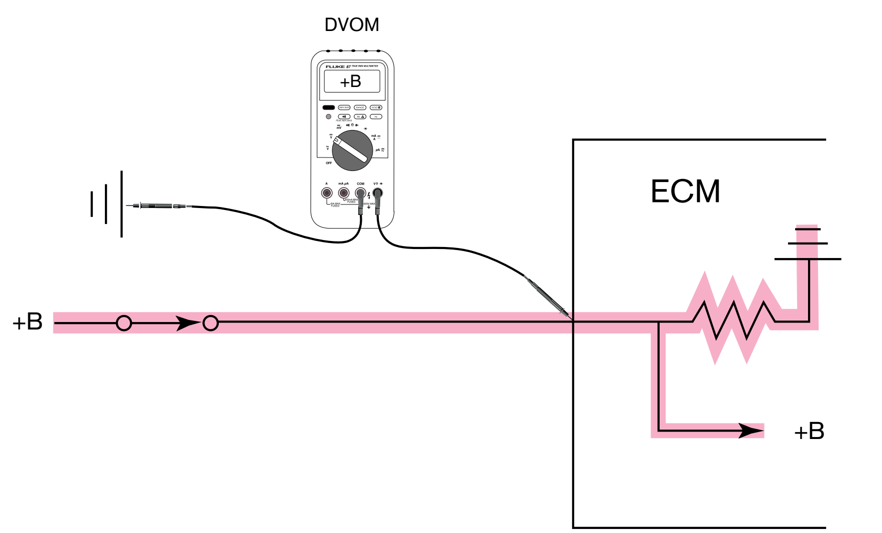


Fig. 2-05

T852f023

Ground Side Switch

On a ground side switch circuit with switch open, the ECM reads supply voltage.

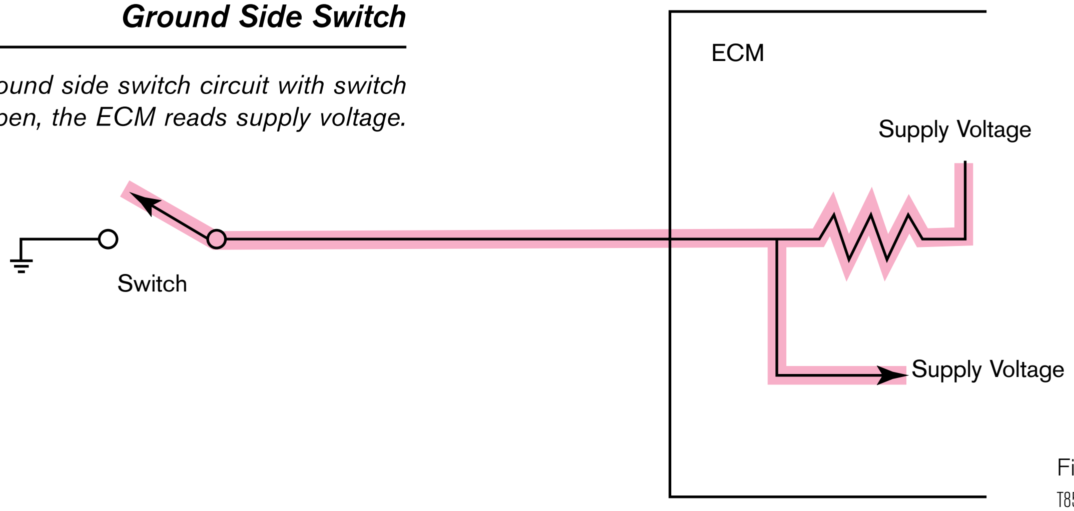


Fig. 2-06
T852f024

Switch Closed

When the switch closes, the ECM reads 0 Volts.

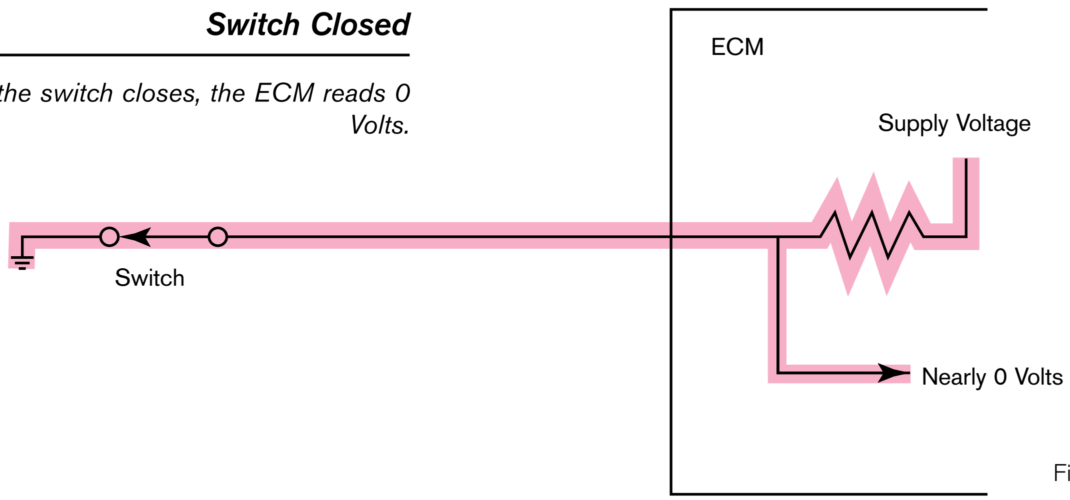


Fig. 2-07
T852f025

Ground Side Switch Circuit

A ground side switch is located between the load and ground in a circuit. Inside the ECM there is resistor (load) connected in series to the switch. The ECM measures the available voltage between the resistor and switch. When the switch is open, the ECM reads supply voltage. When the switch is closed, voltage is nearly zero.

The following switches are typically found on the ground side of the circuit:

- TPS Idle Contact (IDL signal) The TPS Idle Contact Switch uses a 12 volt reference voltage from the ECM.
- Power Steering Pressure Switch.
- Overdrive Switch.

DVOM

A DVOM will measure supply voltage when the switch is open.

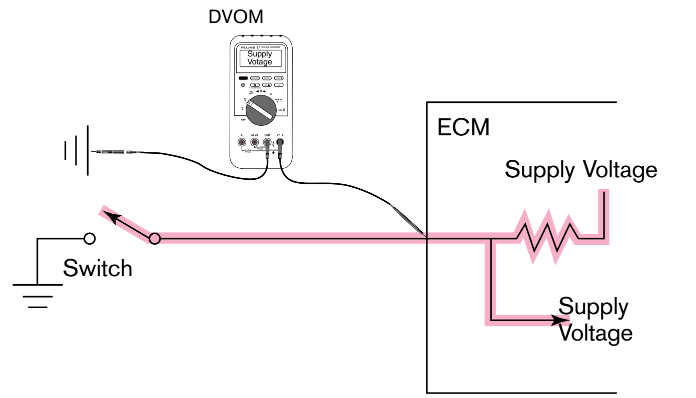


Fig. 2-08

T852f026

DVOM

When the switch closes, the DVOM measures nearly 0 Volts. Using the DVOM confirms the circuit is good.

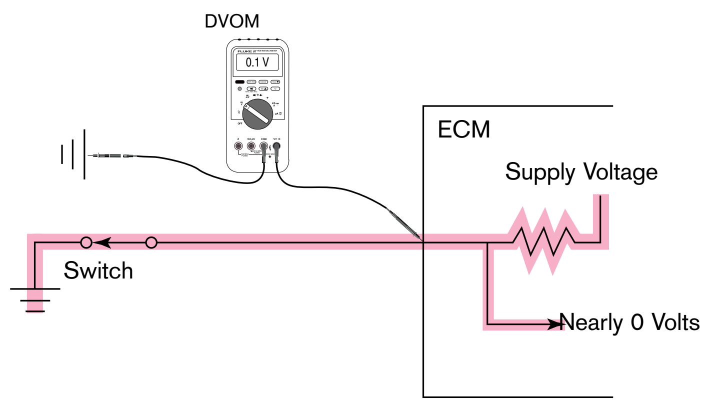


Fig. 2-09

T852f027

STA Mode

When the ignition switch is turned to the Start position, battery voltage is applied to the STA terminal. This drawing is a general representation, there are many variations.

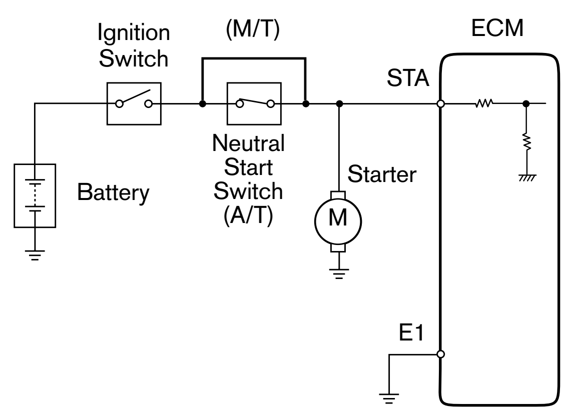


Fig. 2-10

T852f028

Electrical Load Signal

The ELS circuit signals the ECM when a significant electrical load has been placed on the charging system, such as when the defogger or tail lamp circuit is on.

The ELS signal will be low when both circuits are off. If either circuit or both circuits are on, the ELS signal goes to battery voltage. The diodes are used to isolate the circuit.

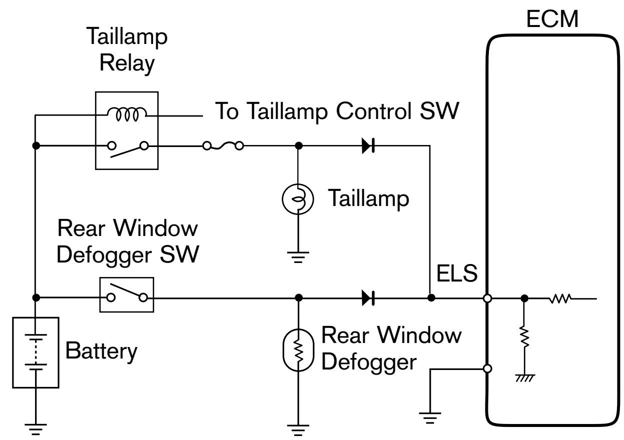


Fig. 2-11

T852f029

A/C Signal

The A/C signal is used by the ECM to stabilize the idle speed, modify ignition timing, and modify deceleration fuel cut parameters when the compressor is running. In the event the signal malfunctions, idle quality may suffer and driveability during deceleration could be affected.

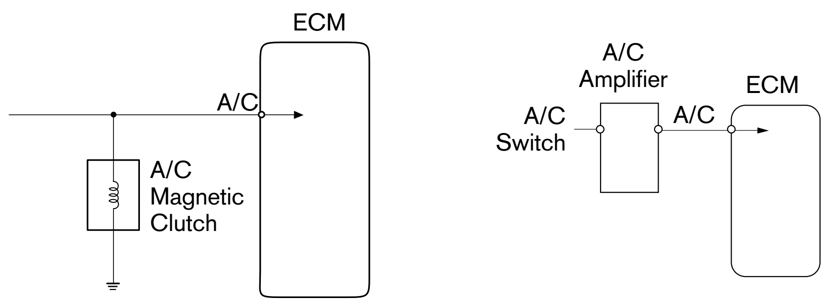


Fig. 2-12

T852f030/T852f031

Overdrive Circuit

The O/D circuit is a ground side switched circuit. When the switch is turned on, overdrive is cancelled and the light illuminates.

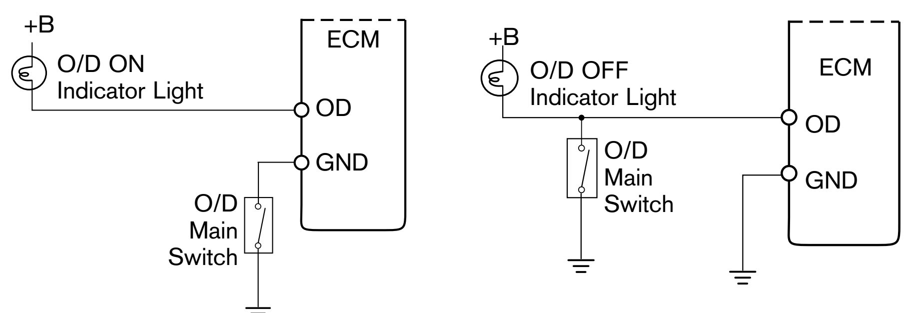


Fig. 2-13

T852f032/T852f349

Temperature Sensors

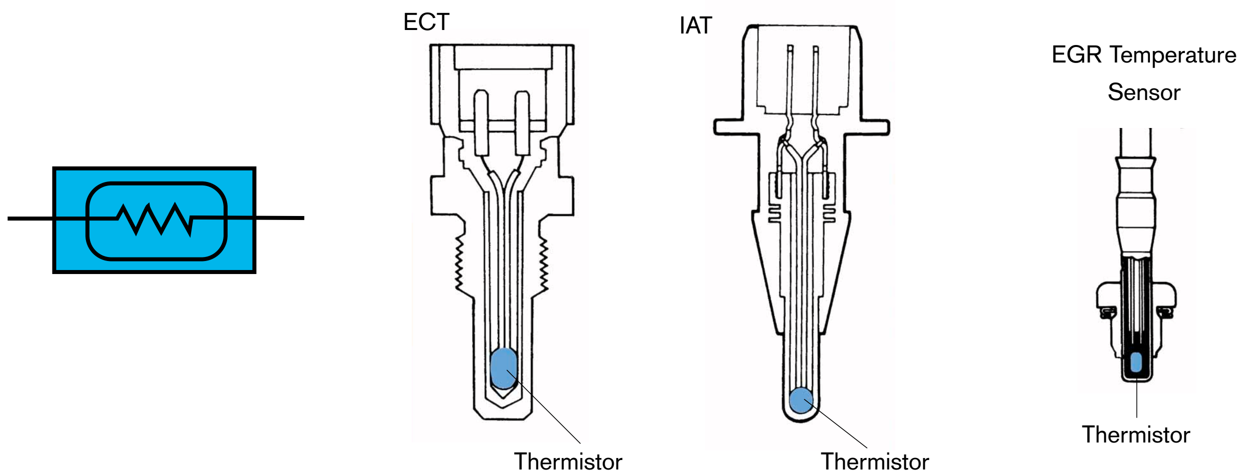


Fig. 2-14
T852f033/T852f034
T852f035/T852f036

Temperature Sensors

The ECM needs to adjust a variety of systems based on temperatures. It is critical for proper operation of these systems that the engine reach operating temperature and the temperature is accurately signaled to the ECM. For example, for the proper amount of fuel to be injected the ECM must know the correct engine temperature. Temperature sensors measure Engine Coolant Temperature (ECT), Intake Air Temperature (IAT) and Exhaust Gas Recirculation (EGR), etc.

ECT Circuit

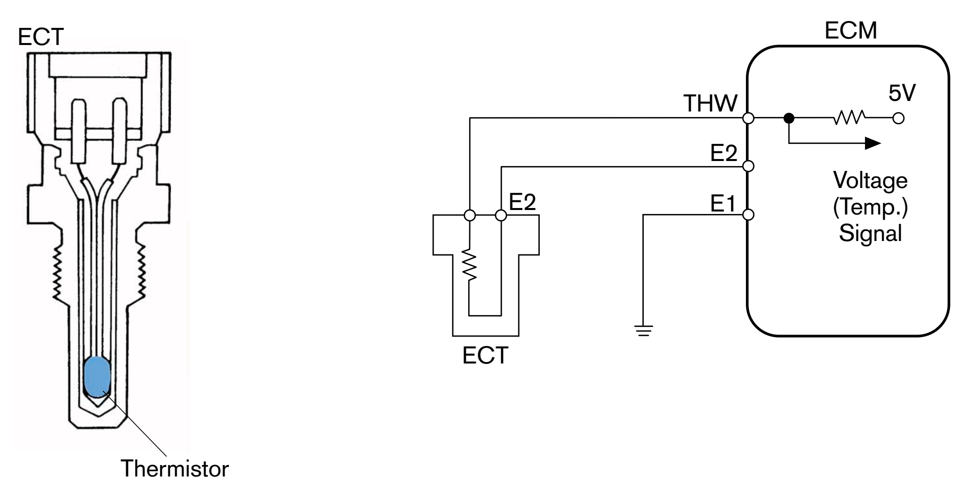


Fig. 2-15
T852f034/T852f037

Engine Coolant Temperature (ECT) Sensor

The ECT responds to change in engine coolant temperature. By measuring engine coolant temperature, the ECM knows the average temperature of the engine. The ECT is usually located in a coolant passage just before the thermostat. The ECT is connected to the THW terminal on the ECM.

The ECT sensor is critical to many ECM functions such as fuel injection, ignition timing, variable valve timing, transmission shifting, etc. Always check to see if the engine is at operating temperature and that the ECT is accurately reporting the temperature to the ECM.

IAT Circuit

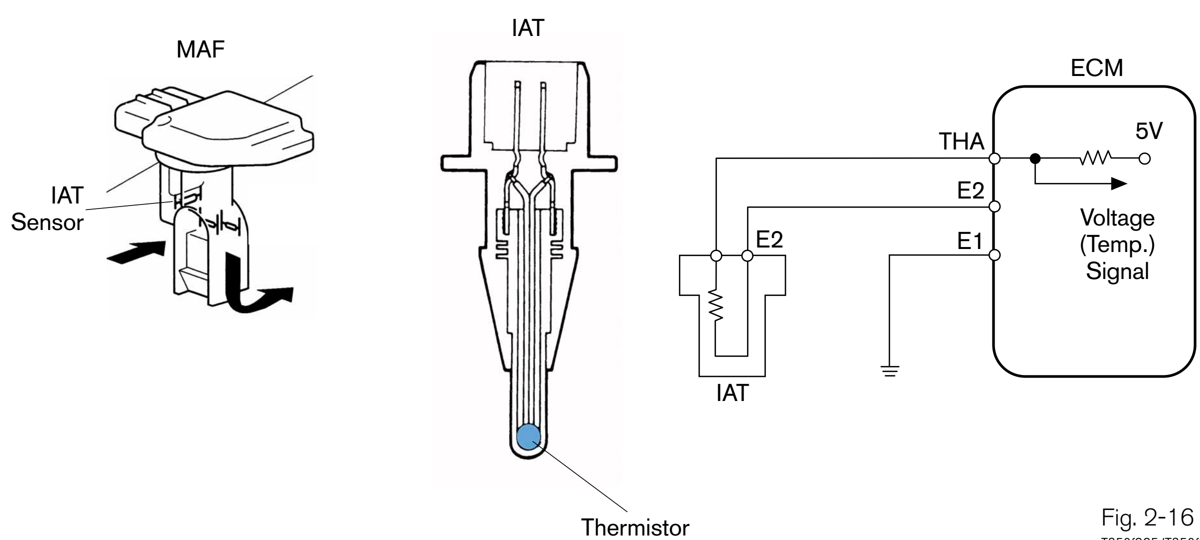


Fig. 2-16
T852f065/T852f035
T852f038

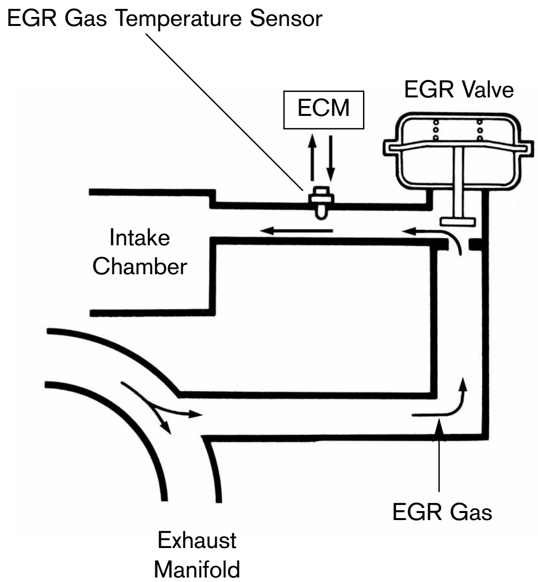
Intake Air Temperature (IAT) Sensor

The IAT detects the temperature of the incoming air stream. On vehicles equipped with a MAP sensor, the IAT is located in an intake air passage. On Mass Air Flow sensor equipped vehicles, the IAT is part of the MAF sensor. The IAT is connected to the THA terminal on the ECM. The IAT is used for detecting ambient temperature on a cold start and intake air temperature as the engine heats up the incoming air.

NOTE

One strategy the ECM uses to determine a cold engine start is by comparing the ECT and IAT signals. If both are within 8°C (15°F) of each other, the ECM assumes it is a cold start. This strategy is important because some diagnostic monitors, such as the EVAP monitor, are based on a cold start.

EGR Temperature Circuit



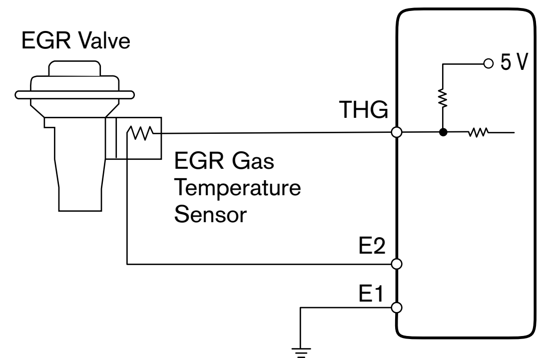


Fig. 2-17

T852f039/T852f040

Temperature Graph

As temperature increases, sensor resistance and the voltage signal decreases. Note that at the upper end of the temperature/resistance scale, ECT resistance changes very little.

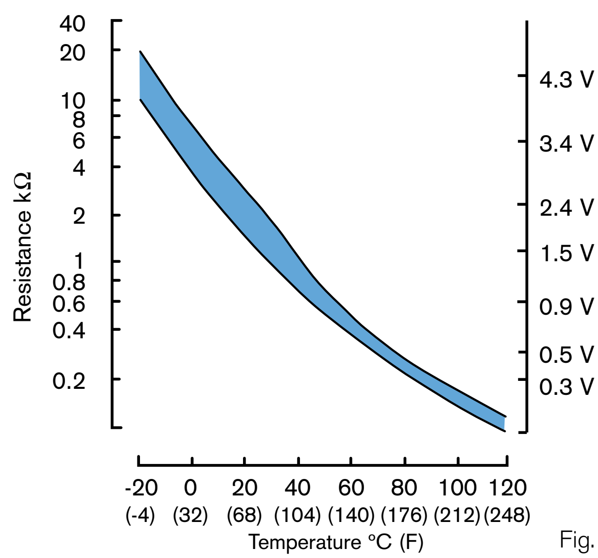


Fig. 2-18

T852f041

Exhaust Gas Recirculation (EGR) Temperature Sensor

The EGR Temperature Sensor is located in the EGR passage and measures the temperature of the exhaust gases. The EGR Temp sensor is connected to the THG terminal on the ECM. When the EGR valve opens, temperature increases. From the increase in temperature, the ECM knows the EGR valve is open and that exhaust gases are flowing.

ECT, IAT, & EGR Temperature Sensor Operation

Though these sensors are measuring different things, they all operate in the same way. From the voltage signal of the temperature sensor, the ECM knows the temperature. As the temperature of the sensor heats up, the voltage signal decreases. The decrease in the voltage signal is caused by the decrease in resistance. The change in resistance causes the voltage signal to drop.

The temperature sensor is connected in series to a fixed value resistor. The ECM supplies 5 volts to the circuit and measures the change in voltage between the fixed value resistor and the temperature sensor.

When the sensor is cold, the resistance of the sensor is high, and the voltage signal is high. As the sensor warms up, the resistance drops and voltage signal decreases. From the voltage signal, the ECM can determine the temperature of the coolant, intake air, or exhaust gas temperature.

The ground wire of the temperature sensors is always at the ECM, usually terminal E2. These sensors are classified as thermistors.

Temperature Sensor Diagnostics

Temperature sensor circuits are tested for:

- opens.
- shorts.
- available voltage.
- sensor resistance.

The Diagnostic Tester data list can reveal the type of problem. An open circuit (high resistance) will read the coldest temperature possible. A shorted circuit (low resistance) will read the highest temperature possible. The diagnostic procedure purpose is to isolate and identify the temperature sensor from the circuit and ECM.

High resistance in the temperature circuit will cause the ECM to think that the temperature is colder than it really is. For example, as the engine warms up, ECT resistance decreases, but unwanted extra resistance in the circuit will produce a higher voltage drop signal. This will most likely be noticed when the engine has reached operating temperatures. Note that at the upper end of the temperature/resistance scale, ECT resistance changes very little. Extra resistance in the higher temperature can cause the ECM to think the engine is approximately 20°F ≈ 30°F colder than actual temperature. This will cause poor engine performance, fuel economy, and possibly engine overheating.

Solving Open Circuit Problems

A jumper wire and Diagnostic Tester are used to locate the problem in an open circuit.

Open Circuit Test at Sensor

A jumper wire is inserted in the circuit as shown in the Repair Manual; the temperature should go high (hot). If it does, the circuit and the ECM must be good, and the temperature sensor or connector is at fault.

If the temperature did not go high (hot), then the problem is with the circuit or ECM.

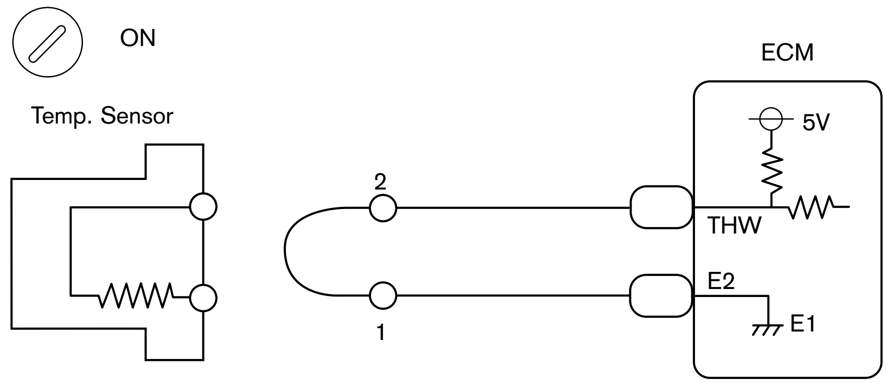


Fig. 2-19

T852f042

Open Circuit Test at ECM

To isolate if the problem is with the circuit or the ECM, a jumper wire is inserted between the temperature (such as THW) terminal and ground (E2), and the temperature should go high. If it does, the problem is in the circuit. If it did not go high, the fault is either in the connection or ECM.

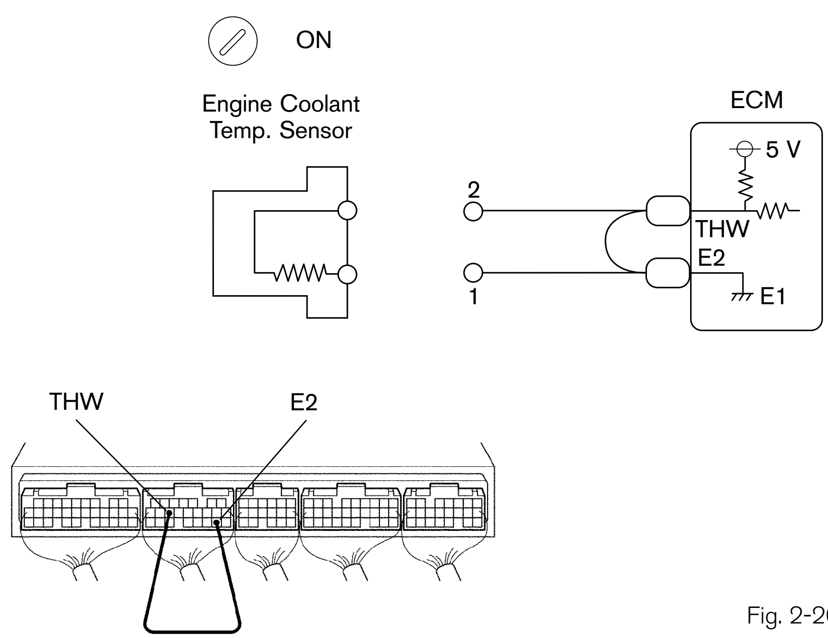


Fig. 2-20

T852f043/T852f044

Solving Shorted Circuit Problems

Creating an open circuit at different points in the temperature circuit will isolate the short. The temperature reading should go extremely low (cold) when an open is created.

Short Circuit Testing

To confirm if the circuit or ECM is at fault, first disconnect the connector at the ECM. Temperature should go low (cold). If it does, the harness or connector is at fault. If not, the problem is with the ECM.

Disconnecting the connector at the ECT should cause the temperature reading to go low (cold). If it does, the problem is in the sensor. If not, the problem is in the circuit harness.

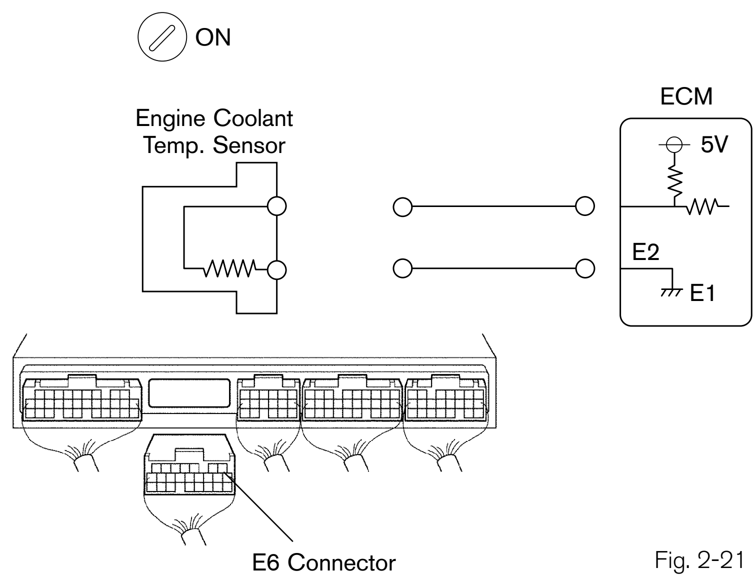


Fig. 2-21

T852f045/T852f046

Temperature Sensor Component Testing

A temperature sensor is tested for accuracy by comparing the resistance of the sensor to the actual temperature. The RM contains the procedure and specifications. To insure accuracy, you must have an accurate thermometer and good electrical connections to the DVOM.

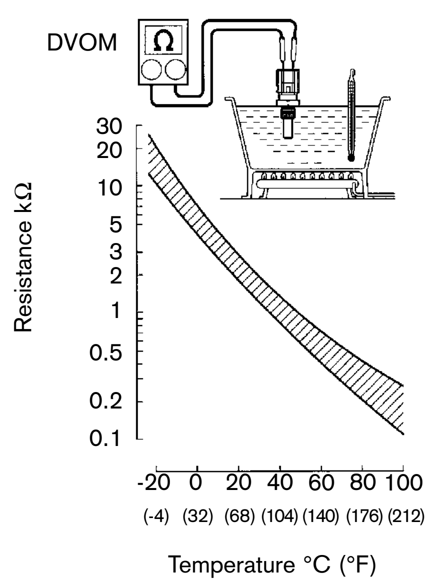


Fig. 2-22

T852f047

Position Sensor

As the wiper arm moves the signal voltage output changes. From this voltage, the ECM is able to determine position.

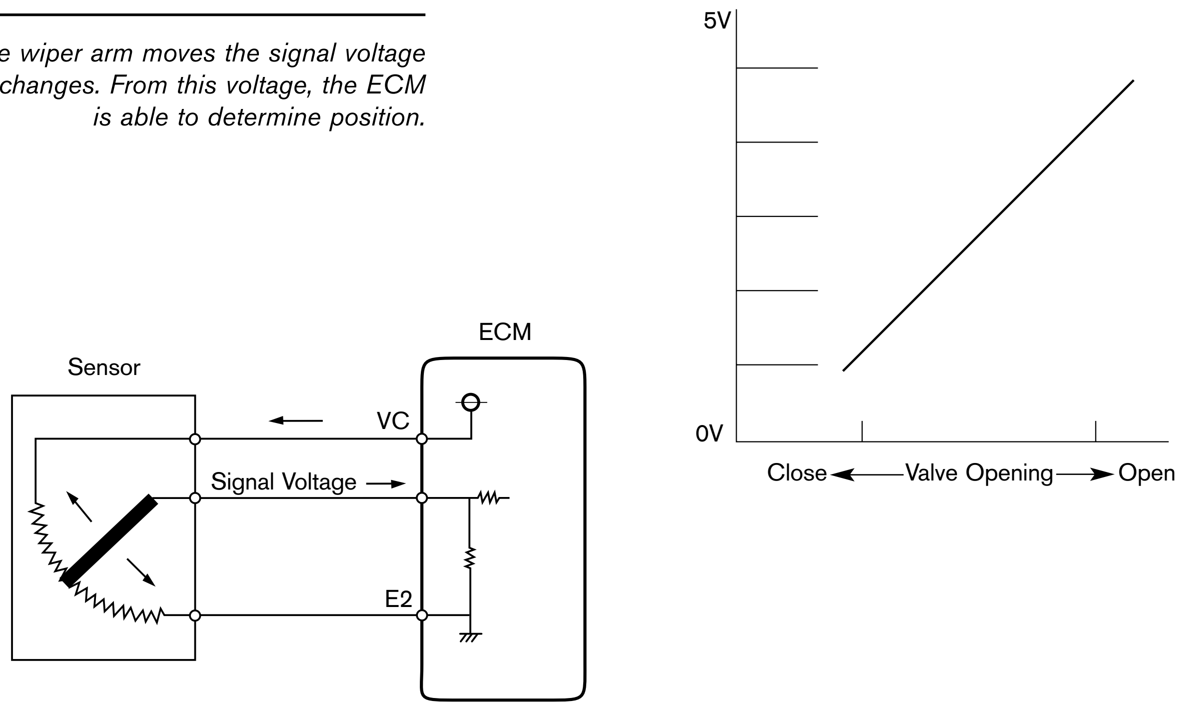


Fig. 2-23
T852f048/T852f049

Position Sensors

In many applications, the ECM needs to know the position of mechanical components. The Throttle Position Sensor (TPS) indicates position of the throttle valve. Accelerator Pedal Position (APP) sensor indicates position of the accelerator pedal. Exhaust Gas Recirculation (EGR) Valve Position Sensor indicates position of the EGR Valve. The vane air flow meter uses this principle.

Electrically, these sensors operate the same way. A wiper arm inside the sensor is mechanically connected to a moving part, such as a valve or vane. As the part moves, the wiper arm also moves. The wiper arm is also in contact with a resistor. As the wiper arm moves on the resistor, the signal voltage output changes. At the point of contact the available voltage is the signal voltage and this indicates position. The closer the wiper arm gets to VC voltage, the higher the signal voltage output. From this voltage, the ECM is able to determine the position of a component.

Throttle Position Sensor Circuit

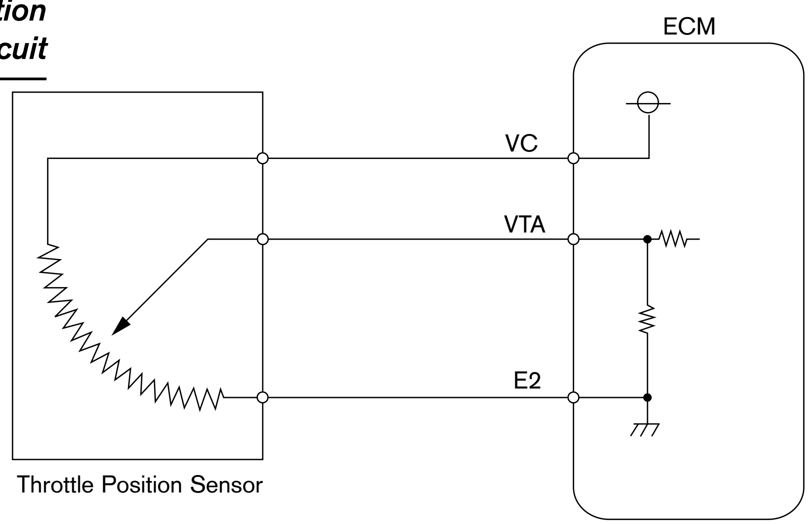


Fig. 2-24

T852f050

Throttle Position Sensor

The TPS is mounted on the throttle body and converts the throttle valve angle into an electrical signal. As the throttle opens, the signal voltage increases.

The ECM uses throttle valve position information to know:

- engine mode: idle, part throttle, wide open throttle.
- when to switch off AC and emission controls at Wide Open Throttle (WOT)
- air-fuel ratio correction.
- power increase correction.
- fuel cut control.

The basic TPS requires three wires. Five volts are supplied to the TPS from the VC terminal of the ECM. The TPS voltage signal is supplied to the VTA terminal. A ground wire from the TPS to the E2 terminal of the ECM completes the circuit.

At idle, voltage is approximately 0.6 - 0.9 volts on the signal wire. From this voltage, the ECM knows the throttle plate is closed. At wide open throttle, signal voltage is approximately 3.5 - 4.7 volts

Inside the TPS is a resistor and a wiper arm. The arm is always contacting the resistor. At the point of contact, the available voltage is the signal voltage and this indicates throttle valve position. At idle, the resistance between the VC (or VCC) terminal and VTA terminal is high, therefore, the available voltage is approximately 0.6 - 0.9 volts. As the contact arm moves closer the VC terminal (the 5 volt power voltage), resistance decreases and the voltage signal increases.

TPS With Idle Contact Switch Circuit

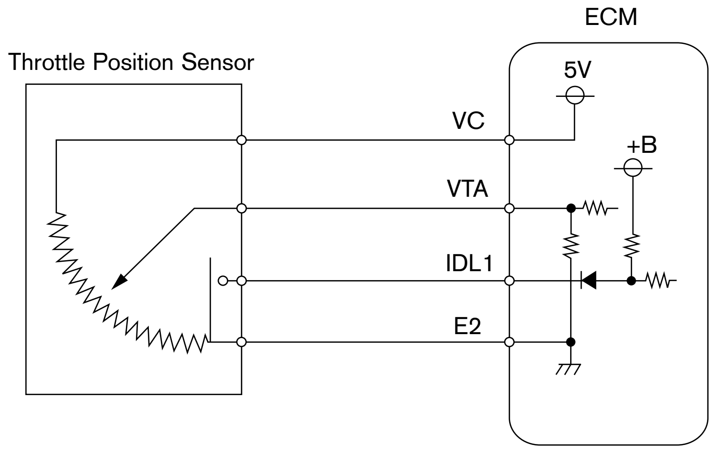


Fig. 2-25
T852f051

TPS With IDL

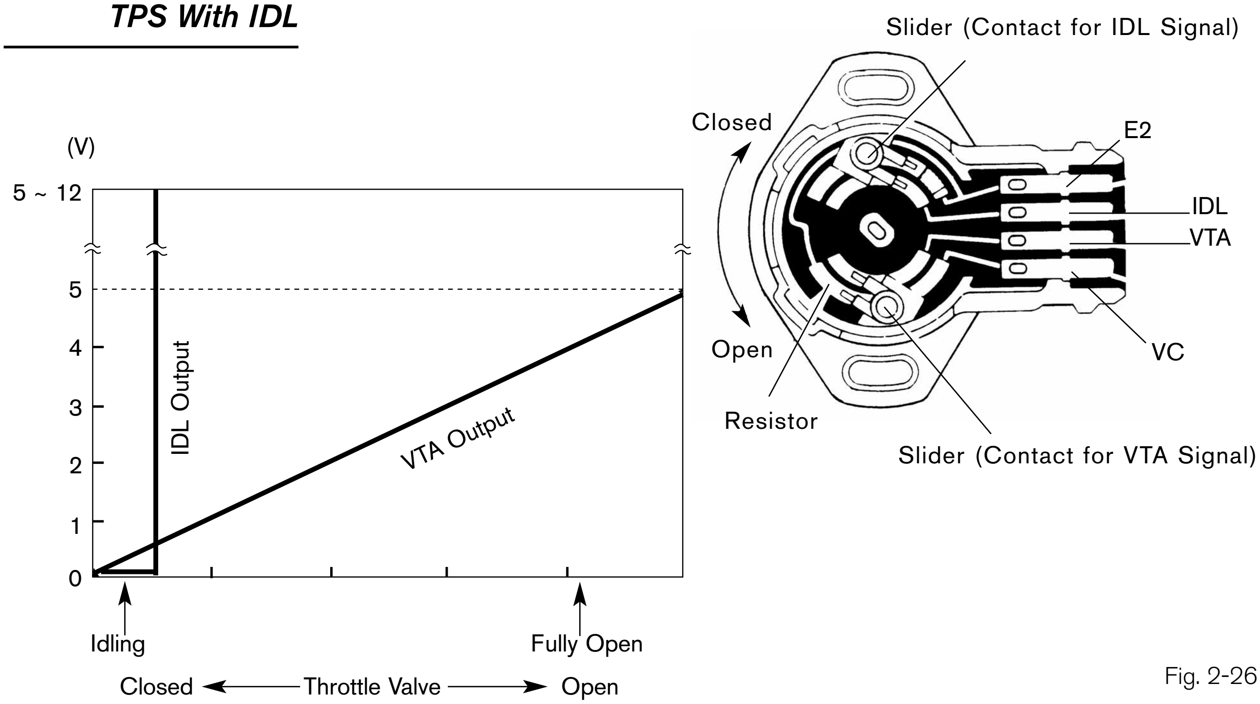


Fig. 2-26
T852f053/T852f052

Some TPS incorporate a Closed Throttle Position switch (also called an idle contact switch). This switch is closed when the throttle valve is closed. At this point, the ECM measures 0 volts and there is 0 volts at the IDL terminal. When the throttle is opened, the switch opens and the ECM reads +B voltage at the IDL circuit.

TPS in the ETCS-i System

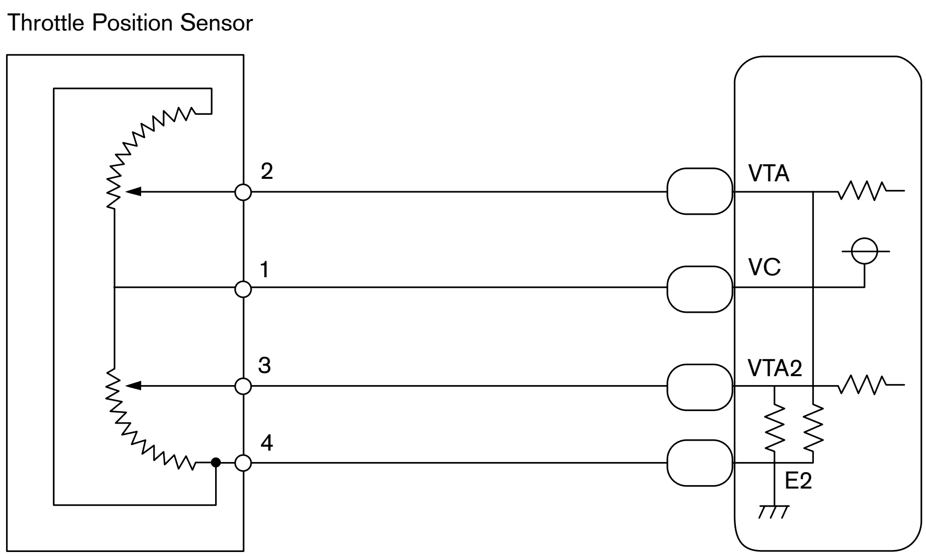


Fig. 2-27

T852f054

The TPS on the ETCS-i system has two contact arms and two resistors in one housing. The first signal line is VTA and the second signal line is VTA2.

TPS Signal Voltages

Note that VTA2 reaches its upper limit earlier than VTA.

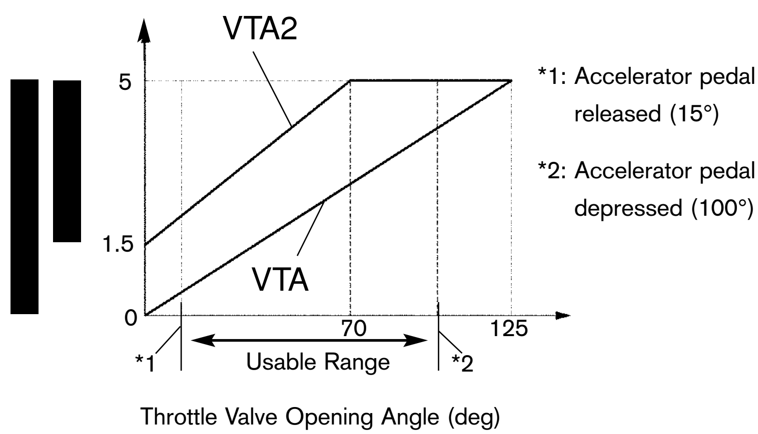


Fig. 2-28

T852f055

VTA2 works the same, but starts at a higher voltage output and the voltage change rate is different from VTA. As the throttle opens the two voltage signals increase at a different rate. The ECM uses both signals to detect the change in throttle valve position. By having two sensors, ECM can compare the voltages and detect problems.

Accelerator Pedal Position (APP) Sensor

The APP sensor is mounted on the throttle body of the ETCS-i. The APP sensor converts the accelerator pedal movement and position into two electrical signals. Electrically, the APP is identical in operation to the TPS.

EGR Valve Position Sensor

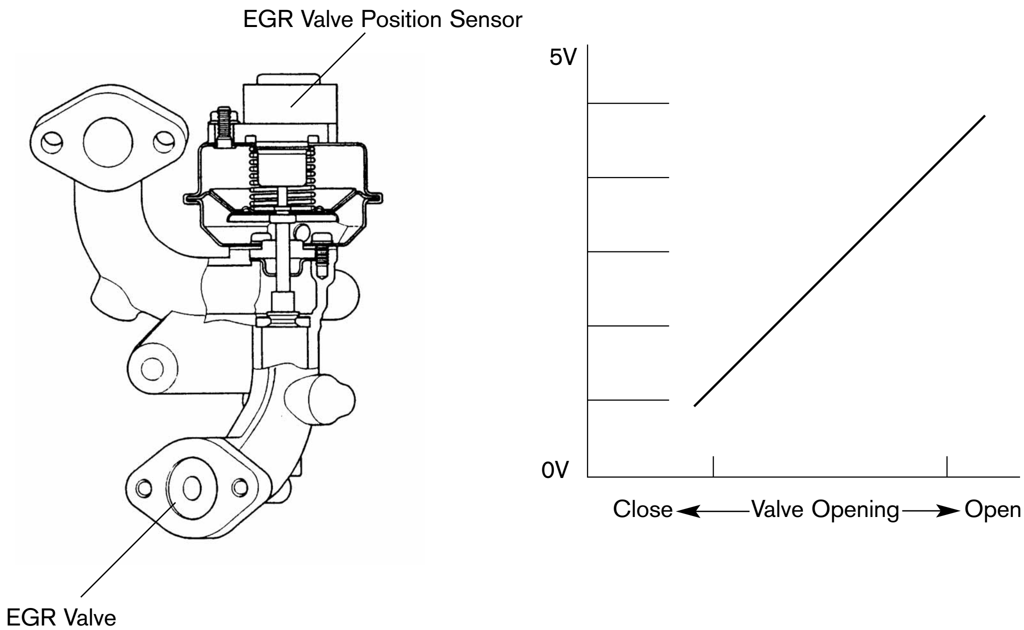


Fig. 2-29

T852f056/T852f049

EGR Valve Position Sensor

The EGR Valve Position Sensor is mounted on the EGR valve and detects the height of the EGR valve. The ECM uses this signal to control EGR valve height. The EGR Valve Position Sensor converts the movement and position of the EGR valve into an electrical signal. Operation is identical to the TPS except that the signal arm is moved by the EGR valve.

Position Sensor Diagnostics

The following explanations are to help you with the diagnostic procedures in the Repair Manual.

Diagnostic Tester

Comparing the position of the sensor to Diagnostic Tester data is a convenient way of observing sensor operation. For example, with the TPS, the lowest percentage measured with Key On/Engine Off is with the throttle valve at its minimum setting, and the highest percentage will be at Wide Open Throttle.

Checking Supply Voltage Between Terminal VC and Body Ground

Disconnecting the sensor connector and measuring the voltage at the VC terminal you should get about 5 volts. If you get this reading it confirms that the wire is good and ECM is providing the correct voltage. If not, the problem may be with the circuit or ECM.

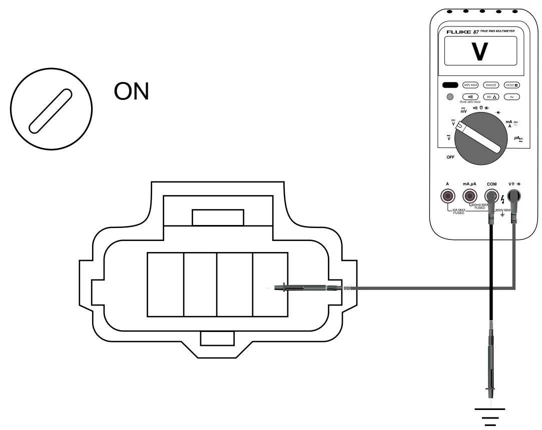


Fig. 2-30

T852f057

Check Voltage Between Terminals VC and E2 of ECM Connector

This test confirms that the ECM is putting out the necessary supply voltage. You would do this test if you did not measure 5 volts at the VC terminal at the TPS connector. If you get 5 volts at the ECM connector, the problem is in the harness. If you did not get 5 volts, the ECM is at fault.

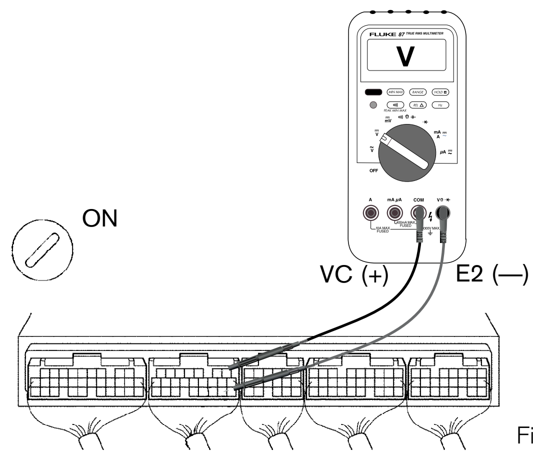


Fig. 2-31

T852f058

Inspect Throttle Position Sensor

On some models, you will find TPS checks in the Throttle Body on Vehicle Inspection in the SF Section.

TPS Resistance Check

A DVOM is used to measure the resistance of the sensor at the specified terminal location.

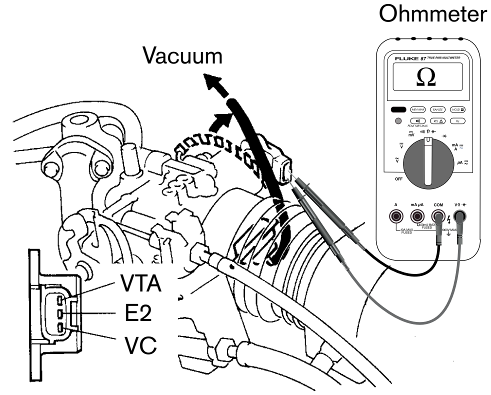


Fig. 2-32

T852f059

TPS Total Resistance Check

This resistance test is measuring total resistance.

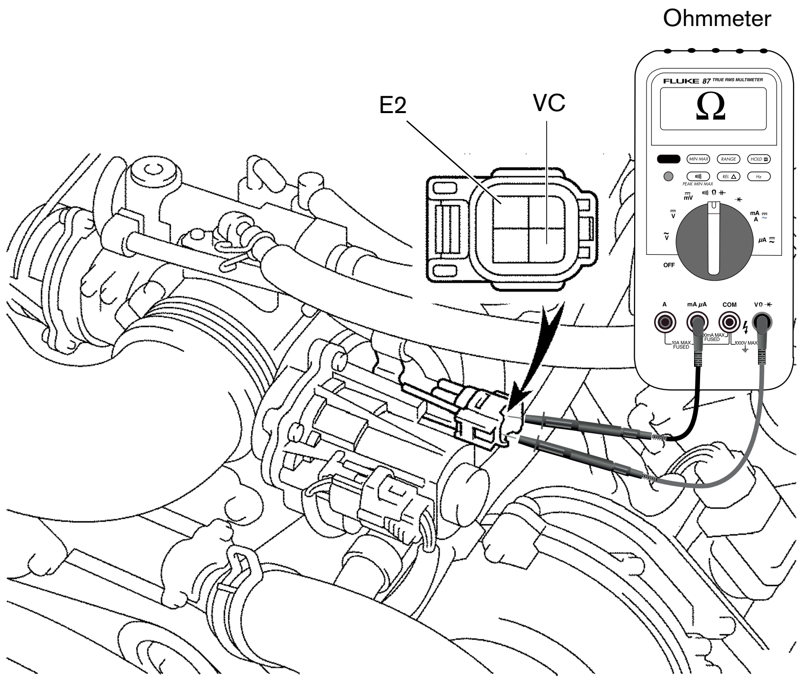


Fig. 2-33

T852f060

Check Voltage Between Terminals VTA and E2 of ECM Connector

This test is to determine if the circuit or the ECM is at fault. If voltage readings are in specifications, the ECM may be at fault. (Intermittent problems in the circuit or sensor may also be the problem.) If voltage readings are not in specifications, there is an open or short in the harness and connector between ECM and TPS on the VTA or E2 line.

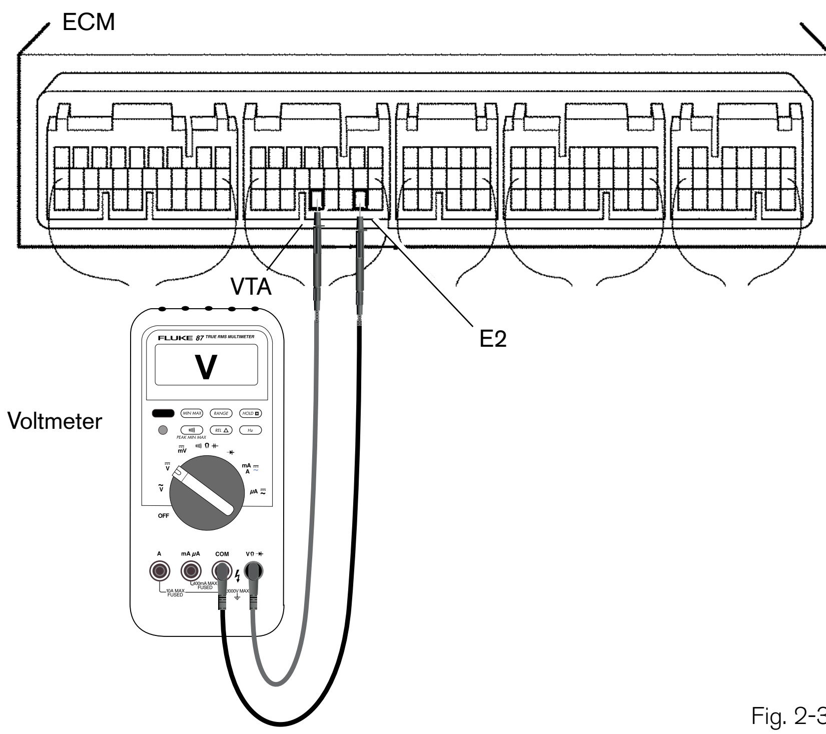


Fig. 2-34

T852f061

Air Flow Sensor

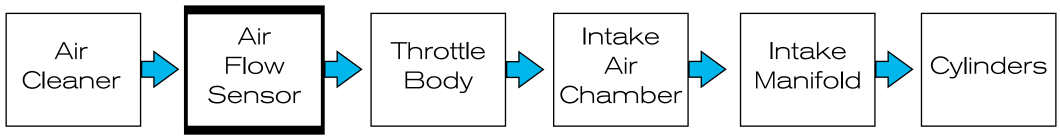


Fig. 2-35
T852f062

Mass Air Flow (MAF) Sensors

The Mass Air Flow Sensors converts the amount of air drawn into the engine into a voltage signal. The ECM needs to know intake air volume to calculate engine load. This is necessary to determine how much fuel to inject, when to ignite the cylinder, and when to shift the transmission. The air flow sensor is located directly in the intake air stream, between the air cleaner and throttle body where it can measure incoming air.

There are different types of Mass Air Flow sensors. The vane air flow meter and Karman vortex are two older styles of air flow sensors and they can be identified by their shape. The newer, and more common is the Mass Air Flow (MAF) sensor.

Hot Wire MAF Sensor

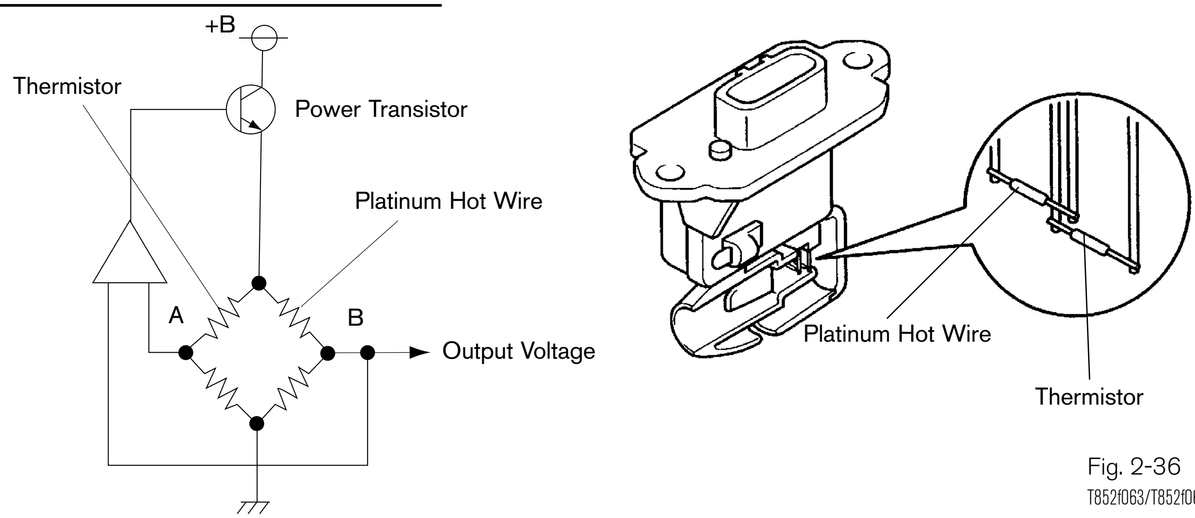


Fig. 2-36
T852f063/T852f064

Mass Air Flow Sensor: Hot Wire Type

The primary components of the MAF sensor are a thermistor, a platinum hot wire, and an electronic control circuit.

The thermistor measures the temperature of the incoming air. The hot wire is maintained at a constant temperature in relation to the thermistor by the electronic control circuit. An increase in air flow will cause the hot wire to lose heat faster and the electronic control circuitry will compensate by sending more current through the wire. The electronic control circuit simultaneously measures the current flow and puts out a voltage signal (VG) in proportion to current flow.

MAF Sensor Signal Voltage

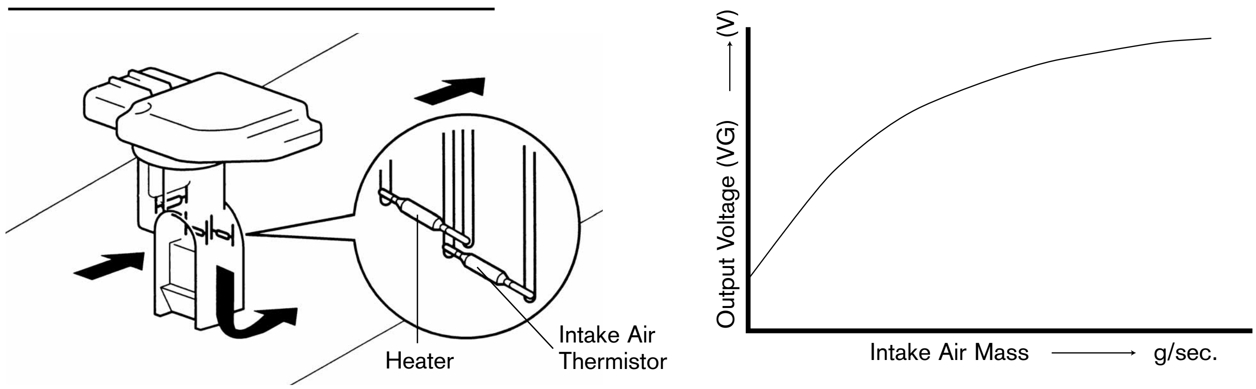


Fig. 2-37
T852f065/T852f066

This type of MAF sensor also has an Intake Air Temperature (IAT) sensor as part of the housing assembly. Its operation is described in the IAT section of Temperature Sensors. When looking at the EWD, there is a ground for the MAF sensor and a ground (E2) for the IAT sensor.

MAF Sensor Circuit

Note that the EFI relay feeds the MAF sensor battery voltage. The MAF has a ground just for the MAF sensor portion.

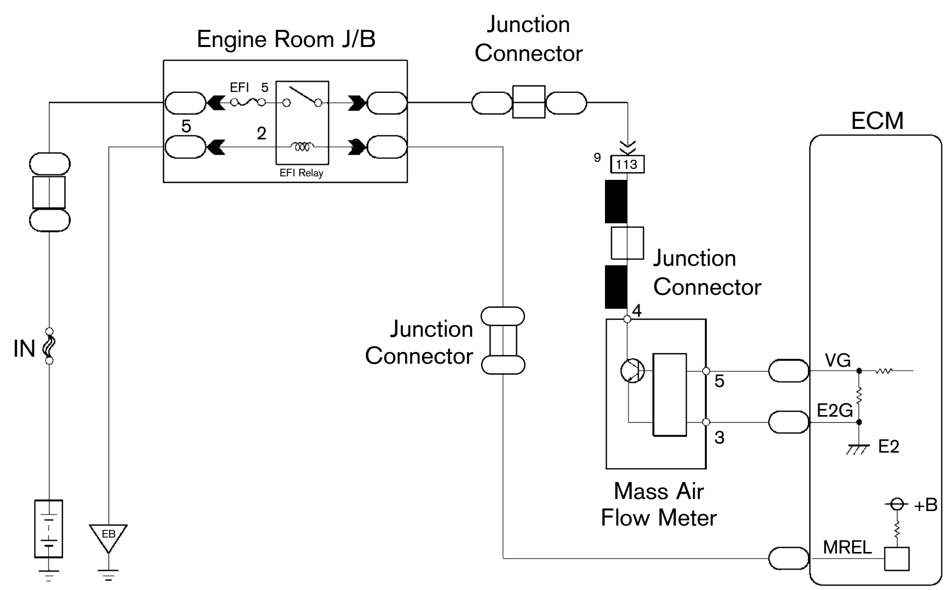


Fig. 2-38
T852f067

Diagnosis

Diagnosis of the MAF sensor involves visual, circuit, and component checks. The MAF sensor passage must be free of debris to operate properly. If the passage is plugged, the engine will usually start, but run poorly or stall and may not set a DTC.

MAF Supply Voltage

The +B terminal supplies voltage for the MAF Sensor. VG is the MAF signal line and E2G is the ground. THA terminal supplies 5 Volts for the IAT sensor and E2 is the ground.

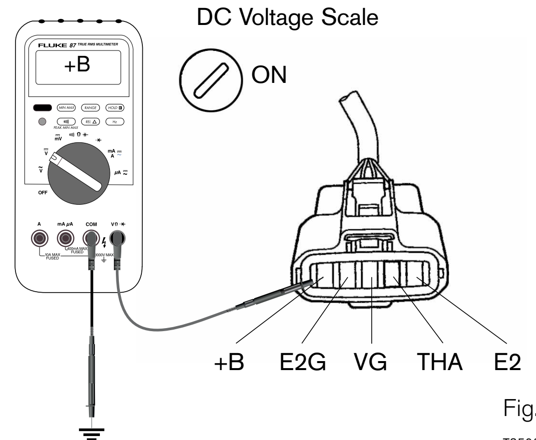


Fig. 2-39

T852f068

MAF Ground Circuit

MAF ground circuit check is performed with an ohmmeter.

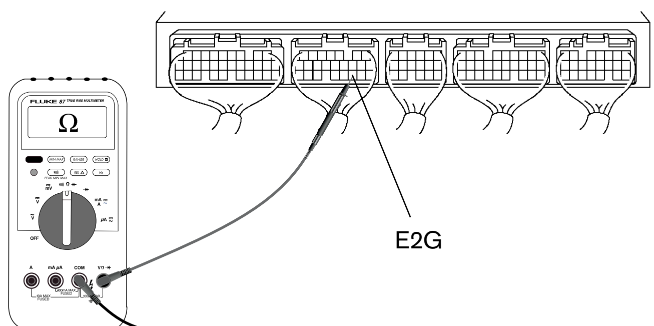


Fig. 2-40

T852f069

Checking MAF Operation

Most MAF sensors can be checked by supplying power and a ground to the right terminals, connecting a voltmeter to the signal (VG) wire, and blowing air through the sensor.

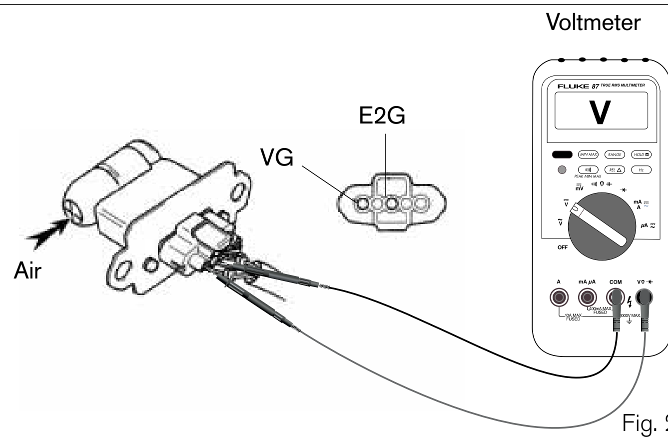


Fig. 2-41

T852f070

Vane Air Flow Meter

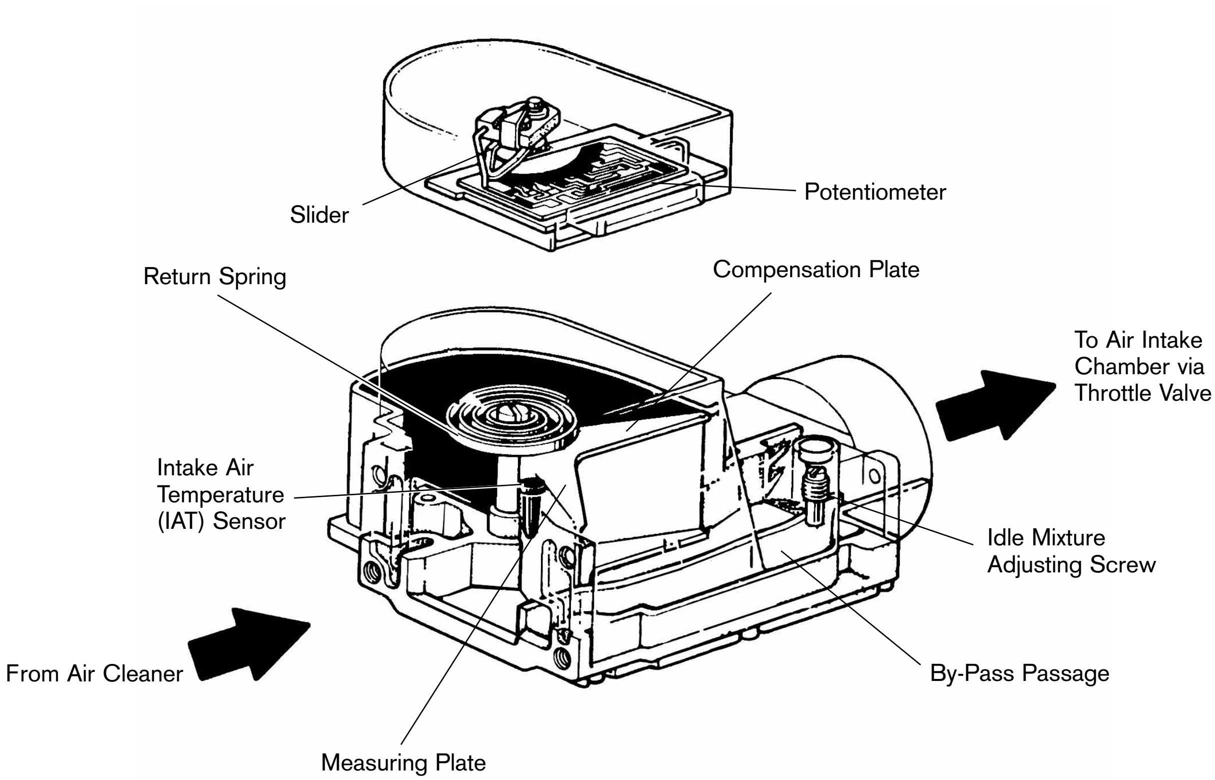


Fig. 2-42

T852f071

Vane Air Flow Meter

The Vane Air Flow Meter provides the ECM with an accurate measure of the load placed on the engine. The ECM uses it to calculate basic injection duration and basic ignition advance angle. Vane Air Flow Meters consist of the following components:

- Measuring Plate.
- Compensation Plate.
- Return Spring.
- Potentiometer.
- Bypass Air Passage.
- Idle Adjusting Screw (factory adjusted).
- Fuel Pump Switch.
- Intake Air Temperature (IAT) Sensor.

VAF Meter Operation

The measuring plate is deflected in proportion to the volume of intake air flow. The damping chamber helps reduce rapid movement of the measuring plate.

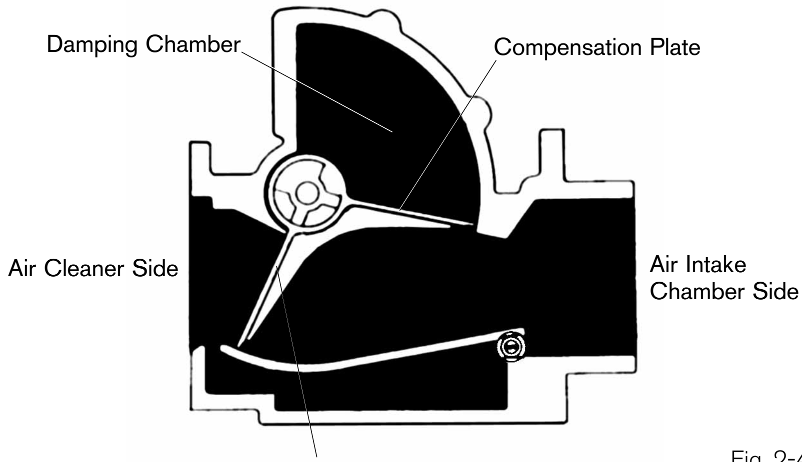


Fig. 2-43
T852f072

During engine operation, intake air flow reacts against the measuring plate (and return spring) and deflects the plate in proportion to the volume of air flow passing the plate. A compensation plate (which is attached to the measuring plate) is located inside a damping chamber and acts as a "shock absorber" to prevent rapid movement or vibration of the measuring plate.

Movement of the measuring plate is transferred through a shaft to a slider (movable arm) on the potentiometer. Movement of the slider against the potentiometer resistor causes a variable voltage signal back to the VS terminal at the ECM. Because of the relationship of the measuring plate and potentiometer, changes in the VS signal will be proportional to the air intake volume.

VAF Meter Circuit

The potentiometer inside the VAF provides a variable voltage signal to the ECM. This is the second design, the newer type.

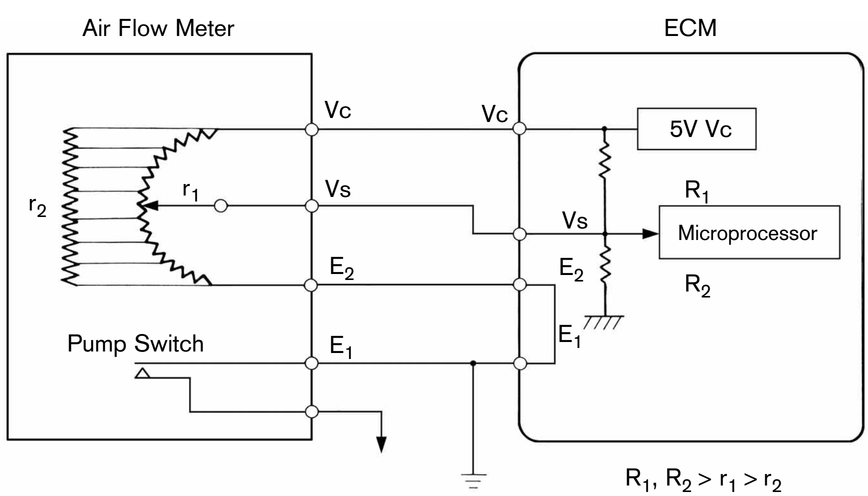


Fig. 2-44
T852f073

The r2 resistor (connected in parallel with r1) allows the meter to continue to provide a VS signal in the event that an open occurs in the main potentiometer (r1). The Vane Air Flow Meter also has a fuel pump switch built into the meter that closes to maintain fuel pump operation once the engine has started and air flow has begun.

The meter also contains a factory adjusted idle adjusting screw that is covered by a tamper-resistant plug. The repair manual does not provide procedures on resetting this screw in cases where it has been tampered with.

Types of VAF Meters

There were two major types of VAF meters. The first design, is the oldest type. It uses battery voltage for supply voltage. With this type of VAF meter, as the measuring plate opens signal voltage increases.

VAF Signal Voltage

There were two different VAF designs. With the newest type (second design), the voltage decreases as the measuring plate opens.

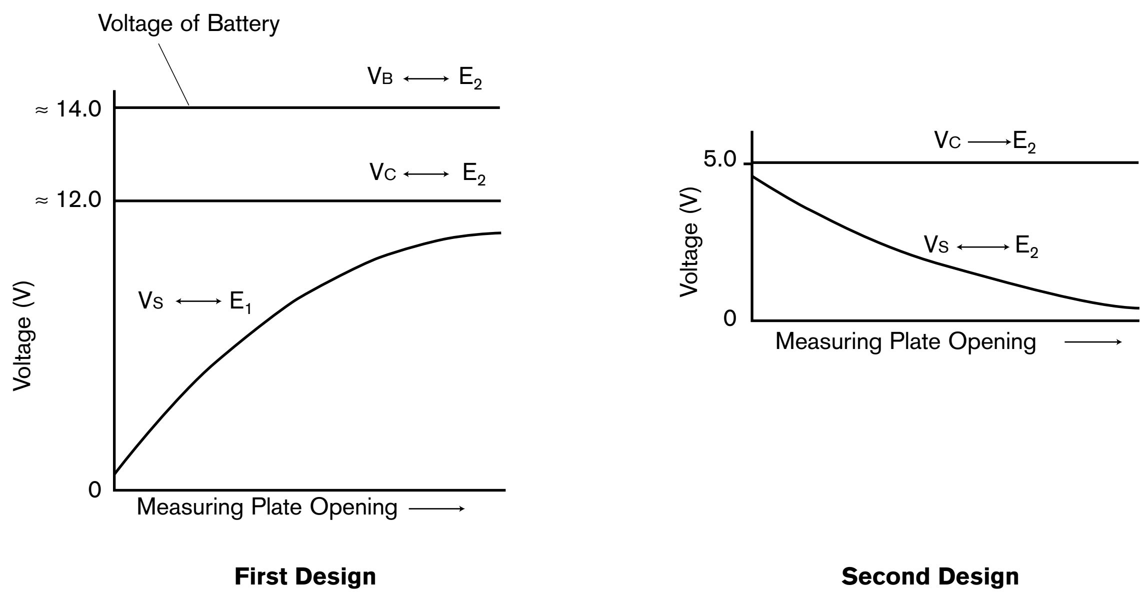


Fig. 2-45

T852f074/T852f075

Karman Vortex Air Flow Meter

Uses a moveable mirror and phototransistor to measure intake air flow. This type of meter operates without restricting air flow.

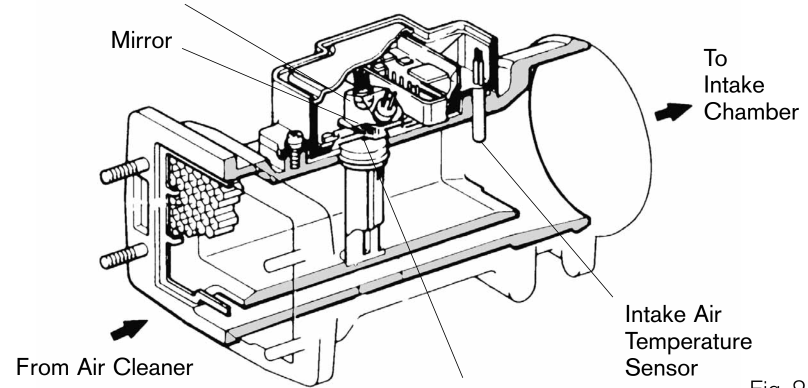


Fig. 2-46

T852f076

Karman Vortex Air Flow Meter

This air flow meter provides the same type of information (intake air volume) as the Vane Air Flow Meter. It consists of the following components:

- Vortex Generator.
- Mirror (metal foil).
- Photo Coupler (LED and photo transistor).

Karman Vortex Air Flow Meter Operation

Intake air flow reacting against the vortex generator creates a swirling effect to the air downstream, very similar to the wake created in the water after a boat passes. This wake or flutter is referred to as a "Karman Vortex." The frequencies of the vortices vary in proportion to the intake air velocity (engine load).

Karman Vortex Operation

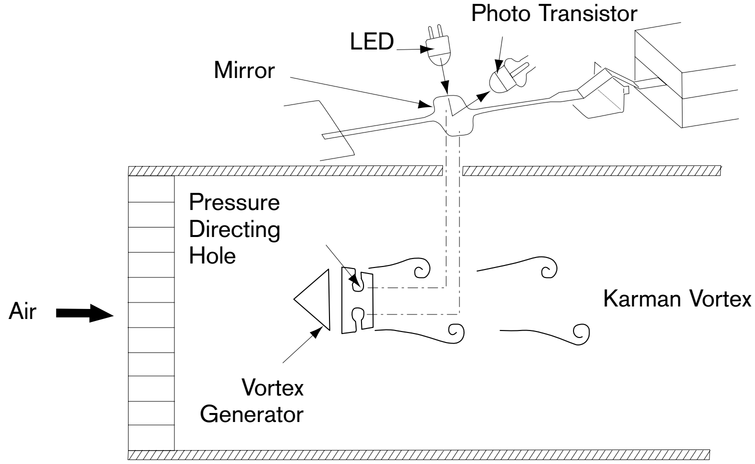


Fig. 2-47

T852f077

The vortices are metered into a pressure directing hole from which they act upon the metal foil mirror. The air flow against the mirror causes it to oscillate in proportion to the vortex frequency. This causes the illumination from the photo coupler's LED to be alternately applied to and diverted away from a photo transistor. As a result, the photo transistor alternately grounds or opens the 5-volt KS signal to the ECM.

Karman Vortex Air Flow Meter Circuit

This type of meter generates a 5 Volt square wave signal that varies in frequency.

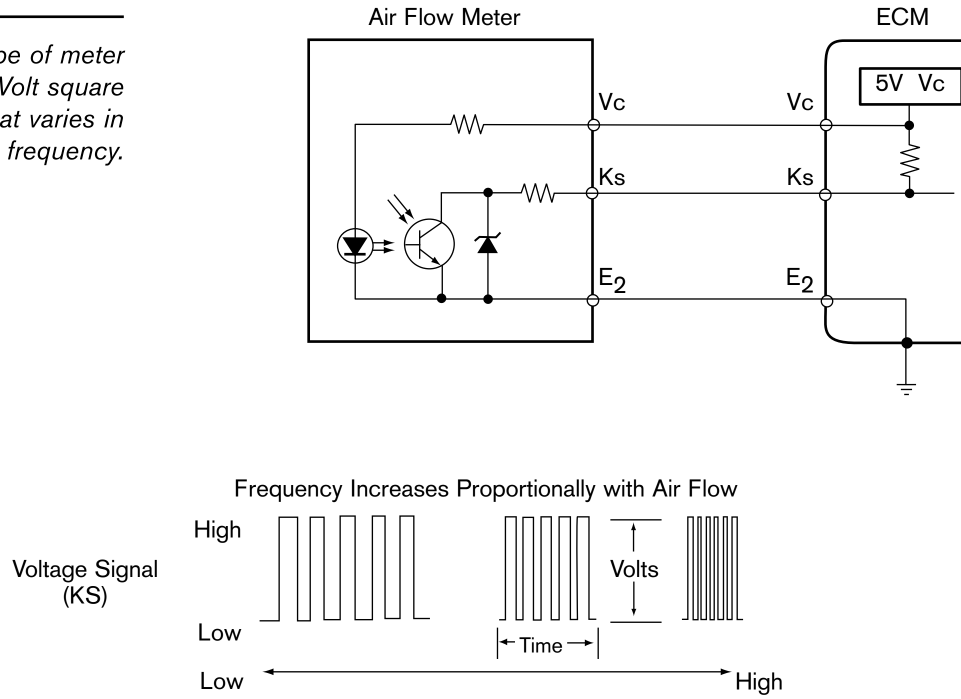


Fig. 2-48

T852f078

This creates a 5 volt square wave signal that increases frequency in proportion to the increase in intake air flow. Because of the rapid, high frequency nature of this signal, accurate signal inspection at various engine operating ranges requires using a high quality digital multimeter (with frequency capabilities) or oscilloscope.

Pressure Sensors

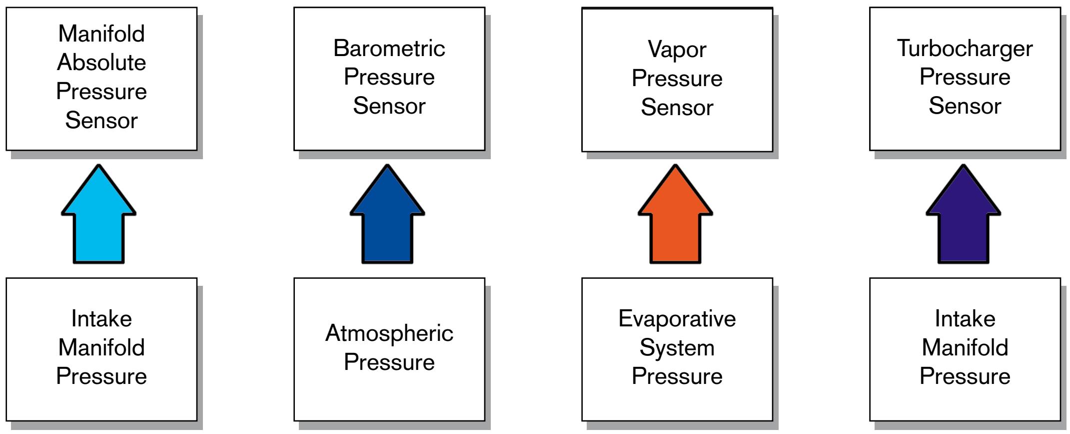


Fig. 2-49

Pressure Sensors

Pressure sensors are used to measure intake manifold pressure, atmospheric pressure, vapor pressure in the fuel tank, etc. Though the location is different, and the pressures being measured vary, the operating principles are similar.

Pressure Sensing

The silicon chip flexes as pressure changes. The amount the silicon chip flexes determines the output voltage signal.

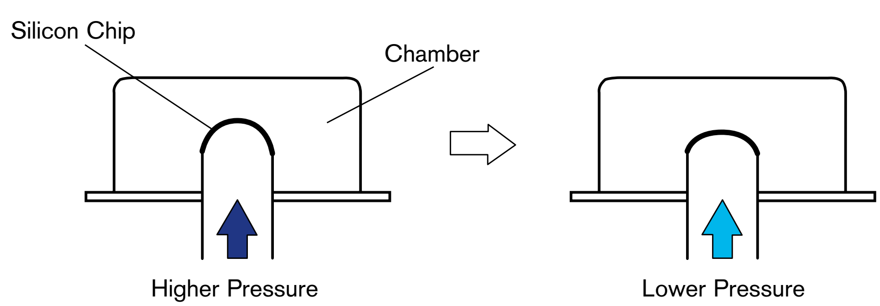


Fig. 2-50

T852f116

Manifold Absolute Pressure (MAP) Sensor

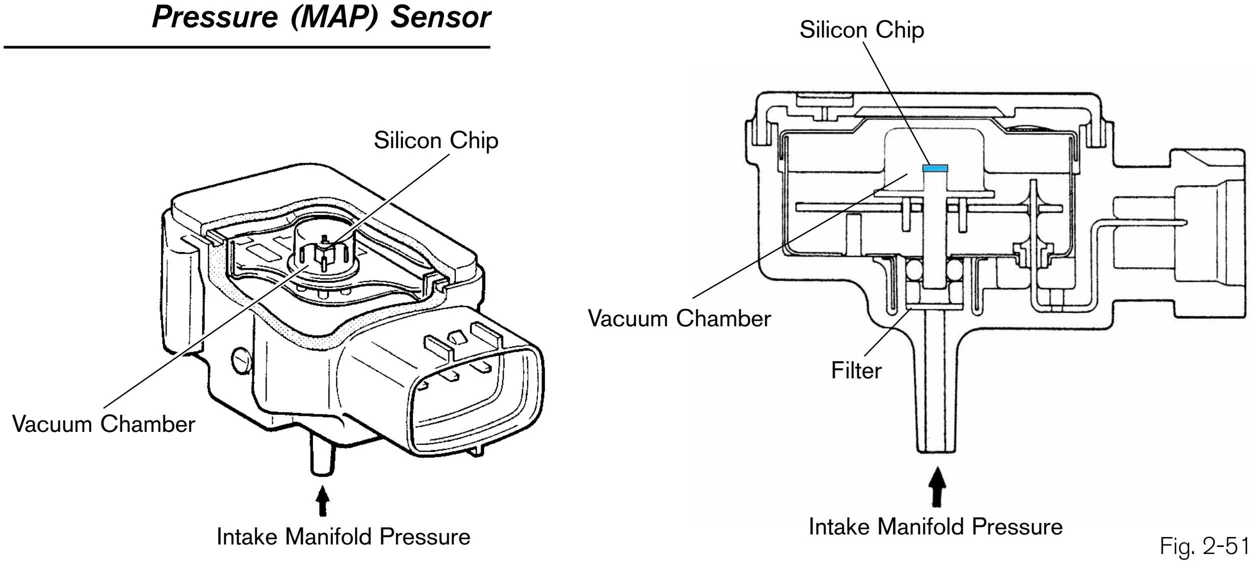


Fig. 2-51
T852f117/T852f118

Manifold Absolute Pressure (MAP) Sensor

In the Manifold Absolute Pressure (MAP) sensor there is a silicon chip mounted inside a reference chamber. On one side of the chip is a reference pressure. This reference pressure is either a perfect vacuum or a calibrated pressure, depending on the application. On the other side is the pressure to be measured. The silicon chip changes its resistance with the changes in pressure. When the silicon chip flexes with the change in pressure, the electrical resistance of the chip changes. This change in resistance alters the voltage signal. The ECM interprets the voltage signal as pressure and any change in the voltage signal means there was a change in pressure.

Intake manifold pressure is directly related to engine load. The ECM needs to know intake manifold pressure to calculate how much fuel to inject, when to ignite the cylinder, and other functions. The MAP sensor is located either directly on the intake manifold or it is mounted high in the engine compartment and connected to the intake manifold with vacuum hose. It is critical the vacuum hose not have any kinks for proper operation.

MAP Sensor Operation

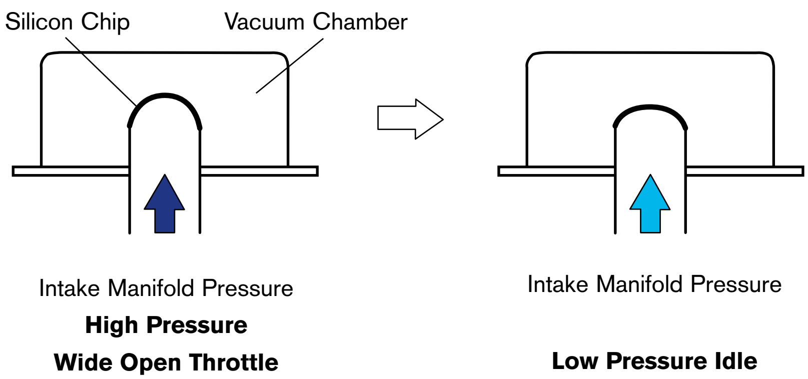


Fig. 2-52
T852f116

The MAP sensor uses a perfect vacuum as a reference pressure. The difference in pressure between the vacuum pressure and intake manifold pressure changes the voltage signal. The MAP sensor converts the intake manifold pressure into a voltage signal (PIM).

Pressure vs. MAP Voltage Signal

As intake manifold pressure rises, the voltage signal increases.

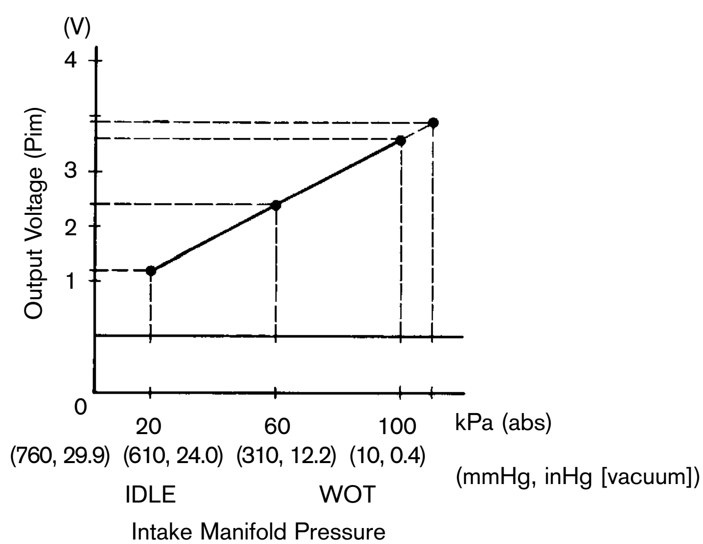


Fig. 2-53
T852f119

MAP Sensor Circuit

The ECM measures this voltage signal at the PIM terminal. This sensor receives 5 Volts from the ECM on the VC (or VCC) line. The ground for the sensor is through a ground wire to the ECM (usually terminal E2).

The PIM signal will be 5 Volts if the PIM wire is disconnected.

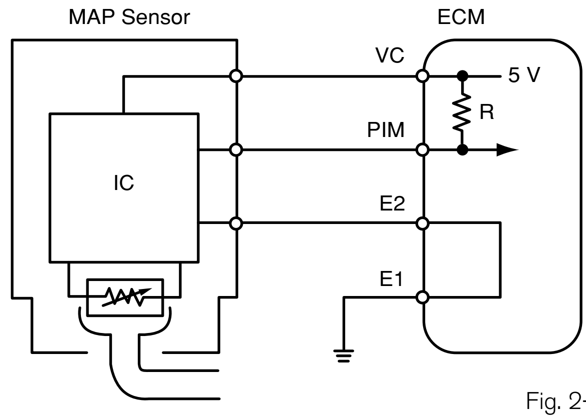


Fig. 2-54
T852f120

The MAP sensor voltage signal is highest when intake manifold pressure is highest (ignition key ON, engine off or when the throttle is suddenly opened). The MAP sensor voltage signal is lowest when intake manifold pressure is lowest on deceleration with throttle closed.

MAP Sensor Diagnosis

The MAP sensor can cause a variety of driveability problems since it is an important sensor for fuel injection and ignition timing.

Visually check the sensor, connections, and vacuum hose. The vacuum hose should be free of kinks, leaks, obstructions and connected to the proper port.

The VC (VCC) wire needs to supply approximately 5 volts to the MAP sensor. The E2 ground wire should not have any resistance.

Sensor calibration and performance is checked by applying different pressures and comparing to the voltage drop specification.

MAP Sensor Performance Check

The chart is representative of testing the MAP sensor. Voltage drop is calculated. Refer to Repair Manual for procedure.

Applied Vacuum kPa mmHg in. Hg.	13.3 100 3.94	26.7 200 7.87	40.0 300 11.81	53.5 400 15.75	66.7 500 19.69
Voltage Drop V	0.3 — 0.5	0.7 — 0.9	1.1 — 1.3	1.5 — 1.7	1.9 — 2.1

Fig. 2-55

Barometric Pressure Sensor Operation

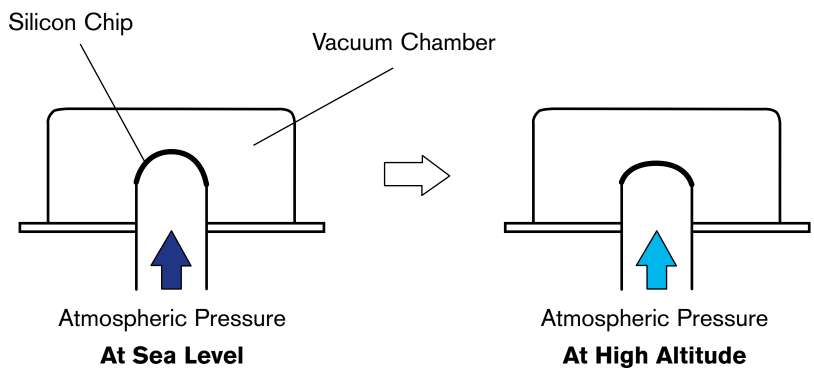


Fig. 2-56

T852f116

Barometric Pressure Sensor

The Barometric Pressure Sensor, sometimes called a High Altitude Compensator (HAC), measures the atmospheric pressure. Atmospheric pressure varies with weather and altitude. At higher elevations the air is less dense, therefore, it has less pressure. In addition, weather changes air pressure. This sensor operates the same as the MAP sensor except that it measures atmospheric pressure. It is located inside the ECM. If it is defective, the entire ECM must be replaced.

Turbocharging Pressure Sensor Chart

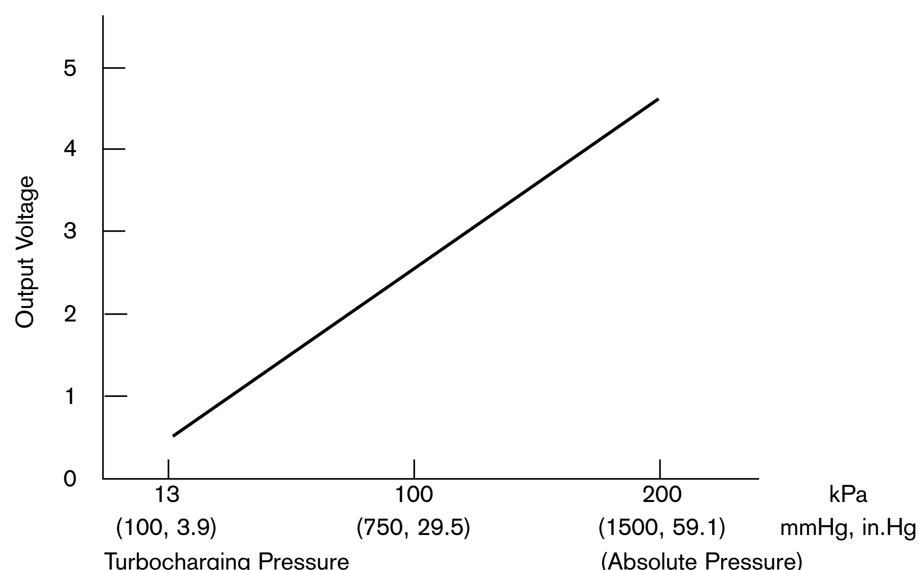


Fig. 2-57

T852f121

Turbocharging Pressure Sensor

The turbocharging pressure sensor operates identically to the MAP sensor and is used to measure intake manifold pressure. The only difference is that when there is boost pressure, the voltage signal goes higher than on a naturally aspirated engine.

Vapor Pressure Sensor

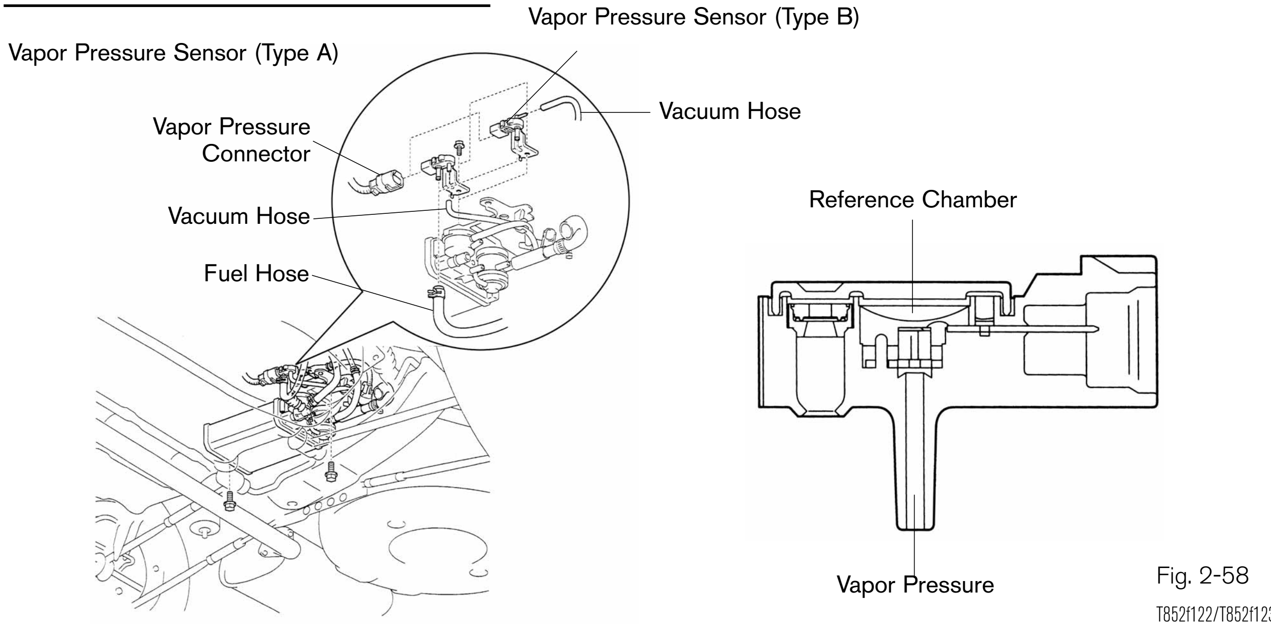


Fig. 2-58

T852f122/T852f123

Vapor Pressure Sensor

The Vapor Pressure Sensor (VPS) measures the vapor pressure in the evaporative emission control system. The Vapor Pressure Sensor may be located on the fuel tank, near the charcoal canister assembly, or in a remote location.

Vapor Pressure Sensor Operation

The pressure inside the reference chamber changes with atmospheric pressure. The reference chamber pressure uses a small flexible diaphragm exposed to atmospheric pressure. This causes the reference pressure to increase with an increase in atmospheric pressure. Using this method allows the vapor pressure reading to be calibrated with atmospheric pressure.

The VPS is extremely sensitive to changes in pressure. 1.0 psi = 51.7 mmHg

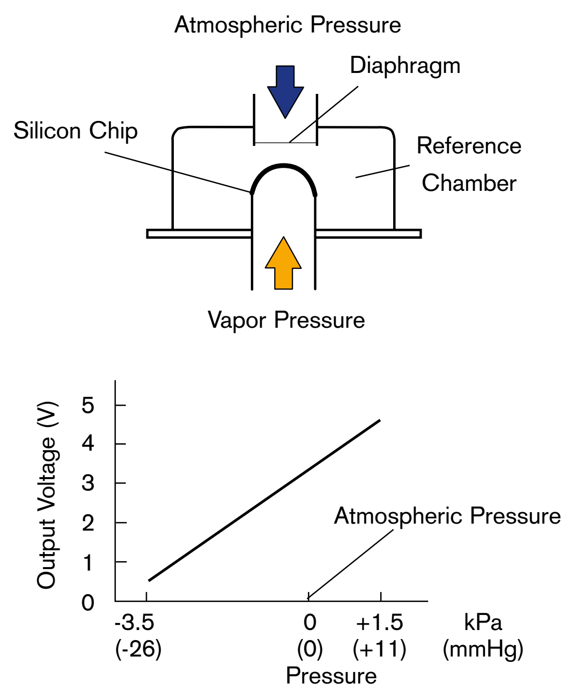


Fig. 2-59

T852f385/T852f124

This sensor uses a silicon chip with a calibrated reference pressure on one side of the chip, the other side of the chip is exposed to vapor pressure. Changes in vapor pressure cause the chip to flex and vary the voltage signal to the ECM. The voltage signal out depends on the difference between atmospheric pressure and vapor pressure. As vapor pressure increases the voltage signal increases. This sensor is sensitive to very small pressure changes (1.0 psi = 51.7 mmHg).

Types of Vapor Pressure Sensors

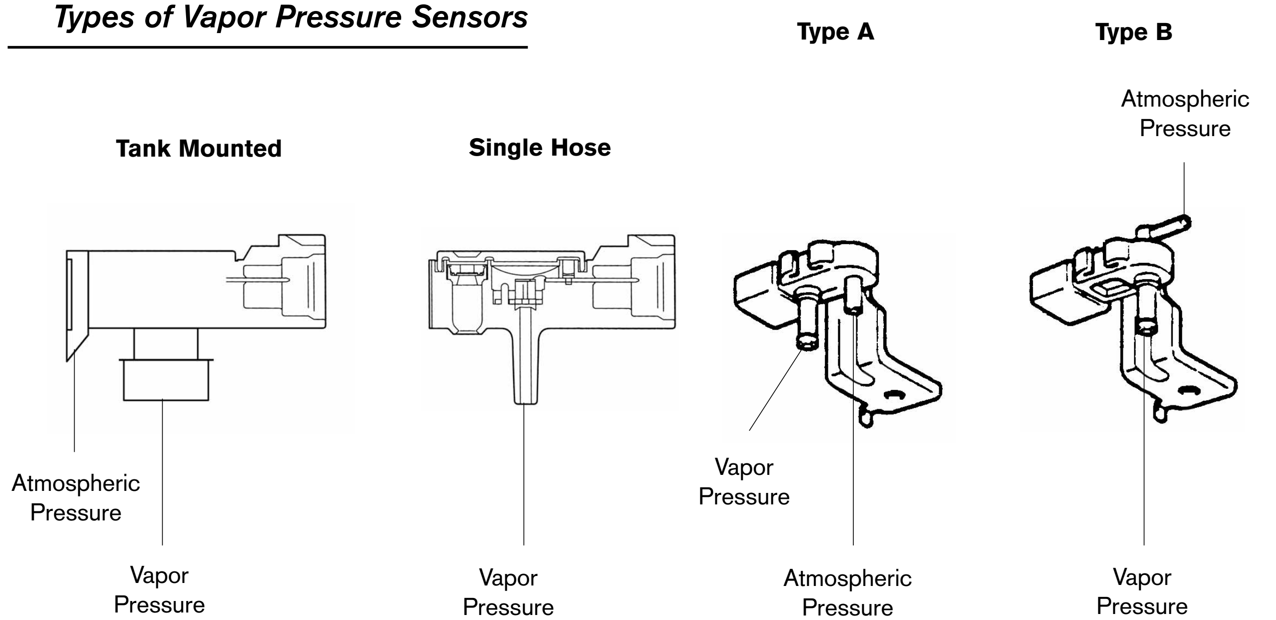


Fig. 2-60

T852f331/T852f123
T852f337/T852f338

Vapor pressure sensors come in variety of configurations. When the VPS is mounted directly on the fuel pump assembly, no hoses are required. For remote locations, there may be one or two hoses connected to the VPS. If the VPS uses one hose, the hose is connected to vapor pressure. In the two hose configuration, one hose is connected to vapor pressure, the other hose to atmospheric pressure. It is important that these hoses are connected to the proper port. If they are reversed, DTCs will set.

VPS Electrical Circuit

The ECM receives this voltage signal at the PTNK terminal. This sensor receives 5 volts from the ECM on the VC line. The ground for the sensor is through a ground wire to the ECM (usually terminal E2).

The PTNK signal will be 5 volts if the PTNK wire is disconnected.

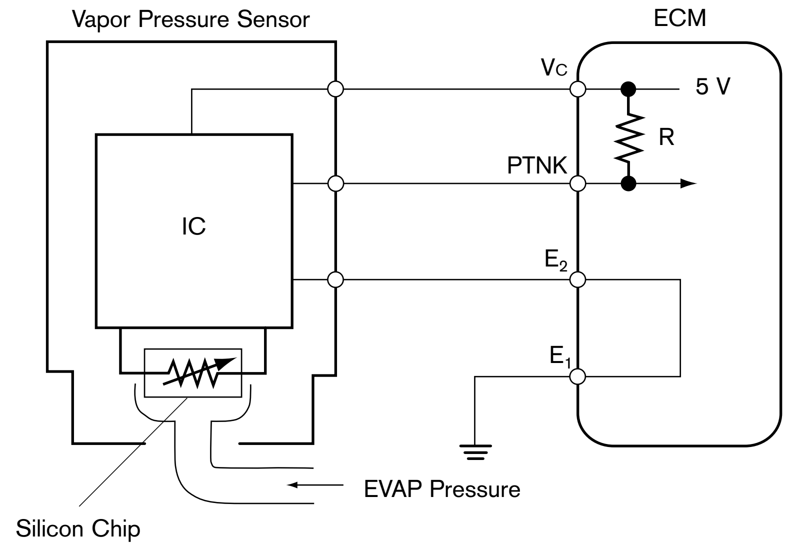


Fig. 2-61

T852f013

VPS Diagnosis

Check all hoses for proper connection, restrictions, and leaks. Check the VC and E2 voltages. Apply the specified pressure and read sensor voltage output. The vapor pressure sensor is calibrated for the pressures found in the EVAP system, so apply only the specified amount to prevent damaging the sensor.

Position/ Speed Sensors

Position/speed sensors provide information to the ECM about the position of a component, the speed of a component, and the change in speed of a component. The following sensors provide this data:

- Camshaft Position Sensor (also called G sensor).
- Crankshaft Position Sensor (also called NE sensor).
- Vehicle Speed Sensor.

Position/Speed Sensors

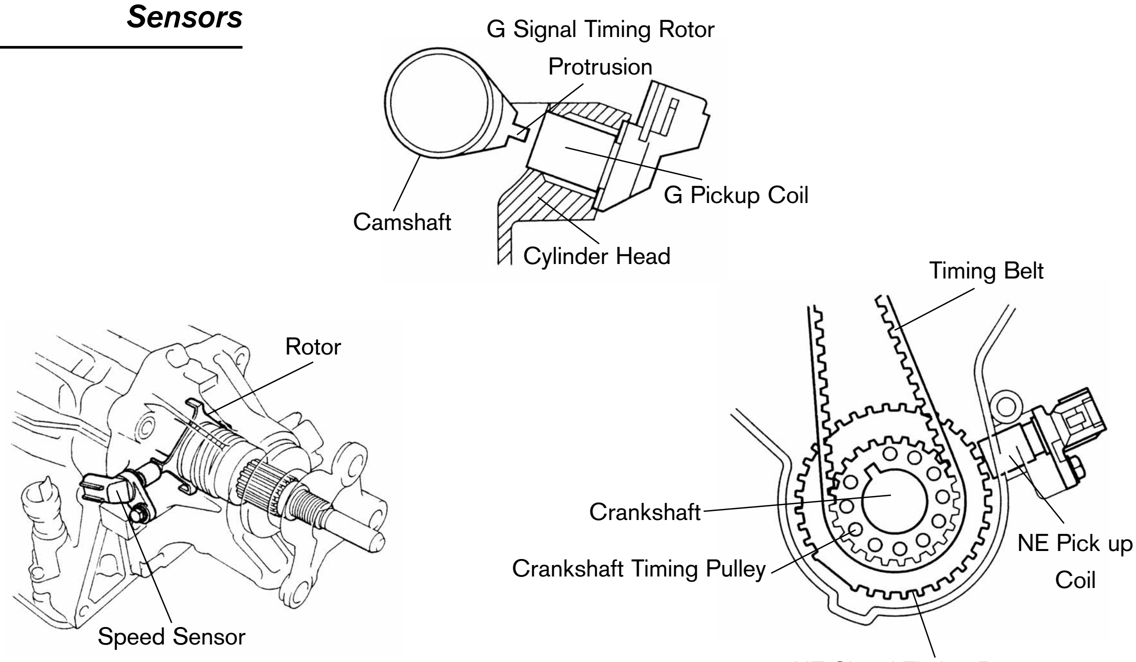


Fig. 2-62

T852f095/T852f096
T852f097

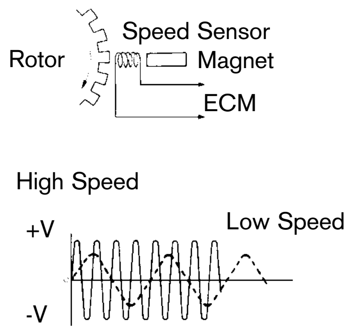
Pick-Up Coil (Variable Reluctance) Type Sensors

The Camshaft Position Sensor, Crankshaft Position Sensor, and one type of vehicle speed sensor are of the pick-up coil type sensor.

This type of sensor consists of a permanent magnet, yoke, and coil. This sensor is mounted close to a toothed gear called a rotor. As each tooth moves by the sensor, an AC voltage pulse is induced in the coil. Each tooth produces a pulse. As the gear rotates faster more pulses are produced. The ECM determines the speed the component is revolving based on the number of pulses. The number of pulses in one second is the signal frequency.

Pick-Up Coil (Variable Reluctance) Sensor

Rotor speed determines the signal frequency. The faster the rotor revolves the higher the frequency.



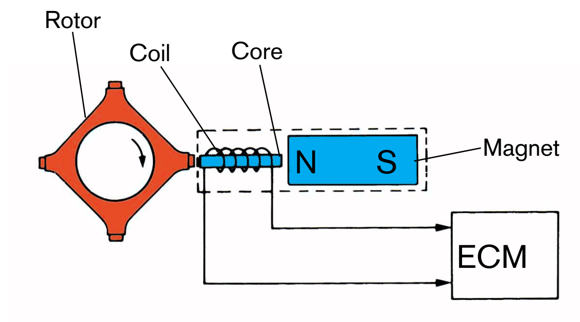


Fig. 2-63

T852f098/T852f099

The distance between the rotor and pickup coil is critical. The further apart they are, the weaker the signal.

Not all rotors use teeth. Sometimes the rotor is notched, which will produce the same effect.

These sensors generate AC voltage, and do not need an external power supply. Another common characteristic is that they have two wires to carry the AC voltage.

The wires are twisted and shielded to prevent electrical interference from disrupting the signal. The EWD will indicate if the wires are shielded.

Camshaft Position Sensor (G Sensor) Variable Valve Timing Position Sensor

By knowing the position of the camshaft, the ECM can determine when cylinder No. 1 is on the compression stroke. The ECM uses this information for fuel injection timing, for direct ignition systems and for variable valve timing systems.

This sensor is located near one of the camshafts. With variable valve timing V-type engines, there is one sensor for each cylinder bank. On distributor ignition systems, it is often called the G sensor and is located in the distributor.

Voltage

An AC signal is generated that is directly proportional to camshaft speed. That is, as the camshaft revolves faster the frequency increases.

Camshaft Position Sensor

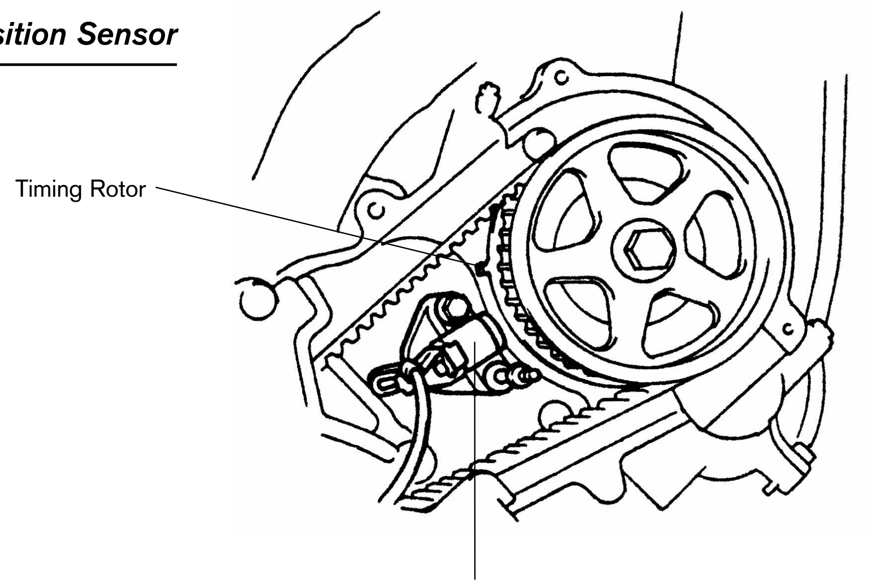


Fig. 2-64

T852f100

The terminal on the ECM is designated with a letter G, and on some models a G and a number, such as G22 is used.

Some variable valve timing systems call the Camshaft Position Sensor the Variable Valve Timing Position Sensor. See section on variable valve timing systems for more information.

Crankshaft Position Sensor (NE Sensor)

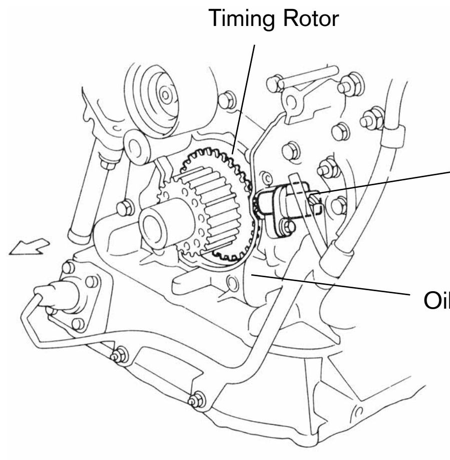


Fig. 2-65
T852f101

Crankshaft Position Sensor (NE Sensor)

The ECM uses crankshaft position signal to determine engine RPM, crankshaft position, and engine misfire. This signal is referred to as the NE signal. The NE signal combined with the G signal indicates the cylinder that is on compression and the ECM can determine from its programming the engine firing order. See Section 3 on ignition systems for more information.

NE and G Signals

The periodic gap in the NE signal is because there are teeth missing in the timing rotor. The gap is used by the ECM as reference to crankshaft position. When combined with the G signal, the ECM can determine cylinder position and stroke.

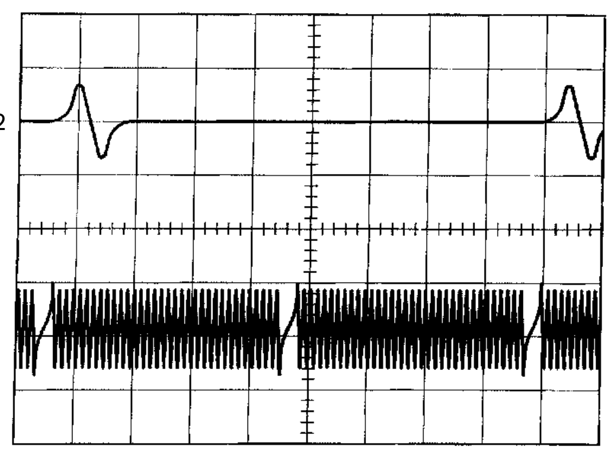


Fig. 2-66
T852f102

Vehicle Speed Sensor Signal Circuit Combinations

There are different configurations by which the vehicle speed sensor signal reaches the ECM.

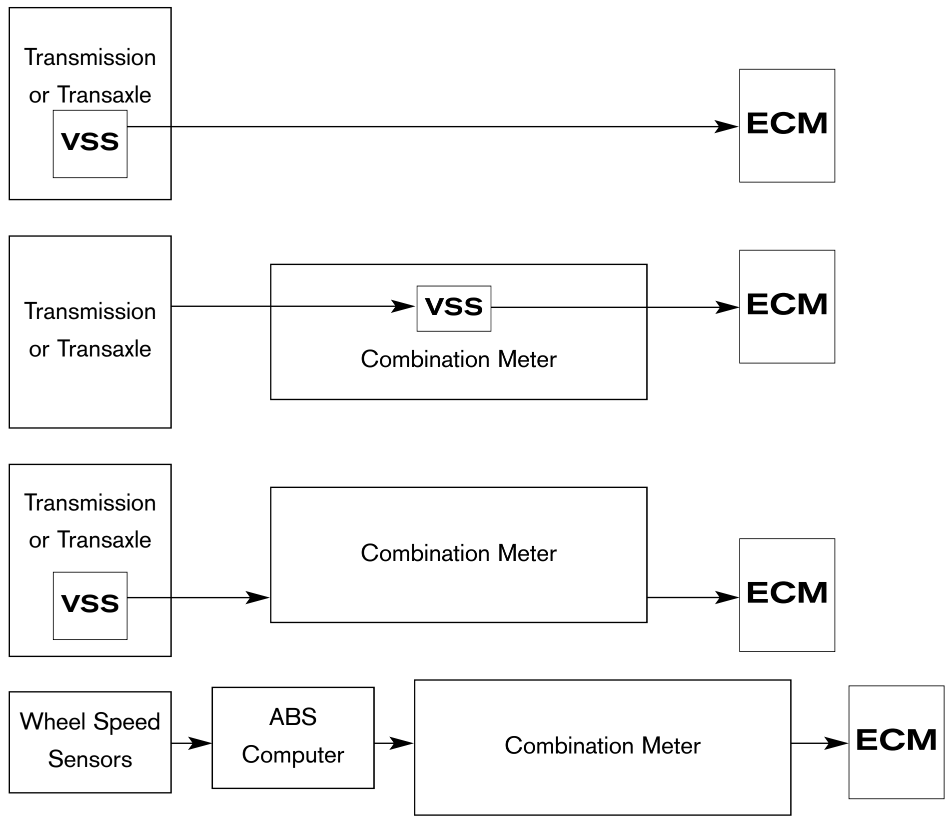


Fig. 2-67

Vehicle Speed Sensor (VSS)

The ECM uses the Vehicle Speed Sensor (VSS) signal to modify engine functions and initiate diagnostic routines. The VSS signal originates from a sensor measuring transmission/transaxle output speed or wheel speed. Different types of sensors have been used depending on models and applications.

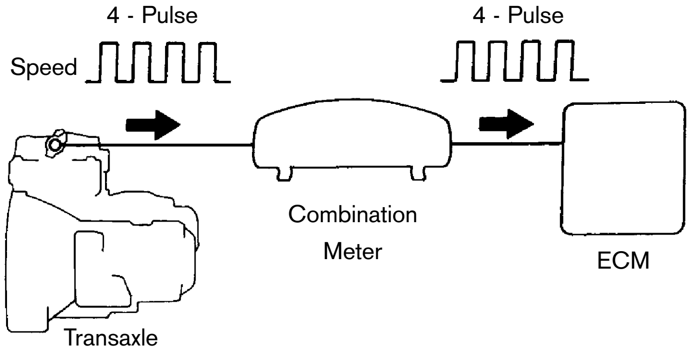
On some vehicles, the vehicle speed sensor signal is processed in the combination meter and then sent to the ECM.

On some anti-lock brake system (ABS) equipped vehicles, the ABS computer processes the wheel speed sensor signals and sends a speed sensor signal to the combination meter and then to the ECM. You will need to consult the EWD to confirm the type of system you are working on.

Pick-Up Coil (Variable Reluctance) Type

This type of VSS operates on the variable reluctance principle discussed earlier and it is used to measure transmission/transaxle output speed or wheel speed depending on type of system.

VSS Mounted in Transaxle



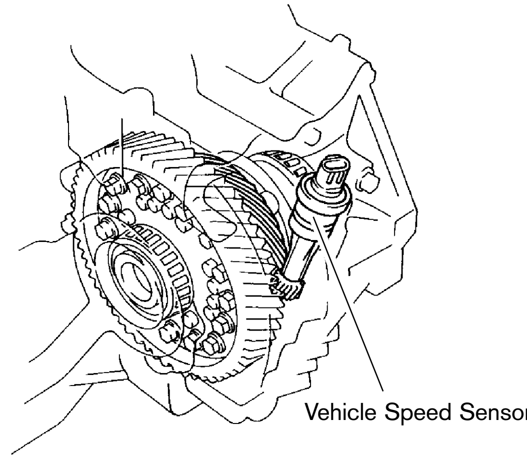
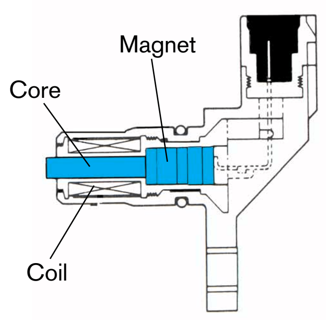


Fig. 2-68

T852f103/T852f104

VSS Mounted in Transmission



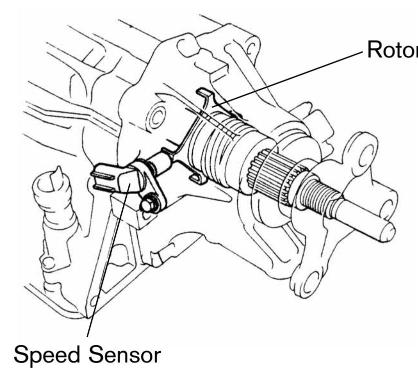
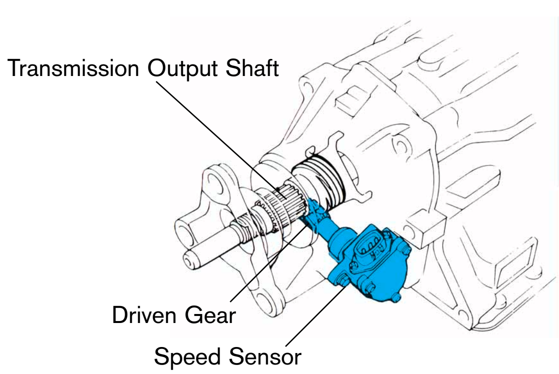


Fig. 2-69

T852f105/T852f095

MRE Type VSS



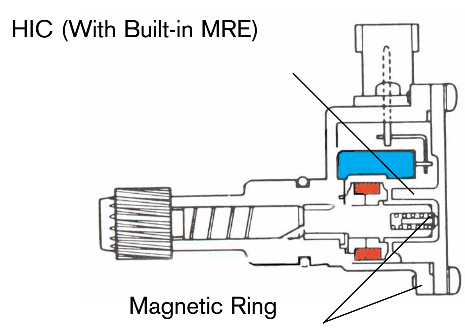


Fig. 2-70

T852f106/T852f107

MRE Operation

As the magnetic ring rotates an AC signal is produced. This is converted into a Digital signal inside the sensor.

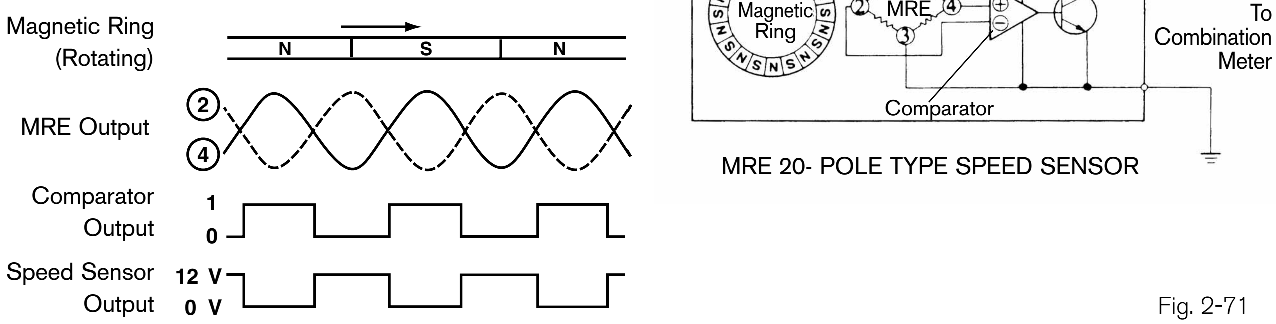


Fig. 2-71

T852f108/T852f109

Magnetic Resistance Element (MRE) Type

The MRE is driven by the output shaft on a transmission or output gear on a transaxle. This sensor uses a magnetic ring that revolves when the output shaft is turning. The MRE senses the changing magnetic field. This signal is conditioned inside the VSS to a digital wave. This digital wave signal is received by the Combination meter, and then sent to the ECM. The MRE requires an external power supply to operate.

Reed Switch Type VSS

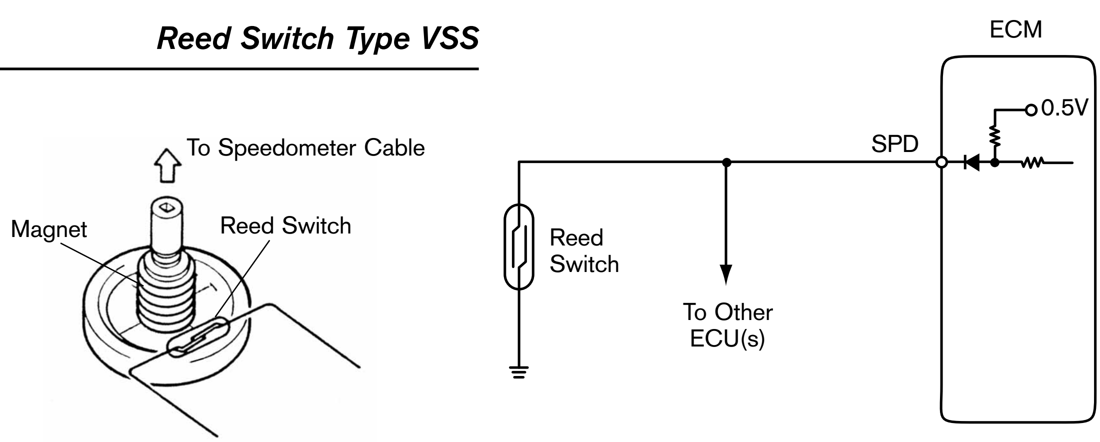


Fig. 2-72

T852f110/T852f111

Reed Switch Type

The reed switch type is driven by the speedometer cable. The main components are a magnet, reed switch, and the speedometer cable. As the magnet revolves the reed switch contacts open and close four times per revolution. This action produces 4 pulses per revolution. From the number of pulses put out by the VSS, the combination meter/ECM is able to determine vehicle speed.

Oxygen Sensor Location

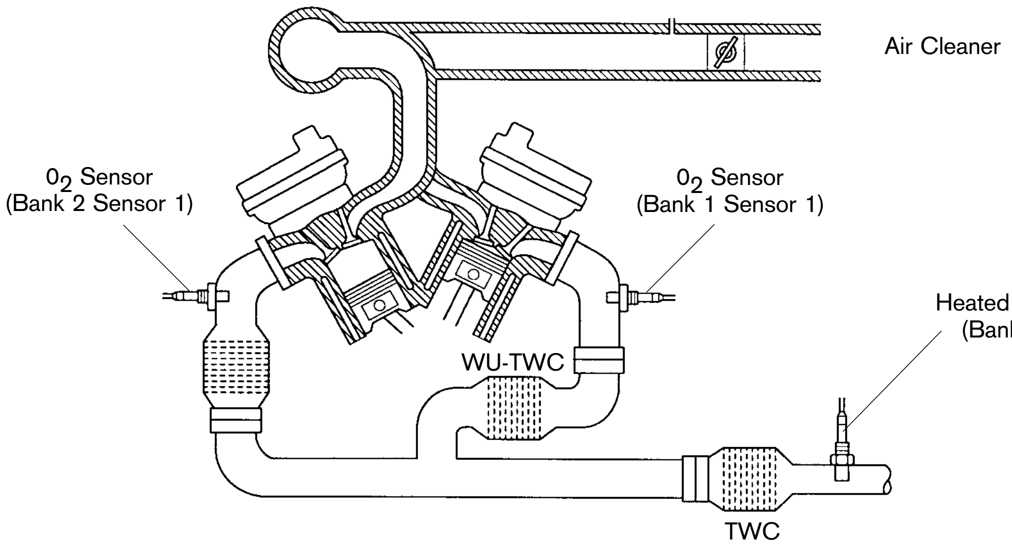


Fig. 2-73

T852f079

Oxygen and Air/Fuel Ratio Sensors

The ECM uses an oxygen sensor to ensure the air/fuel ratio is correct for the catalytic converter. Based on the oxygen sensor signal, the ECM will adjust the amount of fuel injected into the intake air stream.

There are different types of oxygen sensors, but two of the more common types are:

- the narrow range oxygen sensor, the oldest style, simply called the oxygen sensor.
- wide range oxygen sensor, the newest style, called the air/fuel ratio (A/F) sensor.

Also used on very limited models in the early 90s, was the Titania oxygen sensor.

OBD II vehicles require two oxygen sensors: one before and one after the catalytic converter. The oxygen sensor, or air/fuel ratio sensor, before the catalytic converter is used by the ECM to adjust the air/fuel ratio. This sensor in OBD II terms is referred to as sensor 1. On V-type engines one sensor will be referred to as Bank 1 Sensor 1 and the other as Bank 2 Sensor 1. The oxygen sensor after the catalytic converter is used by the ECM primarily to determine catalytic converter efficiency. This sensor is referred to as sensor 2. With two catalytic converters, one sensor will be Bank 1 Sensor 2 and the other is Bank 2 Sensor 2.

Oxygen Sensor Construction

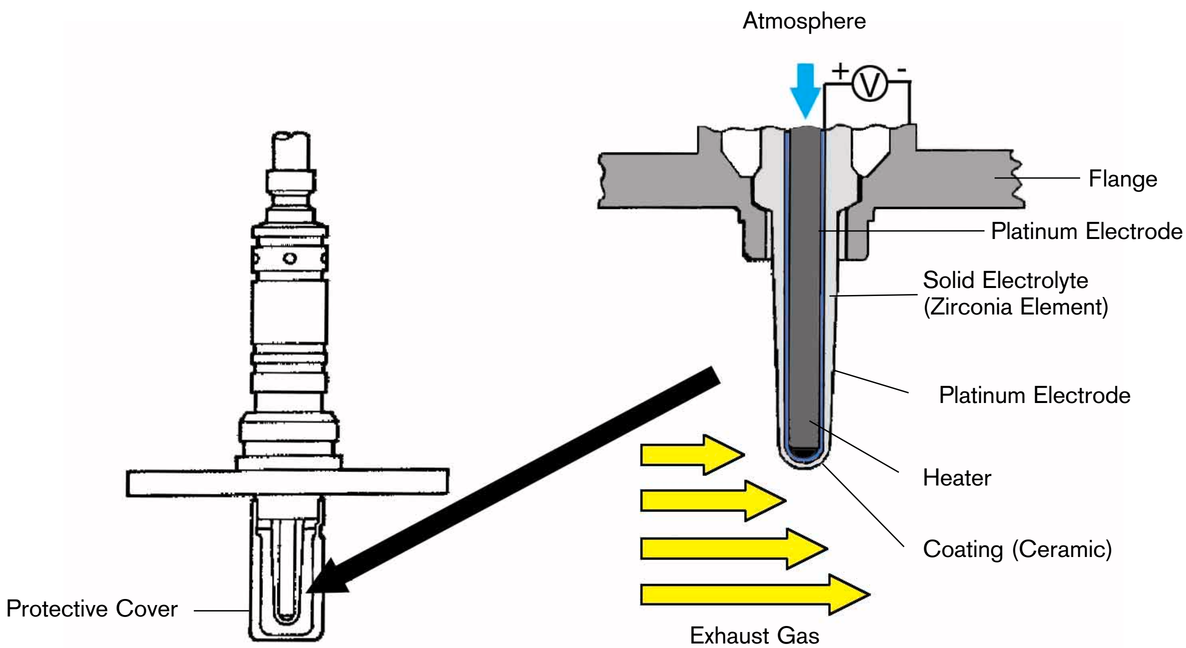


Fig. 2-74

T852f081

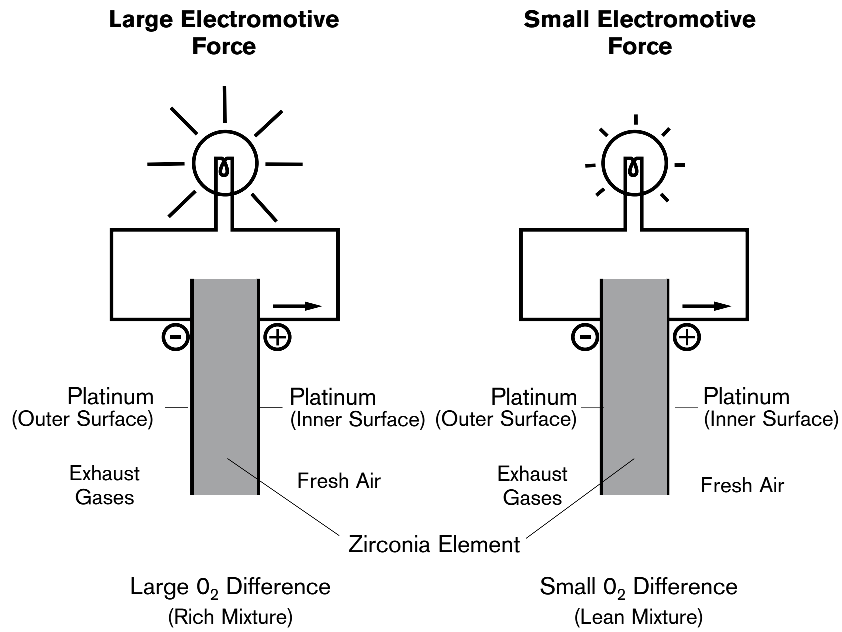
Oxygen Sensor

This style of oxygen sensor has been in service the longest time. It is made of zirconia (zirconium dioxide), platinum electrodes, and a heater. The oxygen sensor generates a voltage signal based on the amount of oxygen in the exhaust compared to the atmospheric oxygen. The zirconia element has one side exposed to the exhaust stream, the other side open to the atmosphere. Each side has a platinum electrode attached to Zirconium dioxide element.

The platinum electrodes conduct the voltage generated. Contamination or corrosion of the platinum electrodes or zirconia elements will reduce the voltage signal output.

Oxygen Sensor Operation

When there is less oxygen in the exhaust, there is a large difference in oxygen content when compared to the atmospheric side. This produces a higher voltage signal. When there is more oxygen in the exhaust, there is a small difference and the voltage output is low.



Operation Principles of Oxygen Sensor

Fig. 2-75

T852f082

Operation When exhaust oxygen content is high, oxygen sensor voltage output is low. When exhaust oxygen content is low, oxygen sensor voltage output is high. The greater the difference in oxygen content between the exhaust stream and atmosphere, the higher the voltage signal.

Exhaust Oxygen Content	Oxygen Sensor Output	Air/Fuel Ratio Judged To Be
Low	High, Above 0.45 volts	Rich
High	Low, Below 0.45 volts	Lean

From the oxygen content, the ECM can determine if the air/fuel ratio is rich or lean and adjusts the fuel mixture accordingly. A rich mixture consumes nearly all the oxygen, so the voltage signal is high, in the range of 0.6 - 1.0 volts. A lean mixture has more available oxygen after combustion than a rich mixture, so the voltage signal is low, 0.4 - 0.1 volts. At the stoichiometric air/fuel ratio (14.7:1), oxygen sensor voltage output is approximately 0.45 volts.

Oxygen Sensor Voltage Range

The oxygen sensor is unable to detect how rich or lean the air/fuel mixture is.

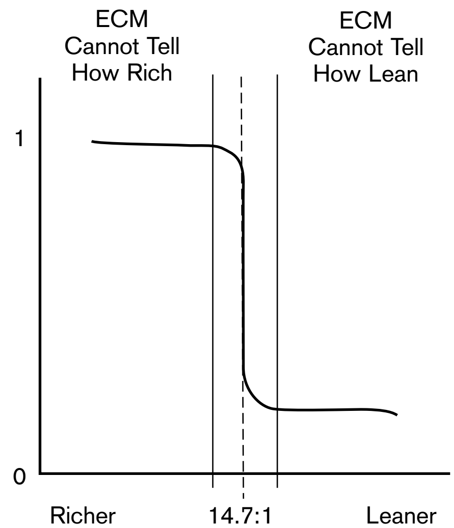


Fig. 2-76
T852f083

Small changes in the air/fuel ratio from the stoichiometric point radically changes the voltage signal. This type of oxygen sensor is sometimes referred to as a narrow range sensor because it cannot detect the small changes in the exhaust stream oxygen content produced by changes in the air/fuel mixture. The ECM will continuously add and subtract fuel producing a rich/lean cycle. Refer to Closed Loop Fuel Control in the Fuel Injection section for more information.

NOTE

Think of the oxygen sensor as a switch. Each time the air/fuel ratio is at stoichiometry (14.7:1) the oxygen sensor switches either high or low.

Oxygen Sensor Output vs. Temperature

When cold, the oxygen sensor acts as a resistor until it reaches operating temperature. At operating temperature, the oxygen sensor acts as a battery. For accurate signal output, it is essential that the oxygen sensor is kept at high temperatures.
In the figure, the rich mixture is not accurately measured until oxygen sensor has reached operating temperature.

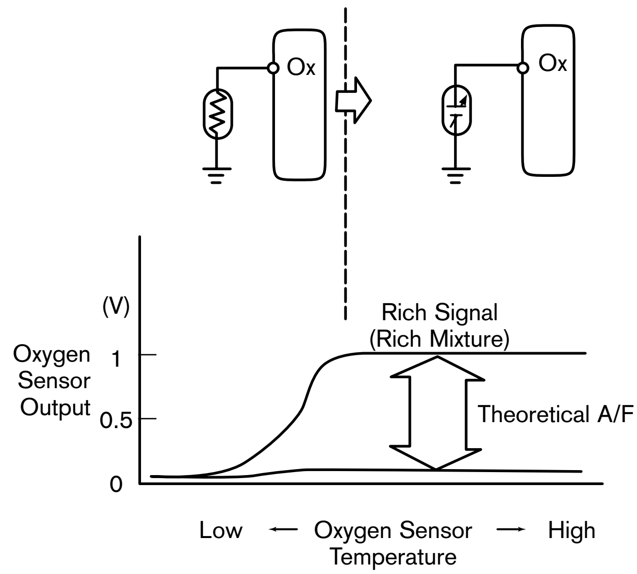


Fig. 2-77
T852f084

The oxygen sensor will only generate an accurate signal when it has reached a minimum operating temperature of 400°C (750°F). To quickly warm up the oxygen sensor and to keep it hot at idle and light load conditions, the oxygen sensor has a heater built into it. This heater is controlled by the ECM. See Oxygen Sensor Heater Control for more information.

Types of Oxygen Signals

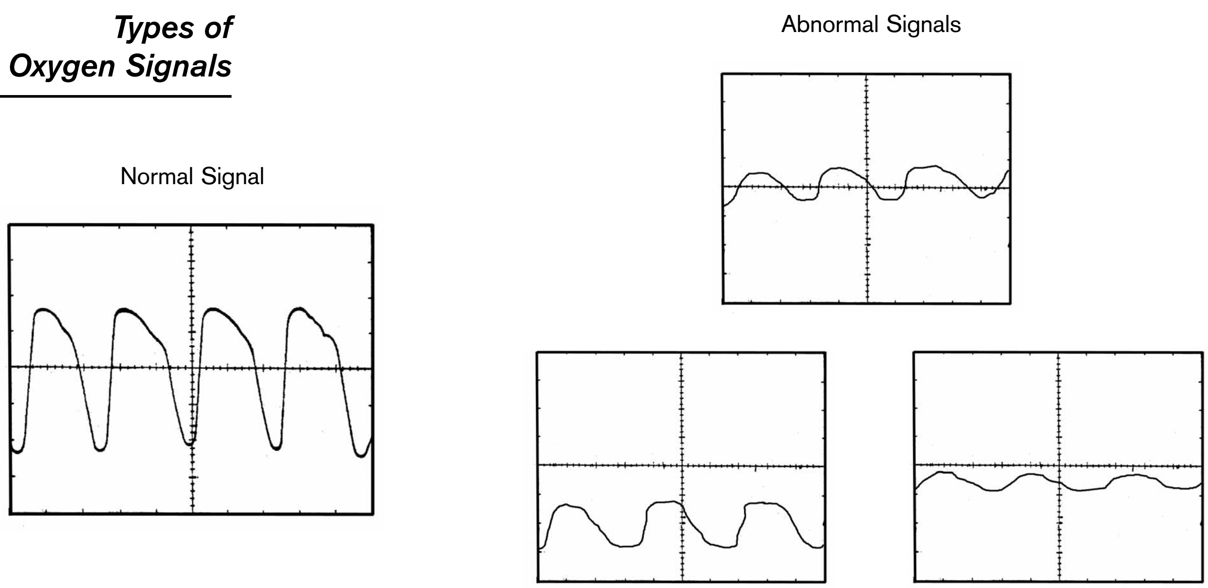
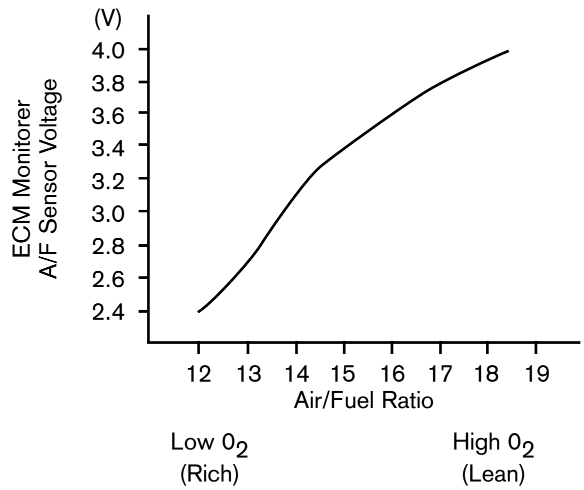


Fig. 2-78
T852f389/T852f390
T852f391/T852f392

Air/Fuel Ratio Sensor

The A/F sensor voltage signal is relatively proportional to exhaust oxygen content. Note that when the air/fuel ratio is leaner, the ECM monitored voltage is higher.



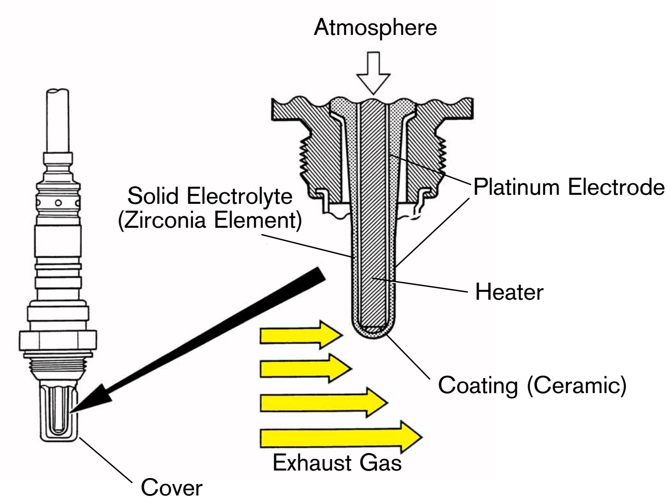


Fig. 2-79

T852f085/T852f086

Air/Fuel Ratio Sensor

The Air/Fuel Ratio (A/F) sensor is similar to the narrow range oxygen sensor. Though it appears similar to the oxygen sensor, it is constructed differently and has different operating characteristics.

The A/F sensor is also referred to as a wide range or wide ratio sensor because of its ability to detect air/fuel ratios over a wide range.

The advantage of using the A/F sensor is that the ECM can more accurately meter the fuel reducing emissions. To accomplish this, the A/F sensor:

- operates at approximately 650°C (1200°F), much hotter than the oxygen sensor 400°C (750°F).
- changes its current (amperage) output in relation to the amount of oxygen in the exhaust stream.

A/F Sensor Detecting Circuit

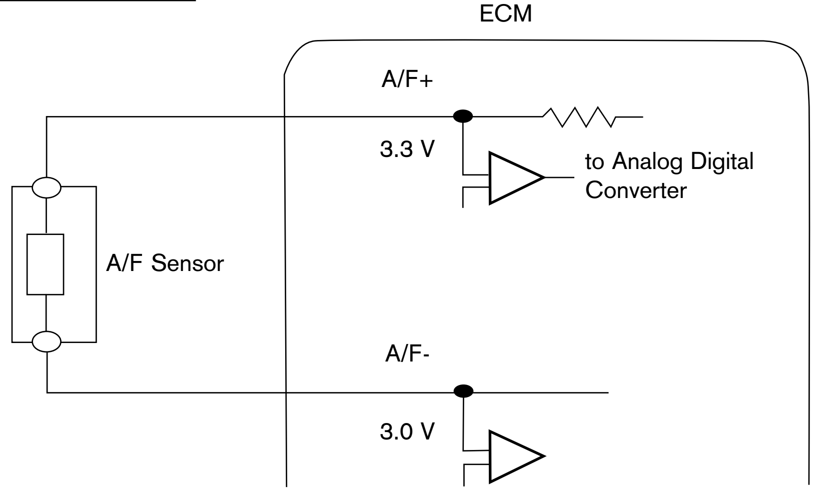


Fig. 2-80
T852f087

Operation A detection circuit in the ECM detects the change and strength of current flow and puts out a voltage signal relatively proportional to exhaust oxygen content.

NOTE

This voltage signal can only be measured by using the Diagnostic Tester or OBD II compatible scan tool. The A/F sensor current output cannot be accurately measured directly. If an OBD II scan tool is used, refer to the Repair Manual for conversion, for the output signal is different.

The A/F sensor is designed so that at stoichiometry, there is no current flow and the voltage put out by the detection circuit is 3.3 volts. A rich mixture, which leaves very little oxygen in the exhaust stream, produces a negative current flow. The detection circuit will produce a voltage below 3.3 volts. A lean mixture, which has more oxygen in the exhaust stream, produces a positive current flow. The detection circuit will now produce a voltage signal above 3.3 volts.

Exhaust Oxygen Content	Current Flow	Voltage Signal	Air/Fuel Mixture Judged To Be:
Low Oxygen Content →	- Direction →	Below 3.3 Volts →	Rich
Stoichiometry →	0 →	3.3 Volts →	14.7:1
High Oxygen Content →	+ Direction →	Above 3.3 Volts →	Lean

NOTE The A/F sensor voltage output is the opposite of what happens in the narrow range oxygen sensor. Voltage output through the detection circuit increases as the mixture gets leaner.

Also, the voltage signal is proportional to the change in the air/fuel mixture. This allows the ECM to more accurately judge the exact air/fuel ratio under a wide variety of conditions and quickly adjust the amount of fuel to the stoichiometric point. This type of rapid correction is not possible with the narrow range oxygen sensor. With an A/F sensor, the ECM does not follow a rich lean cycle. Refer to Closed Loop Fuel Control in the Fuel Injection chapter for more information.

HINT Think of the A/F sensor as a generator capable of changing polarity. When the fuel mixture is rich (low exhaust oxygen content), the A/F generates current in the negative (-) direction. As the air/fuel mixture gets leaner (more oxygen content), the A/F sensor generates current in the positive (+) direction. At the stoichiometric point, no current is generated.

The detection circuit is always measuring the direction and how much current is being produced. The result is that the ECM knows exactly how rich or lean the mixture is and can adjust the fuel mixture much faster than the oxygen sensor based fuel control system. Therefore, there is no cycling that is normal for a narrow range oxygen sensor system. Instead, A/F sensor output is more even and usually around 3.3 volts.

Oxygen Sensor Diagnosis Service

There are several factors that can affect the normal functioning of the oxygen sensor. It is important to isolate if it is the oxygen sensor itself or some other factor causing the oxygen sensor to behave abnormally. See Course 874 Technician Reference book for more information.

A contaminated oxygen sensor will not produce the proper voltages and will not switch properly. The sensor can be contaminated from engine coolant, excessive oil consumption, additives used in sealants, and the wrong additives in gasoline. When lightly contaminated, the sensor is said to be "lazy," because of the longer time it takes to switch from rich to lean and/or vice versa. This will adversely affect emissions and can produce driveability problems.

Many factors can affect the operation of the oxygen sensor, such as a vacuum leak, an EGR leak, excessive fuel pressure, etc.

It is also very important that the oxygen sensor and heater electrical circuits be in excellent condition. Excessive resistance, opens, and shorts to ground will produce false voltage signals.

In many cases, DTCs or basic checks will help locate the problem.

Oxygen Sensor Heater Circuit

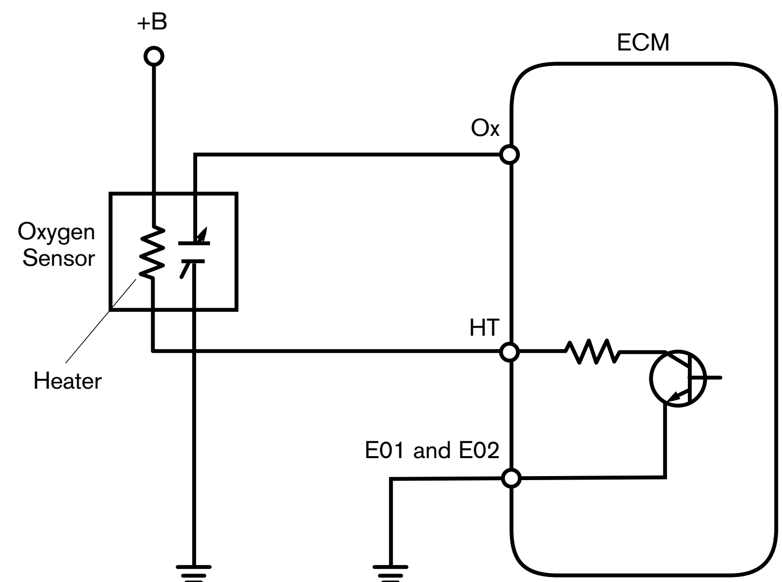


Fig. 2-81
T852f088

Oxygen Sensor Heater

For the oxygen sensor to deliver accurate voltage signals quickly, the sensor needs to be heated. A PTC element inside the oxygen sensor heats up as current passes through it. The ECM turns on the circuit based on engine coolant temperature and engine load (determined from the MAF or MAP sensor signal). This heater circuit uses approximately 2 amperes.

The heater element resistance can be checked with a DVOM. The higher the temperature of the heater, the greater the resistance.

The oxygen sensor heater circuit is monitored by the ECM for proper operation. If a malfunction is detected, the circuit is turned off. When this happens, the oxygen sensor will produce little or no voltage, and possibly set DTC P0125.

Heater Diagnosis

The heater can be checked for resistance with a DVOM. The higher the temperature, the higher the resistance.

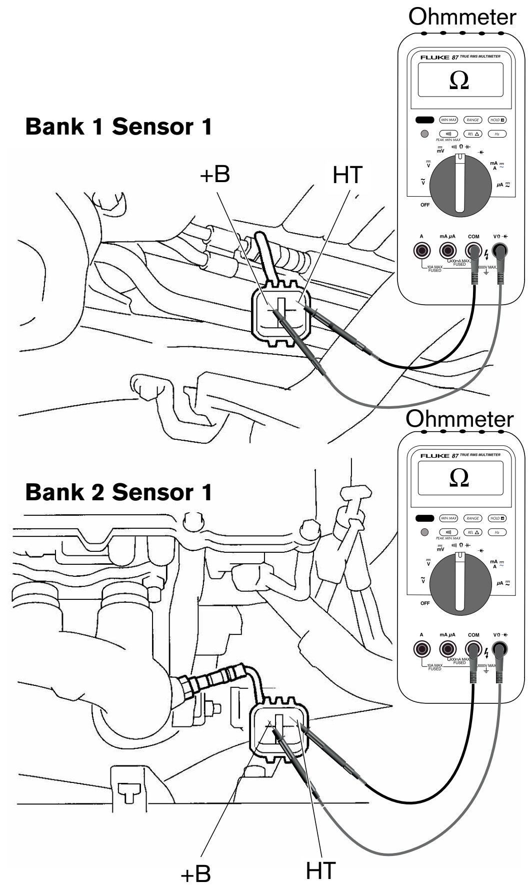


Fig. 2-82

T852f350

Air/Fuel Ratio Heater Circuit

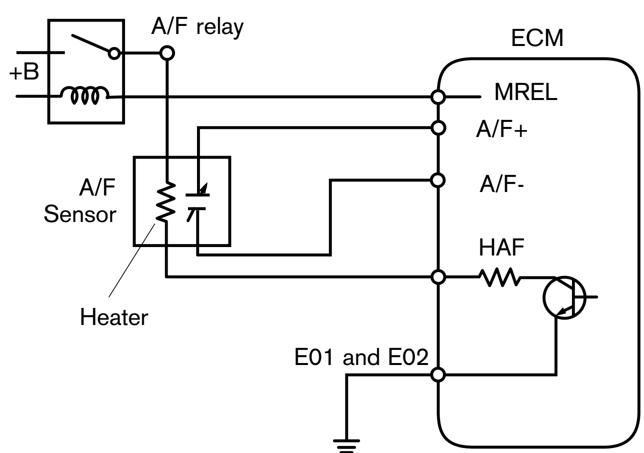


Fig. 2-83

T852f091

Air/Fuel Ratio Sensor Heater

This heater serves the same purpose as the oxygen sensor heater, but there are some very important differences.

Engines using two A/F sensors use a relay, called the A/F Relay, which is turned on simultaneously with the EFI Relay. This heater circuit carries up to 8 amperes (versus 2 amperes for O_2 heater) to provide the additional heat needed by the A/F sensor.

This heater circuit is duty ratio controlled pulse width modulator (PMW) circuit. When cold, the duty ratio is high. The circuit is monitored for proper operation. If a malfunction is detected in the circuit, the heater is turned off. When this happens, the A/F sensor will not operate under most conditions and DTC P0125 will set.

Air/Fuel Ratio Sensor Heater Diagnosis

Diagnosis of the heater is similar to the oxygen sensor. Since the A/F sensor requires more heat, the heater is on for longer periods of time and is usually on under normal driving conditions.

Because the heater circuit carries more current, it is critical that all connections fit properly and have no resistance.

The relay is checked in the same manner as other relays.

Titania Oxygen Sensor

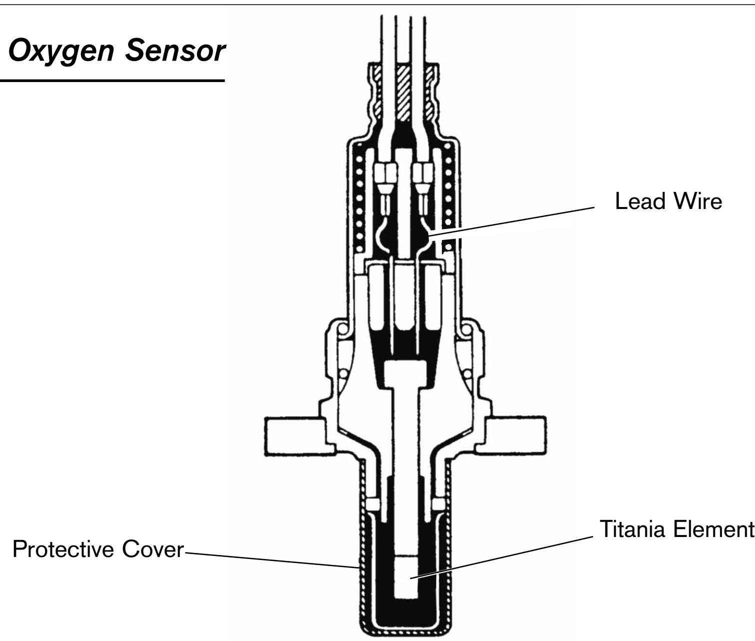


Fig. 2-84

T852f092

Titania Element Type Oxygen Sensor

This oxygen sensor consists of a semiconductor element made of titanium dioxide (TiO_2, which is, like ZrO_2, a kind of ceramic). This sensor uses a thick film type titania element formed on the front end of a laminated substrate to detect the oxygen concentration in the exhaust gas.

Titania Sensor Resistance vs. Air/Fuel Ratio

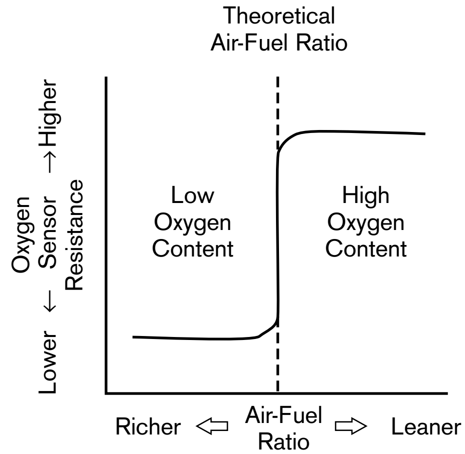


Fig. 2-85

T852f093

Operation The properties of titania are such that its resistance changes in accordance with the oxygen concentration of the exhaust gas. This resistance changes abruptly at the boundary between a lean and a rich theoretical air/fuel ratio, as shown in the graph. The resistance of titania also changes greatly in response to changes in temperature. A heater is, thus built into the laminated substrate to keep the temperature of the element constant.

Titania Sensor Circuit

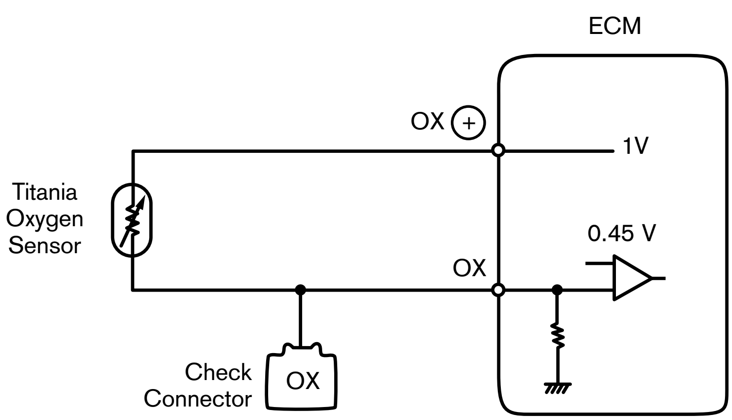


Fig. 2-86

T852f094

This sensor is connected to the ECM, as shown in the following circuit diagram. A 1.0 volt potential is supplied at all times to the O_X positive (+) terminal by the ECM. The ECM has a built-in comparator that compares the voltage drop at the O_X terminal (due to the change in resistance of the titania) to a reference voltage (0.45 volts). If the result shows that the O_X voltage is greater than 0.45 volts (that is, if the oxygen sensor resistance is low), the ECM judges that the air/fuel ratio is rich. If the O_X voltage is lower than 0.45 volts (oxygen sensor resistance high), it judges that the air/fuel ratio is lean.

Knock Sensor

The Knock Sensor detects engine knock and sends a voltage signal to the ECM. The ECM uses the Knock Sensor signal to control timing.

Engine knock occurs within a specific frequency range. The Knock Sensor, located in the engine block, cylinder head, or intake manifold is tuned to detect that frequency.

Knock Sensor Location

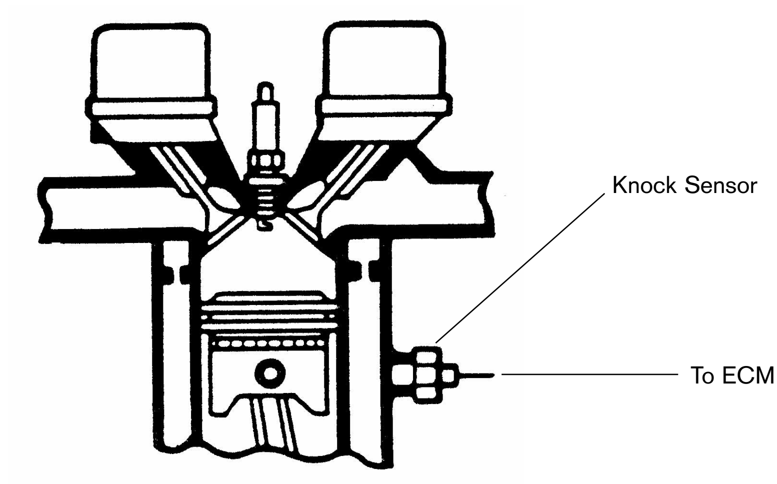


Fig. 2-87
T852f112

Inside the knock sensor is a piezoelectric element. Piezoelectric elements generate a voltage when pressure or a vibration is applied to them. The piezoelectric element in the knock sensor is tuned to the engine knock frequency.

Knock Sensor

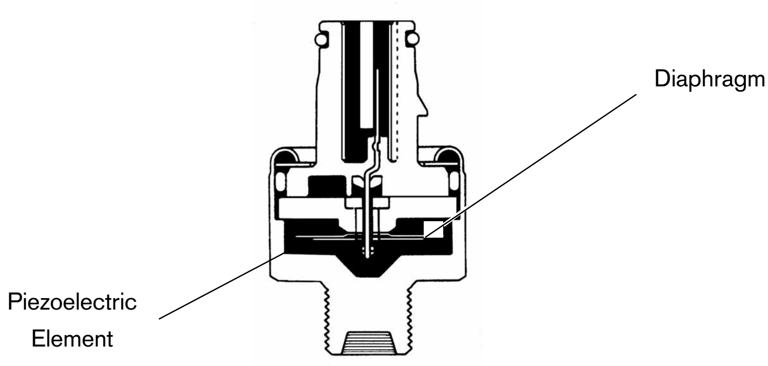


Fig. 2-88
T852f113

Knock Sensor Voltage Generation

When knock occurs, the voltage output increases.

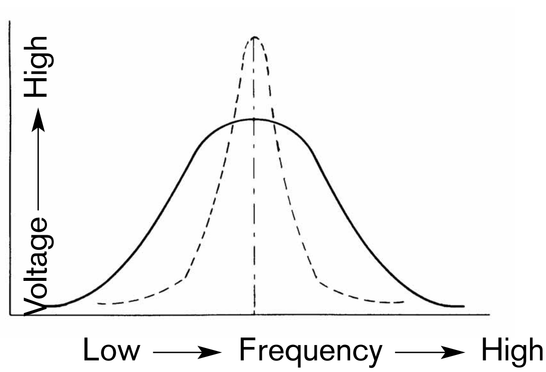


Fig. 2-89
T852f114

Knock Sensor

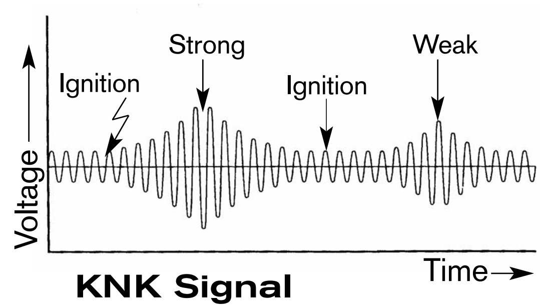


Fig. 2-90
T852f115

The vibrations from engine knocking vibrate the piezoelectric element generating a voltage. The voltage output from the Knock Sensor is highest at this time.